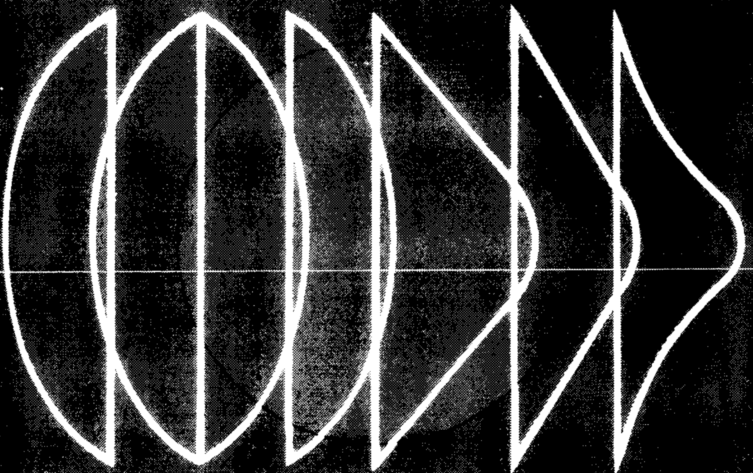
VOYAGER
CAPSULE
PHASE B
FINAL REPORT



VOLUME III SURFACE LABORATORY SYSTEM

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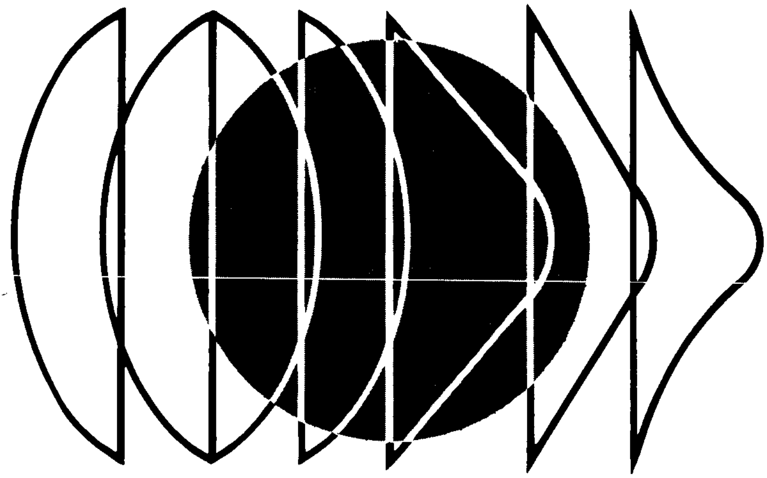
PART C1 SUBSYSTEM FUNCTIONAL DESCRIPTION

VOYAGER CAPSULE PHASE B FINAL REPORT



VOLUME III SURFACE LABORATORY SYSTEM

PREPARED FOR:
CALIFORNIA INSTITUTE OF TECHNOLOGY
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REPORT ORGANIZATION

VOYAGER PHASE B FINAL REPORT

The results of the Phase B Voyager Flight Capsule study are organized into several volumes. These are:

Volume I	Summary
Volume II	Capsule Bus System
Volume III	Surface Laboratory System
Volume IV	Entry Science Package
Volume V	System Interfaces
Volume VI	Implementation

This volume, Volume III, describes the McDonnell Douglas preferred design for the Surface Laboratory System. It is arranged in 5 parts, A through E, and bound in 8 separate documents, as noted below.

Part A	Preferred Design Concept	1 document
Part B	Alternatives, Analyses, Selection	3 documents, Parts B_1, B_2 and B_3
Part C	Subsystem Functional Descriptions	2 documents, Parts C_1 and C_2
Part D	Operational Support Equipment	1 document
Part E	Reliability	1 document

In order to assist the reader in finding specific material relating to the Surface Laboratory System, Figure 1 cross indexes broadly selected subject matter, at the system and subsystem level, through all volumes.

VOLUME III CROSS REFERENCE INDEX

SYSTEM/SUBSYSTEM	VOLUME III PARTS	PART A	APPENDIX A (TO PART A)	APPENDIX B (TO PART A)	PART B	PART C	PART D	PART E
		PREFERRED DESIGN CONCEPT Objectives, Constraints – System Description, Sequence of Operations, Subsystem Summaries.	ENVIRONMENTAL REQUIREMENTS	FUTURE MISSION CONSIDERATIONS	ALTERNATIVES, ANALYSIS, AND SELECTION Trade Studies, Supporting Analyses, and Results	SLS FUNCTIONAL DESCRIPTIONS Subsystem Descriptions	OPERATIONAL SUPPORT EQUIPMENT Equipment, Software and Trade Studies	RELIABILITY Constraints, Analysis, Results, Testing and Control
Surface Laboratory System								
Mission	Objectives	Section 1	1.1 Environmental Design Criteria	1.1 Exploration Strategies	–	–	1. Introduction & Objectives	–
	Constraints	Section 2	1.1 Environmental Design Criteria	1.1 Exploration Strategies	–	–	2. Requirements & Constraints	1 – Reliability Constraints 4 – Program Requirements
	Profile	Section 3.1	1.5 Mission Environmental Conditions	1.2 Mission Profile	4.7 Extended Mission	–	–	–
	Operations	4.1 Sequence 4.2 Timeline 4.3 Contingency Modes	1.3 Source of Environmental Parameters	–	2 – Mission Analysis	–	8. Software	2 – Failure Mode, Effects, Criticality Analysis 3 – Quantitative Estimates
Design	General	3.2 Configuration	1.2 General 1.4 Environmental Design Requirements	–	1 – Study Approach & Analysis 3 – System Functional Requirements 4 – Major Trade Studies	–	3. Preferred Approach 3.2 Design Concept 6 – ASHE & Servicing Equipment 7 – SC Mounted SLS Equipment 10. Analyses & Trade Studies	5 – Component Part Reliability
	Standardization/Growth	11 – Summary	–	–	–	–	4.3.8, 4.5.8	–
	Weight/Physical Characteristics	5 – Summary & Supporting Data	–	1.6 Constraints	–	–	4.3.3, 4.4.3, 4.5.3	–
Reliability		6 – Philosophy, Implementation, Definitions	–	–	4.6 Resource Allocation	–	4.3.6, 4.4.6, 4.5.6	–
Planetary Quarantine		7 – Contamination Analysis, Design for Sterility	1.6 Sterilization & Decontamination	–	–	–	–	–
OSE		8 – General Description	–	–	–	–	Complete OSE Description 3.3 Equipment Summary 4 – System Level Support Equipment 4.3 STC 4.4 LCE 4.5 MDE	–
Interfaces (Also See Volume V)		9 – System Interface Summary	–	–	–	–	4.3.5, 4.4.5, 4.5.5	–
Implementation (Also See Volume VI)		10 – Schedule & Program Summary	–	–	–	–	4.3.7, 4.4.7, 4.5.7	–
Major Subsystems		Section 3.3	–	–	4.3 Analysis of SL Alternatives 5 – Subsystem Studies	Complete Subsystem Functional Descriptions	5 – SL Subsystems Level Test Equipment 5.9 Automatic Processor 5.10 Miscellaneous 9. Equipment Summary	–
Electrical Power		3.3.1 – Requirements, Equipment Description & Operation	–	1.4 Major Considerations	5.1 Power Studies	Section 1	5.3 EPS Test Set	See Part C – Section 1
Sequencer		3.3.2 – Requirements & Description	–	–	4.4 In-Flight Monitoring & Checkout 5.2 Sequencing & Timing Studies	2.1 Sequencer & Timer 2.2 Test Programmer	5.4 Sequencer Subsystem Test Set	See Part C – Section 2
Control		3.3.3 – Requirements & Description	–	–	5.3 High Gain Antenna Pointing Studies	Section 3	–	See Part C – Section 3
Telecommunications		3.3.4 – Requirements & Description	–	–	5.4 Telecommunications Studies	4. Radio Subsystem 5. Antenna Subsystem 6. Command Subsystem 7. Telemetry Subsystem 8. Data Storage Subsystem	5.5 TCM Test Set	See Part C – Sections 4, 5, 6, 7, and 8
Structure (Including Mechanisms)		3.3.5 – Reqmts & Description 3.3.5.6 – Mechanisms	–	–	4.2 Leveling 5.5 Structural/Mechanical	9. Structure 10. Mechanical	–	See Part C – Sections 9, 10
Pyrotechnic		3.3.6 – Requirements & Description	–	–	Section 5.6	Section 11	5.8 Pyro Initiation Test Set	See Part C – Section 11
Packaging and Cabling		3.3.7 – Description	–	–	Section 5.7	Section 12	–	See Part C – Section 12
Thermal Control		3.3.8 – Description	–	1.5 Major Considerations	Section 5.8	Section 13	5.7 TCS Test Set	See Part C – Section 13
Science		3.3.9 – Sequence & Description 3.3.9.4 – Integration	–	1.3 Major Considerations 2 – Stationary Laboratories 3 – Extended Sample Gathering 4 – Mobile Laboratories 5 – Mobile Systems Performance	4.1 Science Integration 4.5 Independent Data Package Study 5.9.1 Science Data Subsystem 5.9.2 Sample Acquisition & Processing 5.9.3 Science Instruments	14.1 Science Data Subsystem 14.2 Sample Acquisition & Processing Equipment 14.3 Science Instruments	5.6 Science Test Set	See Part C – Section 14

Figure 1

TABLE OF CONTENTS

This Document Consists of the Following Pages:

Title Page
i through v
PART C: 1
1-1 through 1-24
2.1-1 " 2.1-28
2.2-1 " 2.2-6
3-1 " 3.16
4.1-1 " 4.1-19
4.2-1 " 4.2-15
4.3-1 " 4.3-10
5-1 " 5-9
5.2-1 " 5.2-4
6-1 " 6-21
7-1 " 7-24
7.2-1 " 7.2-10
8-1 " 8-9
9-1 " 9-10
10-1 " 10-11

PART C

SURFACE LABORATORY SUBSYSTEM FUNCTIONAL DESCRIPTION

This document (Part C) presents functional descriptions of subsystems and functional assemblages selected to implement the Surface Laboratory preferred design concept presented in Part A. Each functional description was developed from comprehensive engineering analyses and studies performed prior to, and during, Phase B of the VOYAGER Capsule Program. A summary of the significant engineering analyses and studies is presented in Part B of this Volume (III).

The following considerations which influenced the determination of the preferred systems design concept are explicitly reflected in the functional description of each subsystem:

- Maximum reliability to the extent possible, with provisions for degraded modes of operation.
- Fully satisfying science objectives.
- Meeting the inviolate launch window.
- Minimizing development risk.
- Providing performance margin

A standard format is used in most subsystem functional descriptions. The format is as follows:

- Equipment Identification and Usage
- Design Requirements and Constraints
- Physical Characteristics
- Operation Description
- Performance Objectives
- Interface Definition
- Reliability and Safety Considerations
- Test Requirements
- Development Requirements

SECTION 1

ELECTRICAL POWER SUBSYSTEM

The Surface Laboratory Electrical Power Subsystem is described herein. For a detailed discussion of the trade studies performed and selections made in design of the Electrical Power Subsystem, see Part B, Section 5.1.

1.1 EQUIPMENT IDENTIFICATION AND USAGE - The Surface Laboratory (SL) Electrical Power Subsystem provides the basic energy storage and power management for the SL electrical equipment and provides the backup energy requirements of both the Capsule Bus (CB) and Entry Science Package (ESP) Electrical Power Subsystems. The electrical power and energy requirements of the SL electrical, electronic, and experiment equipment are tabulated in Figure 1-1. The energy values are for a baseline 28 hour morning landing mission. Additional energy of 3400 watt-hours (electrical) provides thermal control for operation in a continuous -190°F environment. This energy is sufficient to provide extended mission time, a development contingency, and a reliability redundancy. An overall distribution loss factor of 6% of the total SL energy is added to arrive at a battery capacity for equipment. The power profile of the mission is shown in Figure 1-2.

A functional block diagram of the SL Electrical Power Subsystem is shown in Figure 1-3. The SL Electrical Power Subsystem consists of four batteries, providing the energy storage, four battery chargers, and a power switching and logic unit, providing the energy distribution and switching functions. A schematic block diagram of the Electrical Power Subsystem is shown in Figure 1-4. In addition, the Electrical Power Subsystem contains a low voltage, regulated potential DC-to-DC converter to provide instrumentation power for the SL experiments.

1.1.1 Batteries - The SL energy storage is supplied by four, equally sized batteries to eliminate any single energy source failure mode causing mission abort and to provide packaging convenience. The batteries provide the energy requirement of the SL cruise commutator when Flight Spacecraft cruise power is not available, and provide the energy requirements of all SL equipment after Flight Capsule (FC) separation from the Flight Spacecraft (FSC).

Each battery is a sealed, manually activated, Ag-Zn battery. The battery consists of 18, 75-ampere-hour cells connected in series to provide an average output potential of 27.5 volts. The battery provides a minimum of four complete charge-discharge cycles and is heat sterilizable prior to the formation charge.

SL ELECTRICAL POWER SUBSYSTEM

ENERGY ALLOCATION

EQUIPMENT	POWER (watts)	ENERGY (watt-hours)
Data Transmission Subsystem		
High Rate Transmitter	117	1083
Tape Recorder	10	143
Antenna Tracking	13	93
Antenna Erection	–	48
Low Rate Transmitter	30	330
Radio Command Subsystem	12	336
Science Data	10	280
Telemetry	21	588
Sequencer and Timer	12	426
Cruise Commutator	4	30
Science		
Experiments	–	596
Heat	–	73
Power Supply	5	140
Instrumentation	8	284
Equipment Subtotal	–	4450
6% Distribution Loss	–	267
Heating for –190° Day	–	3400
Total Electrical Energy	–	8117

Figure 1–1

SL ELECTRICAL POWER SUBSYSTEM POWER PROFILE

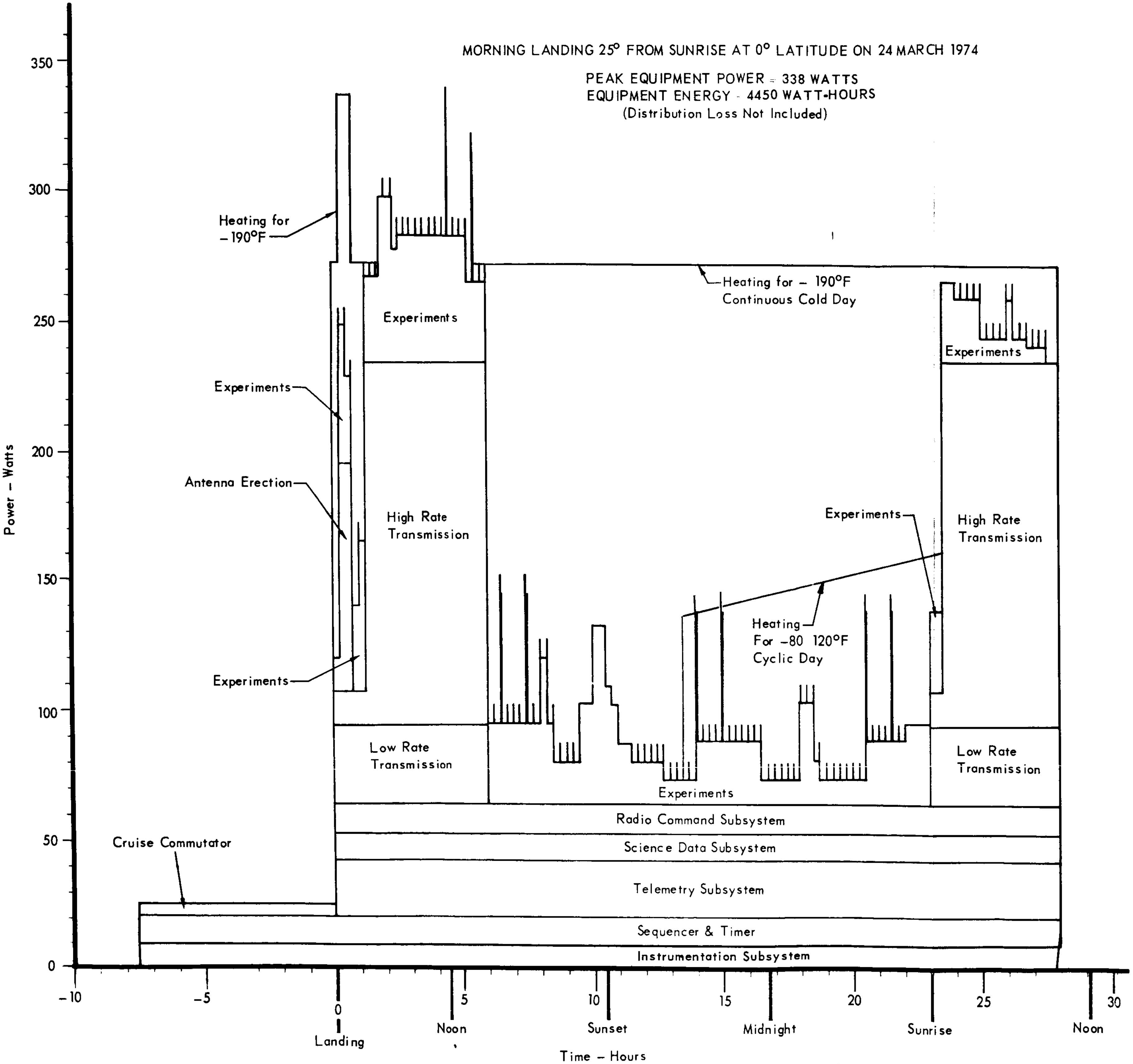


Figure 1–2

SL ELECTRICAL POWER SUBSYSTEM FUNCTIONAL DIAGRAM

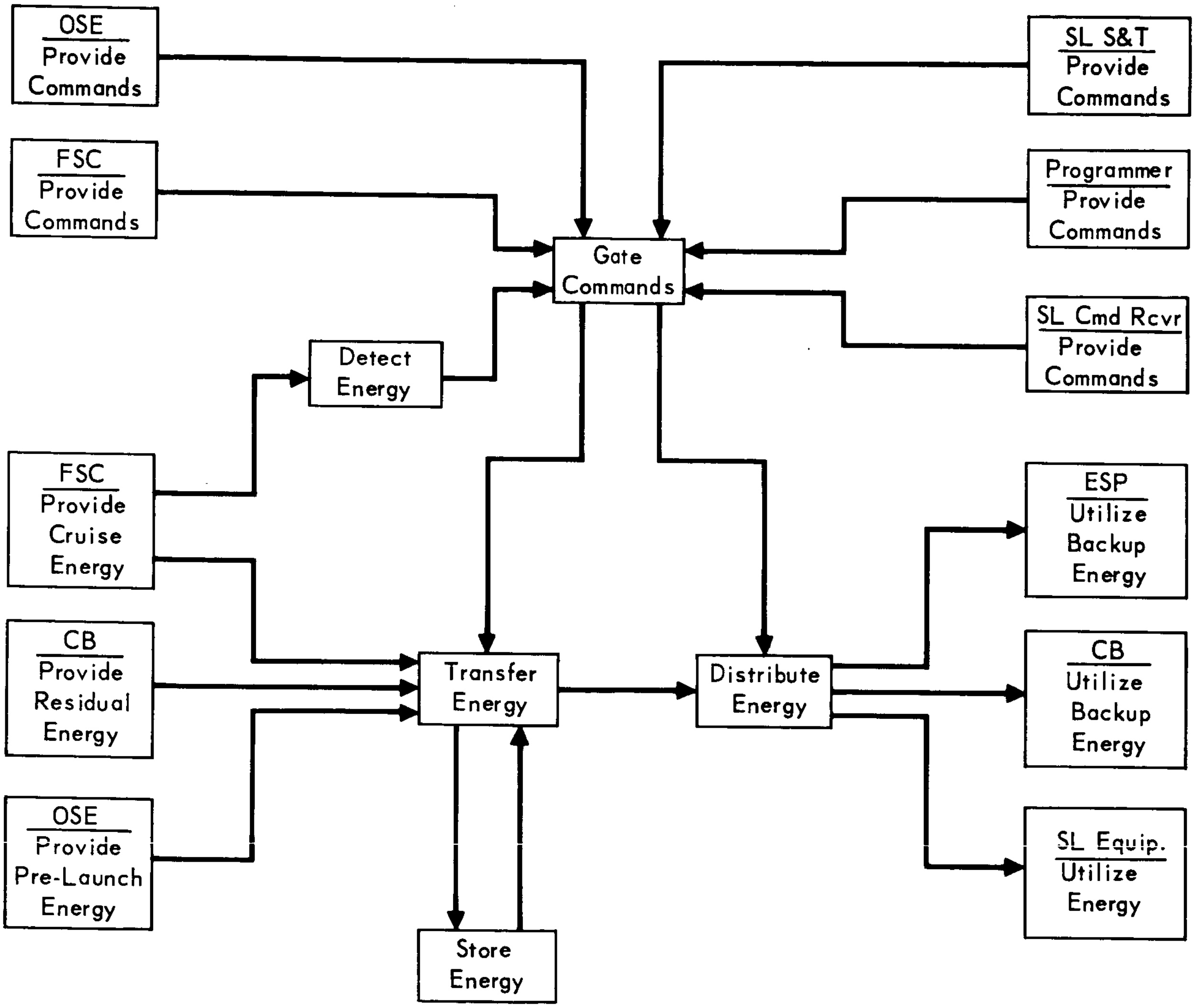


Figure 1-3

SL ELECTRICAL POWER SUBSYSTEM EQUIPMENT BLOCK DIAGRAM

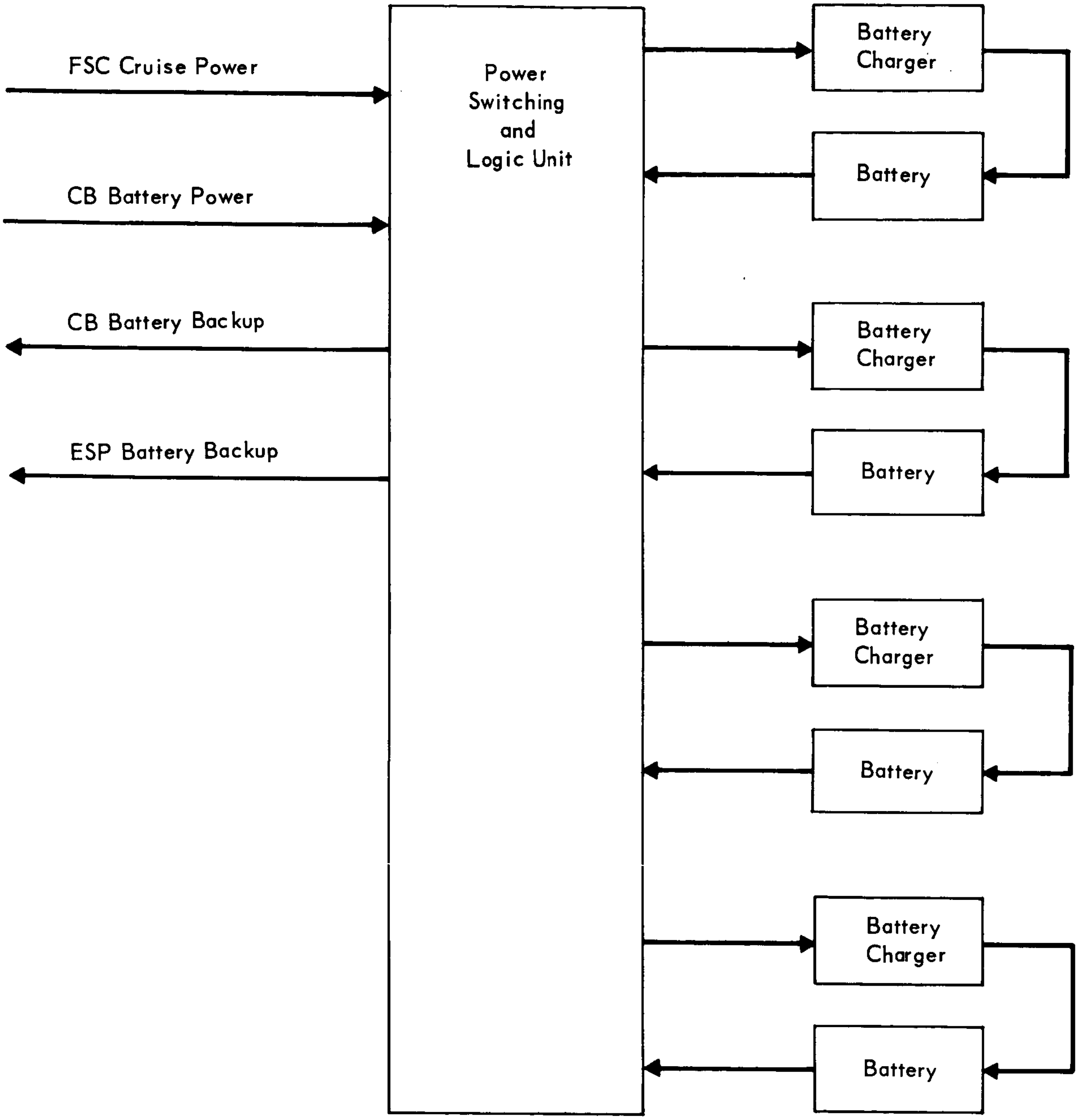


Figure 1-4

During Earth storage, after heat sterilization and performance verification, the batteries will be stored in the discharged condition. The batteries will be launched in a fully charged condition. After FSC solar panel deployment, the batteries will be float charged whenever FSC cruise power is available to the SL Electrical Power Subsystem.

1.1.2 Battery Chargers - One battery charger is provided for each of the four SL batteries. The charger maintains the battery in a charged condition during cruise and recharges the battery after periods of battery usage during cruise.

The battery charger is a two step float charger with operating characteristics as shown in Figure 1-5. The charger has two modes of operation: current-limited, constant potential, and constant potential at open circuit battery potential.

The current-limited, constant potential mode is the initial mode of charging the batteries. In this mode the charger output potential is reduced due to current limiting at a rate of C/50 (battery capacity in ampere-hours/desired charge time in hours) during the major portion of charging. During the final portion of this mode, the battery charges at the constant potential of 1.98 ± .01 volts per cell until the output current reduces to C/100. This reduced output current is sensed in the battery charger, and the charger transfers to the constant potential mode at open circuit battery potential.

In the constant potential mode, the charger output is a constant potential at the open circuit battery potential of 1.87 ± .01 volts per cell. This mode is essentially float charging as negligible output current flows.

Each time input power is removed from and reapplied to a battery charger, the charger reverts to the current-limited, constant potential mode of operation. If the battery has not been discharged, or only slightly discharged, the charger will quickly cycle through this mode to the constant potential mode.

1.1.3 Power Switching And Logic Unit - The Power Switching And Logic Unit (PS&L) contains the SL power distribution bus and the associated switching devices and logic circuits to control and distribute electrical power to the various subsystems within the SL. The PS&L controls power application to each of the various SL subsystems as a result of commands from the SL Sequencer And Timer (S&T), SL radio command link, and/or FSC command link. It also manages FSC cruise power and SL battery power to provide uninterrupted SL power, as well as backup power for the ESP and CB electrical power subsystems.

The PS&L contains the SL electrical power distribution bus. This bus is supplied from the four SL batteries, the CB battery, and FSC cruise power during various

SL ELECTRICAL POWER SUBSYSTEM
TYPICAL BATTERY CHARGER OPERATING CHARACTERISTICS

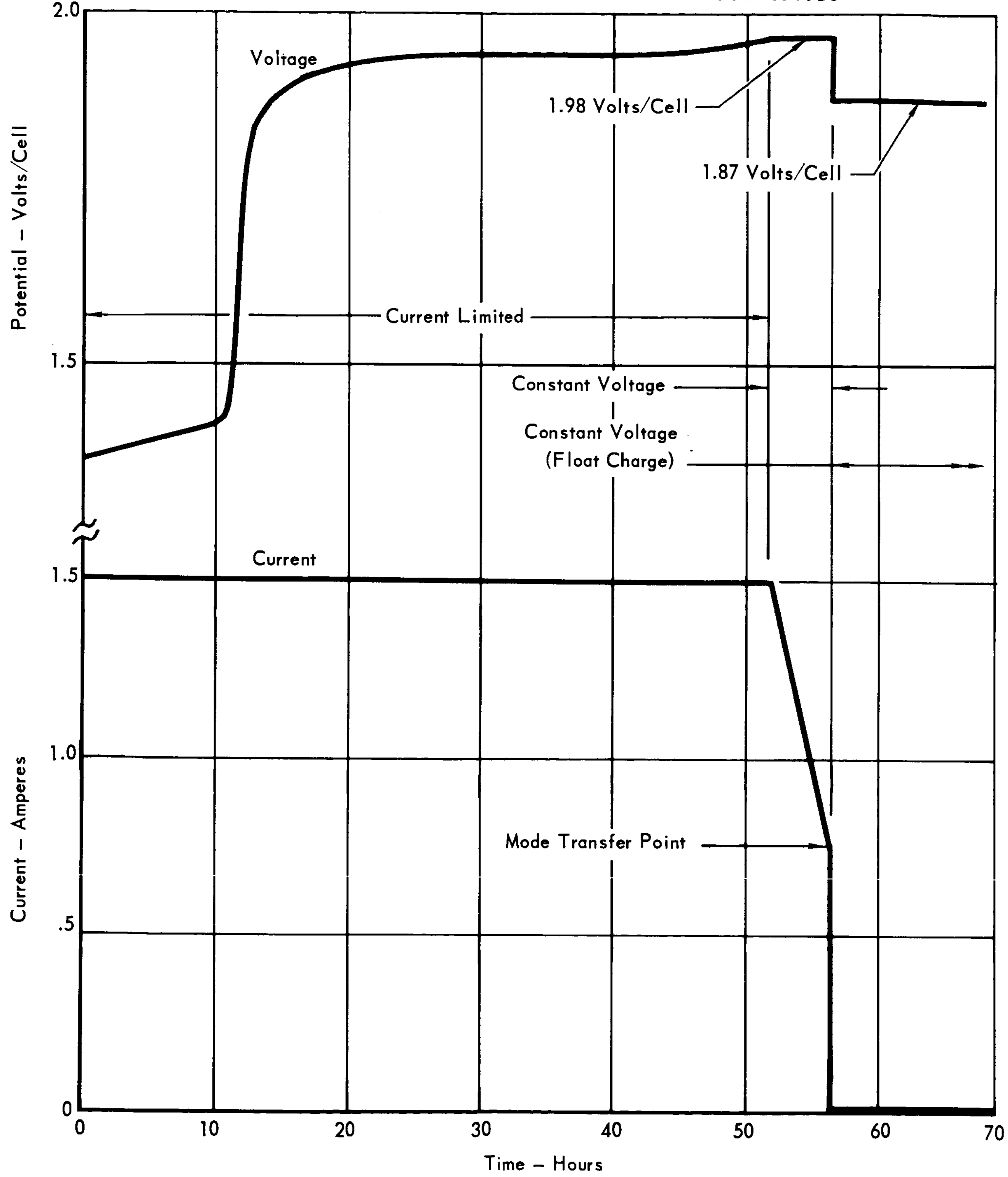


Figure 1-5

phases of the mission. The FSC cruise power is directly applied (through an isolation diode) to the distribution bus, and is utilized whenever available. Each of the four batteries is individually switched on or off the distribution bus through commands from the launch complex for pre-launch control, from the internal voltage sensor and FSC command link during cruise, and from the SL S&T and SL radio command link after landing upon Mars. After landing and completion of ESP and CB operations, the PS&L removes the ESP and CB backup power lines and accepts residual power from the CB battery.

Power diodes isolate the six parallel sources of power (four SL batteries, CB battery, and FSC cruise power). Isolation diodes are required at each battery interconnection to prevent any battery failure from shorting or drawing power from the SL distribution bus, thereby causing abort or early termination of the SL mission. Isolation at the FSC cruise power interconnection is also required for the same reasons as well as prevention of power flow into the FSC cruise power source from the SL distribution bus.

The PS&L contains a switching section which receives commands from the voltage sensor, the SL Sequencer And Timer (S&T), the FSC, and SL radio command decoder. The switching section translates these commands into the proper energy source interconnection and distribution in the SL. The switching section is schematically represented in Figure 1-6. The switching section contains 10 latching relays to provide basic energy source management plus additional latching relays to distribute power to the various SL equipment loads. Four relays (K1-K4) are used to apply the SL batteries to the distribution bus or remove them from the bus. Four relays (K5-K8) are used to turn on or off the battery chargers. One relay (K9) is used to apply or remove the interconnected pair of SL batteries to the ESP power backup interface. One relay (K10) is used to apply or remove the other interconnected pair of SL batteries to the CB power backup interface. During normal conditions, these 10 relays are controlled in groups (see Section 1.4), rather than individually, to accomplish the basic sequence of operations. However, each battery, battery charger, and backup connection may be individually commanded via Earth communications link to circumvent any energy source failure mode.

The switching section also contains the required relays to turn on or off the various SL telemetry, experiment, data storage, tracking, and sequencer subsystems and subsystem sections. These relays are controlled from the S&T in either preprogrammed sequence or by Earth command update of the S&T. A typical relay (K13) and circuit is shown in Figure 1-6.

SL ELECTRICAL POWER SUBSYSTEM SWITCHING SCHEMATIC

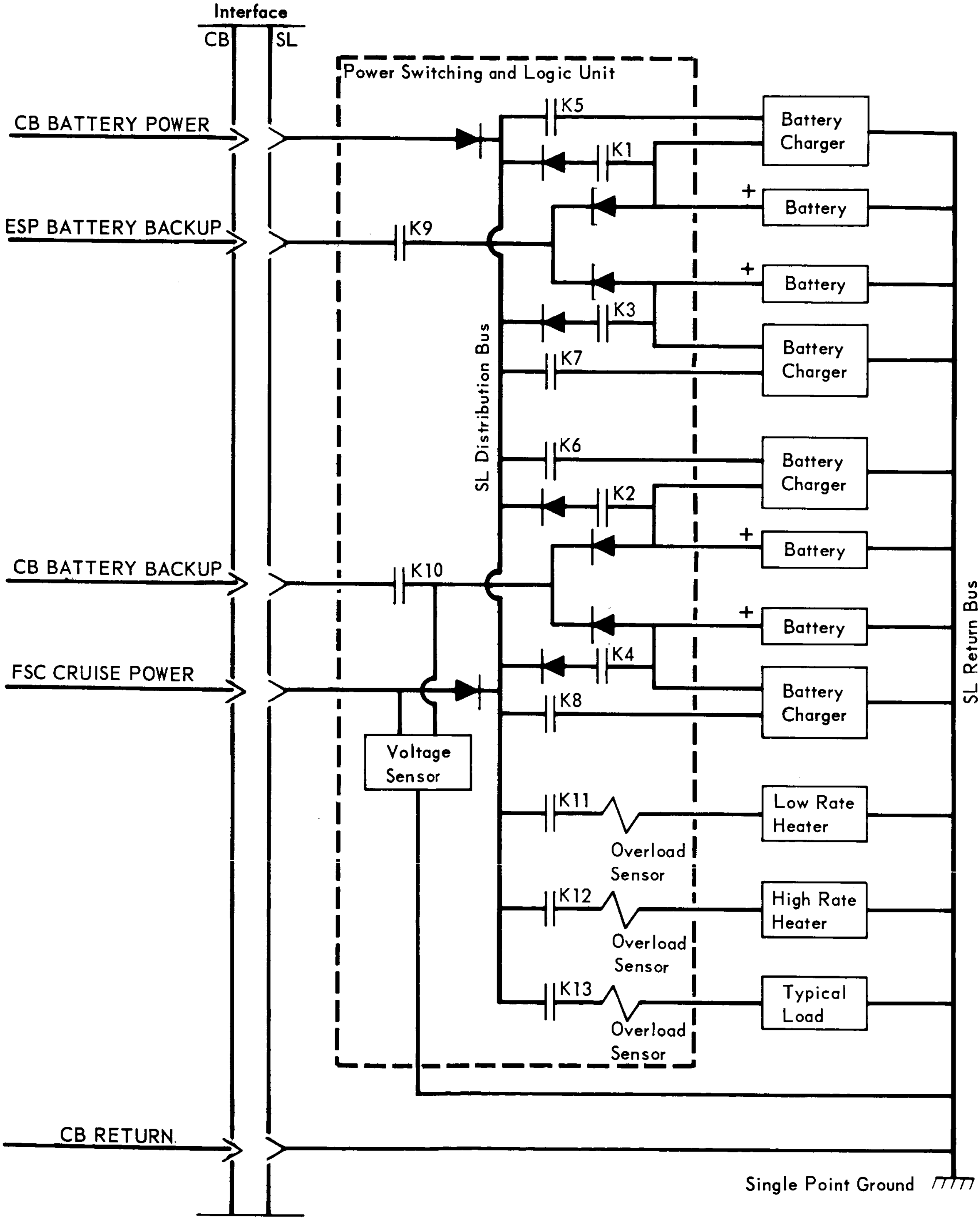


Figure 1-6

The PS&L contains one voltage sensor to detect the presence of FSC cruise power. The sensor commands the battery and battery charger relays in the switching section of the PL&S from Earth launch to SL preseparation checkout. The sensor is utilized to command the transfer of the SL batteries from the distribution bus and to command application of power to the battery chargers to float charge the batteries upon detection of FSC cruise power. With loss of FSC cruise power, the sensor commands application of two of the SL batteries to the distribution bus and removes all the battery chargers from the distribution bus. Redundant commands for the sensor originate in the FSC. For a continuous power source to provide the sensor output commands upon loss of FSC cruise power, the pair of SL batteries interconnected to provide CB backup is used.

The PS&L provides the proper circuit protection devices to prevent catastrophic failure of the SL electrical power system. The isolation diodes provide the required energy source protection. Overload-fault sensing devices provide protection for the bus from load circuit failures. These devices actuate the equipment control relay turning off the equipment and may be preempted by Earth command. These protection devices are not to protect the load equipment. The S&T and radio command receiver do not have overload-fault protection devices since their "turn off" jeopardizes the mission.

1.1.4 Experiment Power Supply - The experiment power supply provides low voltage, regulated power to the atmosphere and subsurface experiment instrumentation equipment. Nominal 28 volt power from the distribution bus is converted by a DC-to-DC converter to five volts and regulated to 5.000 ± .025 volts. The power supply connection to the distribution bus is shown by the "typical load" circuit of Figure 1-6.

1.2 DESIGN REQUIREMENTS AND CONSTRAINTS - Except for the batteries, current state-of-the-art electrical equipment presents no inherent problems for use in the VOYAGER program. However, the battery design requires sterilization development and is discussed in Section 1.9.

Continuous cruise commutator operation to gather engineering data during the eight month cruise period requires approximately 22,000 watt-hours of energy. The exorbitant weight of a battery to store this energy precludes its use for continuous cruise power. Therefore, the energy requirement during cruise is provided by the available FSC cruise power except during periods of FSC high power usage. During these limited periods, nominally totaling 10 hours, battery energy is used.

The requirement for continuous engineering data, especially during periods when FSC cruise power is not available, requires battery activation prior to launch. Therefore, the batteries undergo a wet stand period of eight to twelve months, depending upon the pre-launch storage time. Batteries incur a capacity loss on wet stand of 4-12% per month. This capacity loss plus the 10-hour cruise power requirement requires a large excess initial capacity to arrive at Mars with a remaining energy of 8100 watt-hours. Rather than incur the battery weight penalty for this excess capacity, four battery chargers are included to maintain the battery capacity during wet stand, and replace the energy loss during periods when the cruise commutator operates from battery energy. FSC cruise power is utilized to operate the battery chargers.

1.3 PHYSICAL CHARACTERISTICS - The SL Electrical Power Subsystem total equipment weight is 272 pounds and occupies a volume of 5228 cubic inches. The physical characteristics of the individual equipment are tabulated in Figure 1-7.

1.4 OPERATIONAL DESCRIPTION - The following is a description of the operation of the SL Electrical Power Subsystem by mission phase, and is summarized in Figure 1-8. Refer to Figure 1-6 for the switching circuit configuration.

1.4.1 Pre-Launch - During the pre-launch phase, the launch complex OSE provides power to the SL. This power is utilized for SL subsystem testing and to maintain battery charging. Relays K5 through K8 are closed.

1.4.2 Launch - During the pre-launch phase the launch complex OSE commands relays K1 and K2 closed to provide battery energy for SL operations until FSC cruise power becomes available, and relays K5 through K8 open to remove the battery chargers from the distribution bus. The launch phase load on the SL Electrical Power Subsystem is light, and one battery can supply the load at a low depth of discharge, however, two batteries are used for redundancy. The other two batteries are not used in this phase. Relays K5 through K8 are open unless FSC cruise power is available to charge batteries.

1.4.3 Cruise - After FSC solar panel deployment, FSC cruise power becomes available to the FC. The FSC commands the SL PS&L relays K1 and K2 open and relays K5 through K8, and K11 closed. Simultaneously the PS&L voltage sensor detects the cruise power input and redundantly commands relays K1 and K2 open and relays K5 through K8, and K11 closed. The SL batteries are removed from the SL distribution bus, and relays K5 through K8 apply the available cruise power to the four battery chargers. These chargers initially charge all batteries in the current-limited, constant potential mode, however, the chargers for the two unused batteries immediately

SL ELECTRICAL POWER SUBSYSTEM PHYSICAL CHARACTERISTICS

EQUIPMENT	SIZE (IN.)	VOLUME (CU. IN.)	WEIGHT (LB)	QUANTITY	TOTAL VOLUME (CU. IN.)	TOTAL WEIGHT (LB.)
Battery	5.5 x 8.5 x 22.5	1052	58	4	4208	232
Battery Charger	2.5 x 3 x 8	60	3	4	240	12
Power Switching and Logic Unit	8 x 9 x 10	720	25	1	720	25
Experiment Power Supply	3 x 4 x 5	60	3	1	60	3
Total Electrical Power Subsystem	▨	▨	▨	▨	5228	272

Figure 1–7

SL ELECTRICAL POWER SUBSYSTEM MISSION SEQUENCE

MISSION PHASE	DURATION	ENERGY SOURCE	EQUIPMENT OPERATING
Prelaunch	3 Days	OSE	Battery Chargers All Other Equipment Tested
Launch	3 Hours	Batteries	Cruise Commutator
Transit	7½ Months	FSC	Battery Chargers Cruise Commutator Heaters
Trajectory Corrections	10 Hours	Batteries	Cruise Commutator
Pre-Separation Checkout	75 Minutes	FSC	Cruise Commutator Equipment Being Tested
Separation and Descent	7½ Hours	Batteries	Cruise Commutator Sequencer and Timer
Post Touchdown	28 Hours	Batteries	All Equipment Except Cruise Commutator

Figure 1–8

transfer to the float charge mode. Both batteries utilized for the launch phase source of energy require a short charging period in the current-limited, constant potential mode before transferring to the float charge mode. Relay K11 enables the low rate SL heaters for thermal control during cruise.

1.4.4 Trajectory Corrections - Prior to entering periods of high FSC power usage, the FSC commands the FSC cruise power removal from the FC and commands the SL PS&L relays K1 and K2 closed and relays K5 through K8, and K11 open. Simultaneously, the PS&L voltage sensor detects absence of cruise power input and provides a redundant command. Relays K1 and K2 close to provide battery energy for SL cruise commutator operation until the FSC cruise power becomes available again. Relays K5 through K8 remove the battery chargers from the SL distribution bus, and relay K11 deactivates the SL cruise heaters. Cooling is acceptable during this short period. After termination of FSC high power usage, the FSC commands FSC cruise power input to the FC and commands the SL PS&L relays to the cruise position simultaneously with voltage sensor detection of cruise power input and redundant command.

1.4.5 Pre-Separation Checkout - Pre-separation checkout is performed using FSC cruise power. The test programmer commands relays K5 through K8, and K11 open upon starting the test cycle to provide maximum FSC cruise power available for equipment checkout. During the test cycle, the test programmer commands relays in the PS&L to control subsystem equipment power input. Upon completion of the test cycle, the programmer commands the relays to float charge the SL batteries and activate the SL cruise heater. Sufficient heat is generated by equipment operation during checkout to allow deactivation of the cruise heaters.

1.4.6 Separation and Descent - Approximately one hour prior to FSC/FC separation, the SL S&T commands the SL PS&L relays K1 through K4, K9, and K10 closed and relays K5 through K8 open. Relays K1 through K4 apply the SL batteries onto the SL distribution bus in parallel with the FCS cruise power. The SL batteries provide the energy source for the SL equipment from this time until termination of SL operation. Relays K5 through K8 remove the battery chargers from the distribution bus. Relays K9 and K10 are closed to provide the ESP and CB electrical system backup energy sources. The voltage sensor is deactivated by the same S&T command.

1.4.7 Post Touchdown - After touchdown the SL S&T controls the PS&L relays in the preprogrammed sequence. Update of the program sequence is controlled by Earth radio command update of the S&T. Override commands to the PS&L are accomplished by Earth radio command via the SL radio command receiver. Upon touchdown the S&T

commands relay K12 to activate the high rate thermal control heaters. On completion of post touchdown CB and ESP operation, the SL S&T commands relays K9 and K10 open to remove the ESP and CB energy backup source, thereby preventing unforseen energy drain on the SL batteries. On completion of CB operations, the CB PS&L switches the CB battery to provide the SL distribution bus with the residual energy of the CB battery.

1.5 PERFORMANCE OBJECTIVES - The performance characteristics of the Electrical Power Subsystem equipment can be well defined except for the batteries. Sterilizable Ag-Zn batteries have demonstrated satisfactory post sterilization performance, however, limited testing has been accomplished. Therefore, the battery performance objectives presented herein are necessarily conservative. The battery terminal potential will be between the limits of 24.5 to 33.5 volts. All SL equipment will be required to operate with input potentials between 23 and 33 volts. The performance objectives of the Electrical Power Subsystem components are tabulated in Figures 1-9, 1-10, and 1-11.

1.6 INTERFACE DEFINITION - The SL Electrical Power Subsystem has interfaces with all SL subsystems, the CB, the ESP via the SL/CB interface and the FSC via the SL/CB interface. The interface block diagram is shown in Figure 1-12. Within the SL, the power interface with all subsystems consists of latching relay contacts within the PS&L which control power application to the subsystem equipment. These PS&L relays are controlled by the SL S&T, the test programmer, the SL radio command receiver, and the FSC.

The SL Electrical Power Subsystem contains the single point ground (SPG) for the CB, ESP, and SL Electrical Power Subsystems. The return line from the ESP connects to the CB return bus, and the return line from the CB connects to the SL return bus. These return lines are required for the SL backup of the ESP and CB energy sources. The SL return bus is directly connected to the SPG.

1.7 RELIABILITY CONSIDERATIONS - The components of the SL Electrical Power Subsystem involve present day hardware and proven design techniques, except for the batteries. It is projected that the sterilizable, silver-zinc battery will reach the same reliability obtained by the Mariner silver-zinc battery, i.e., demonstrated mission probability of success of .998 @ 80% confidence level.

1.7.1 Reliability Estimate - The functional relationship of components in the SL Electrical Power Subsystem is depicted in the Reliability Diagram, Figure 1-13. The Energy Probability Summary, Figure 1-14, evidences the electrical energy calculated reliability of .9895 for the baseline mission using a battery failure rate of 7.6 per million hours. The Energy Probability Summary is graphically depicted

SL ELECTRICAL POWER SUBSYSTEM
BATTERY CHARACTERISTICS

CHARACTERISTIC	REQUIREMENT
Type	Sealed Manually Activated Silver-Zinc
Life	12 Months Wet Stand 4 Charge-Discharge Cycles to 100% Rated Capacity
Capacity	75 Ampere-Hours 2030 Watt-Hours
Energy Density	35 Watt-Hours Per Pound Minimum
Regulation	33.5 Volts Initial (Open Circuit) 24.3 Volts Final (Full Load)
Number of Cells	18
Temperature	0°F to 60°F on Float Charge 50°F to 120°F Normal Discharge Rate 20°F to 120°F Limited Discharge Rate 0°F to 90°F Full Discharged Condition

Figure 1-9

SL ELECTRICAL POWER SUBSYSTEM
BATTERY CHARGER CHARACTERISTICS

CHARACTERISTIC	REQUIREMENT
Type	Float Charger Two Mode Operation
Life	12 Months Operating
Operation	Constant Potential Current Limited Mode 35.6 ± .4 Volt Output Potential 1.5 ± .1 Amp Current Limit 10 Watts Maximum Dissipation Constant Potential (Float Charge) Mode 33.5 ± .4 Volts Output Potential 8 Watts Maximum Dissipation
Temperature	-65°F to 165°F Operating

Figure 1-10

SL ELECTRICAL POWER SUBSYSTEM POWER SUPPLY CHARACTERISTICS

CHARACTERISTIC	REQUIREMENT
Type	DC-To-DC Converter-Regulator
Input	28 ± 5 Volts Direct Current
Output	5.000 ± .025 Volts including regulation, ripple, and setting variations. 1.5 Amps DC continuous
Protection	Short Circuited Output Reverse Polarity Input No Fuses
Temperature	−65°F to 165°F Operating

Figure 1–11

SL ELECTRICAL POWER SUBSYSTEM INTERFACE BLOCK DIAGRAM

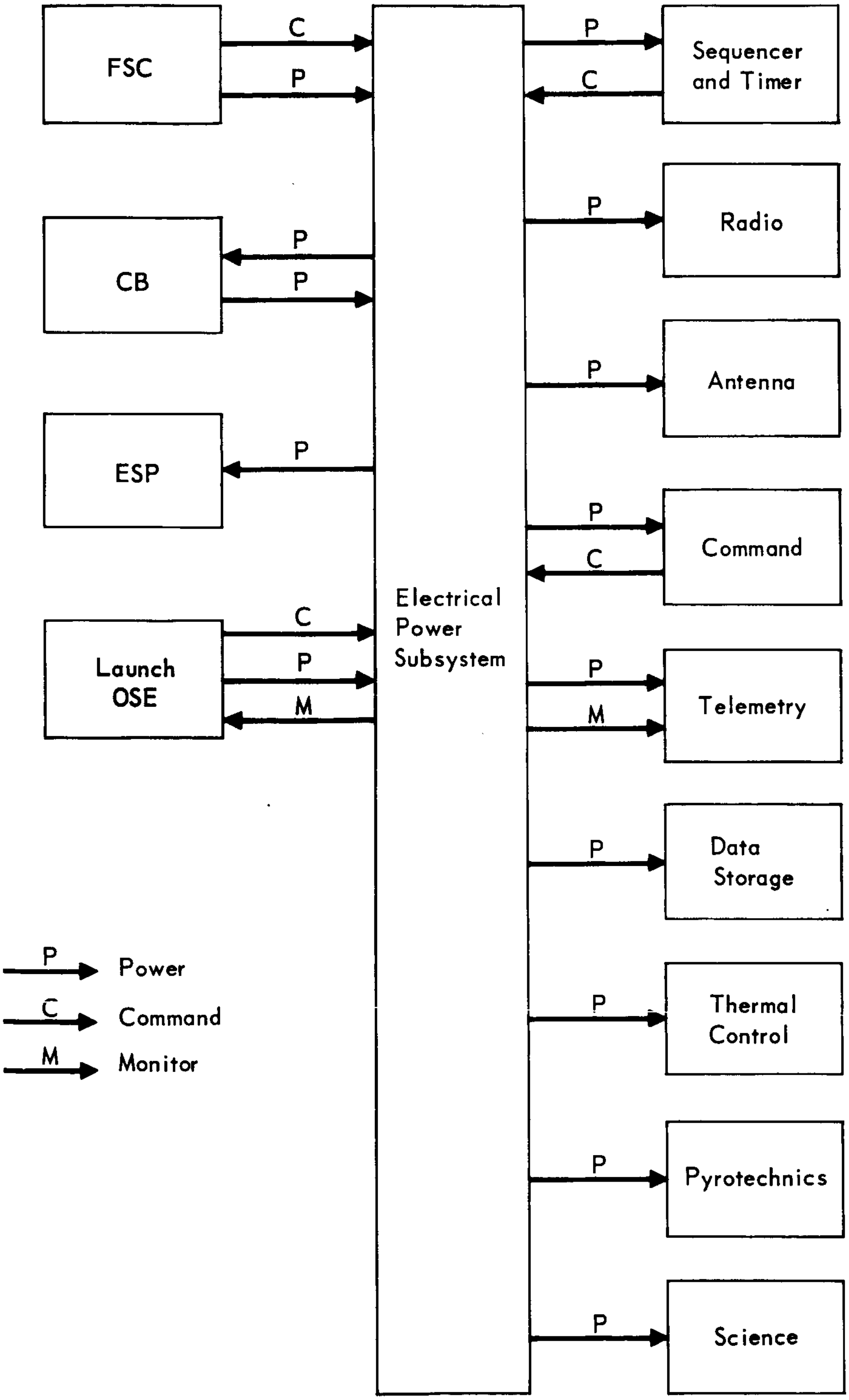
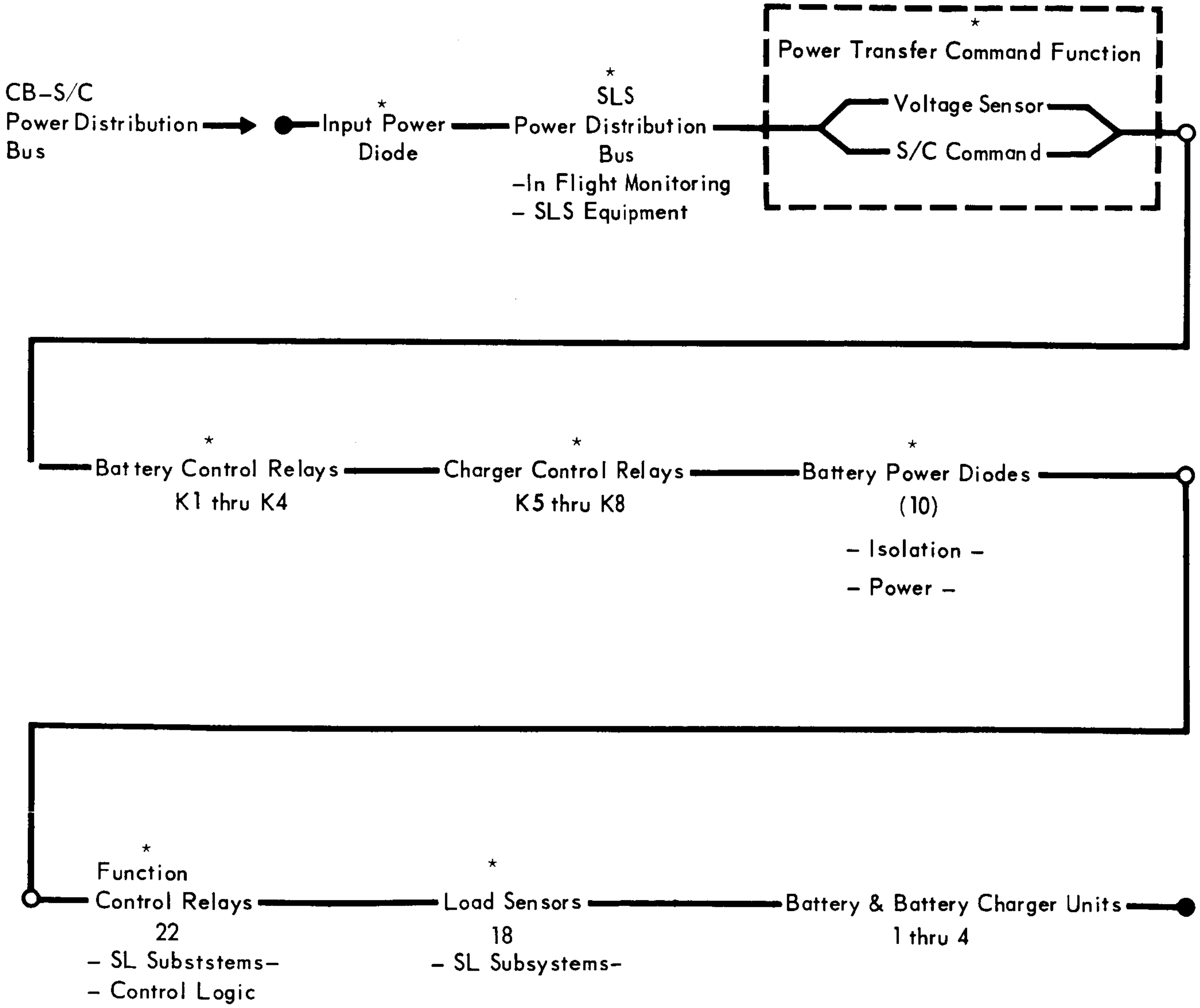


Figure 1-12

SURFACE LABORATORY ELECTRICAL POWER RELIABILITY PROGRAM



*Contained within SL Power Switching and Logic Unit

Figure 1-13

SL ELECTRICAL POWER SUBSYSTEM
ENERGY PROBABILITY SUMMARY

MARS ARRIVAL WITH:	FAILED EQUIPMENT	WATT HOUR DELIVERY MINIMUM	P_s
A. 4 Battery-Charger Units	Nothing	8120	.7550
B. 3 Battery-Charger Units and 1 Battery	1 Battery Charger	7500	.8391
C. 2 Battery-Charger Units and 2 Batteries	2 Battery Chargers	6861	.8414
D. 1 Battery-Charger Unit and 3 Batteries	3 Battery Chargers	6261	.8414
E. 4 Batteries	4 Battery Chargers	5642	.8414+
F. 3 Battery-Charger Units	1 Battery Charger Unit	6090	.9778
G. 2 Battery-Charger Units and 1 Battery	1 Battery Charger Unit and 1 Battery Charger	5470	.9891
H. 1 Battery-Charger Unit	1 Battery Charger Unit and 2 Battery Chargers	4851	.9895
		4700 Nominal Mission	.9895+

Notes:

(1) P_s values are based on battery-charger unit combinatorial analysis.

(2) Battery-charger unit refers to battery and associated charger.

(3) The watt-hour delivery minimums shown are strictly worst case and, therefore, conservative. From an energy standpoint, chargers were considered lost at launch with battery wet stand energy decay at 4% per month.

(4) Nominal mission is considered to be 4700 watt-hours.

(5) Mission energy $P_{CB} \times P_{ESP} \times P(4700) + P_{CB} \times P_{ESP} \times P(4930) + P_{CB} \times P_{ESP} \times P(6300 + P_{CB} \times P_{ESP} \times P(6630)$
$P_S = .9878$ (P_{CB} & P_{ESP} refer to CB & ESP Battery Energy)

(6) Mission energy P_S of .9878 provides a SL electrical power subsystem reliability of .9848.

Figure 1-14

in Figure 1-15. This curve illustrates the relationship of the energy carried, the energy requirements, and the resultant energy probabilities. With the energy probability of .9895, the calculated reliability of the Electrical Power Subsystem is .9848.

1.7.2 Failure Mode, Effect, and Criticality Analysis - An analysis was conducted for the Electrical Power Subsystem, and the results are presented in Figure 1-16. This analysis evidences only "no effect" failures.

1.7.3 Operational Reliability - The Electrical Power Subsystem is simply configured but includes redundant command sources and a battery weight contingency. The battery weight added for thermal contingency, also provides contingency for some battery capacity loss due to failure of battery chargers and a battery failure. The division of the battery requirement into four independent batteries provides functional redundancy, which combined with the weight contingency, allows failure of a battery and two other battery chargers without affecting the baseline mission capability.

Redundant switching commands during cruise, to backup the Flight Spacecraft commands, are provided by the PS&L voltage sensor and by Earth radio command via the Flight Spacecraft. Redundant commands for landed operations, to backup the Sequencer And Timer commands, are provided by Earth command update of the S&T and by Earth commands to the PS&L via the SL command subsystem.

1.8 TEST REQUIREMENTS - All pre-launch testing of SL subsystem equipment is accomplished using OSE power except for a very brief period on SL battery power at launch. Testing of the SL Electrical Power Subsystem, during cruise, pre-launch checkout, and post landing operation, consists of monitoring the terminal voltage and current of each battery during loading and battery charging, monitoring the SL distribution bus voltage, monitoring the positions of relays K1 through K10 in the PS&L, and monitoring the position of the PS&L voltage sensor relay. In addition, during post sterilization tests, a performance check is performed on each SL battery. This performance check requires one complete charge-discharge cycle while continuously recording the battery terminal voltage and charge/discharge currents. Monitoring of the SL Electrical Power Subsystem is tabulated in Figure 1-17.

1.9 DEVELOPMENT REQUIREMENTS - The components of the SL Electrical Power Subsystem are not long lead time development items, except for the batteries. Demonstration of performance capability following heat sterilization has been accomplished. Two, six cell, manually activated batteries have demonstrated the capability to survive heat sterilization followed by wet stand time of flight duration. In

SL ELECTRICAL POWER SUBSYSTEM ENERGY DELIVERY PROBABILITY

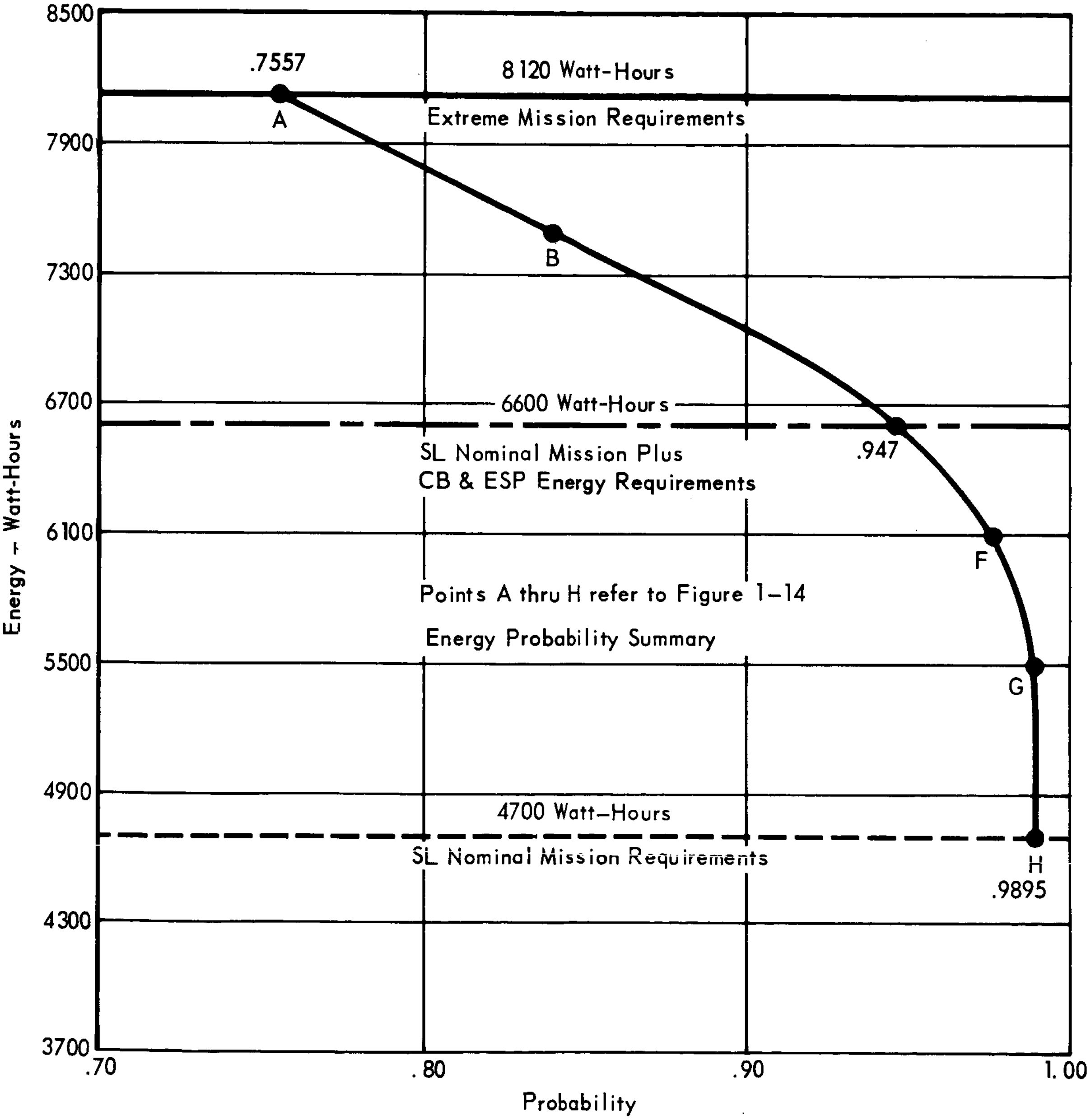


Figure 1–15

FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	FAILURE CATEGORY				REMARKS
			LANDING	ENTRY SCIENCE	LANDED SCIENCE	ENGR. DATA	
PS & L							
Input Power Diode	Open	None	1	1	1	1	Loss of spacecraft power input which is SL battery backed up for SL functions. Only instrumentation involved during cruise.
Voltage Sensor (S/C Power Loss)	Inoperative	None	1	1	1	1	Backed up by spacecraft command for power transfer switching SL batteries #1 and #2 on the line.
Battery Float Charger #1 thru #4	Inoperative	None	1	1	1	1	SLS batteries lose energy at nominal rate of 4%/month. Batteries provide energy above nominal SL mission under worst case charger loss at launch
Batteries (Main) #1 thru #4	Loss	a) One battery-charger unit. Nominal mission – none.	1	1	1	1	3 battery-charger units can provide energy above SL nominal mission.
	Loss	b) One battery-charger unit and one charger. Nominal mission – none.	1	1	1	1	2 battery-charger units and 1 battery can provide energy beyond SL nominal mission.
	Loss	c) One battery-charger unit and two chargers. Nominal mission – none.	1	1	1	1	1 battery-charger unit and 2 batteries can provide energy beyond SL nominal mission.

Failure Category Definition:
1. No effect on mission objectives
2. Degrading effect on mission objectives
3. Possible catastrophic effect on mission objectives

Figure 1-16

SL ELECTRICAL POWER SUBSYSTEM
INFLIGHT TEST REQUIREMENTS

EQUIPMENT	CHARACTER-ISTIC MEASURED	SAMPLING FREQUENCY SAMPLE/SEC.	PURPOSE OF TEST	CORRECTIVE ACTION
Each Battery (4)	Voltage Current Temperature	.01	Verify Battery Charging	Earth Command Charger Relay
			Monitor Performance	Earth Command Battery Relay
Each Battery Relay (4)	Contact Status	.01	Verify Operation	Earth Command Relay
Each Charger Relay (4)	Constant Status	.01	Verify Operation	Earth Command Relay
Distribution Bus	Voltage	.01	Monitor Performance	Earth Command to Reduce Bus Loading
CB Backup Relay	Contact Status	.01	Verify Operation	Earth Command Relay
ESP Backup Relay	Contact Status	.01	Verify Operation	Earth Command Relay

Figure 1-17

these tests the heat sterilization time was less than current requirements for the VOYAGER mission, but these tests and other tests indicate that a battery to meet the VOYAGER mission requirements can be developed. Prior to initiating the Phase D hardware program, current battery development must be extended to prove the capability of Ag-Zn batteries to survive the VOYAGER heat sterilization criteria followed by the wet stand time. Testing of sterilized batteries to compare performance capability after extended wet stand time in a charged condition versus discharged condition is recommended.

SECTION 2

SEQUENCER SUBSYSTEM

The Sequencer Subsystem enables the Surface Laboratory (SL) to be a fully automatic device from the time of in-flight checkout until after landing on the surface of Mars. Without primary Earth commands (except for "START" commands), this subsystem performs the on-board sequencing and timing functions to support the Science Data Subsystem (SDS) and its associated experiments. The two major portions of the Sequencer Subsystem are (a) the Sequencer And Timer (S&T) and (b) the Test Programmer (TP).

2.1 SEQUENCER AND TIMER -

2.1.1 Equipment Identification and Usage - The Sequencer and Timer (S&T) provides the SL with the means for accomplishing, autonomously, the sequential time-based events from landing on the surface of Mars until shutdown. During the portion of the mission between "Earth-set", and "Earth-rise" plus command acquisition time, no Earth commands may be utilized for on-board control of sequential actions.

The S&T fulfills the following functions:

a. Provides on-board time reference for time-based control of SL subsystems.
b. Provides reference clock frequencies for interfacing SL subsystems.
c. Provides decoding and non-volatile storage capabilities for non-real-time (delayed) commands for use as time-based control of SL subsystems. The information contained in this storage must be capable of being up-dated (or modified) prior to launch, inflight prior to separation, and after landing.
d. Provides output driver/circuit closures signals as required for use as time-based control of SL subsystems.
e. Inserts or up-dates adjacent subsystem time-based digital data words.

Figure 2.1-1 shows the Functional Block Diagram of the SL S&T to accomplish these functions.

The S&T consists of the following functional elements as shown on the schematic block diagram of Figure 2.1-2: memory, memory buffer register, decrementer and zero detector, timing and control, master oscillator, converter-regulator and power detector, and the required interface units (digital data, telemetry, command link input sensor, reference frequency and discrete output). The SL impact sensor, also contained within the S&T, is a time-delay-gated gravity sensor to verify that touchdown has occurred.

SEQUENCER & TIMER FUNCTIONAL BLOCK DIAGRAM

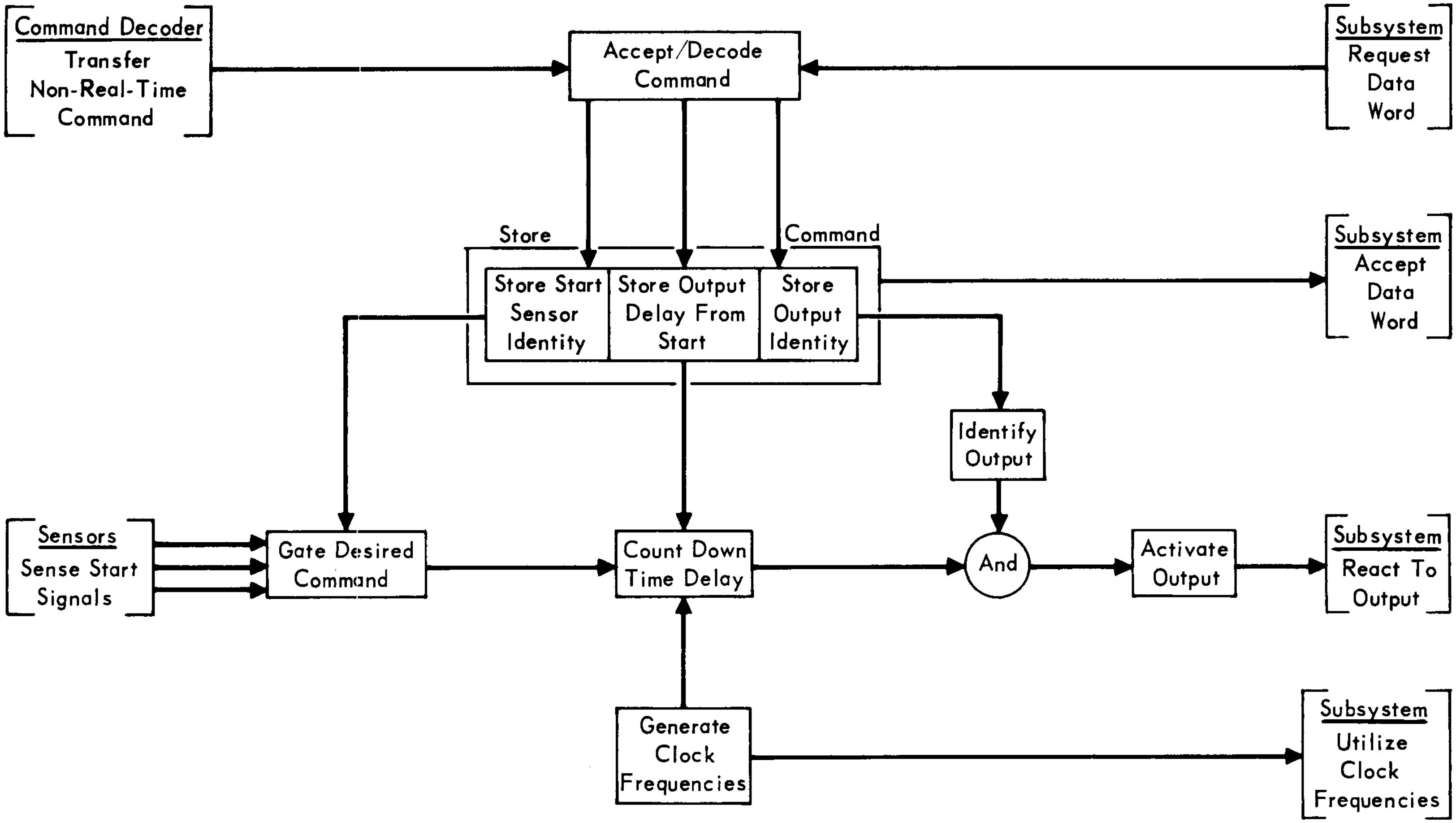


Figure 2.1-1

SL SEQUENCER AND TIMER SCHEMATIC BLOCK DIAGRAM

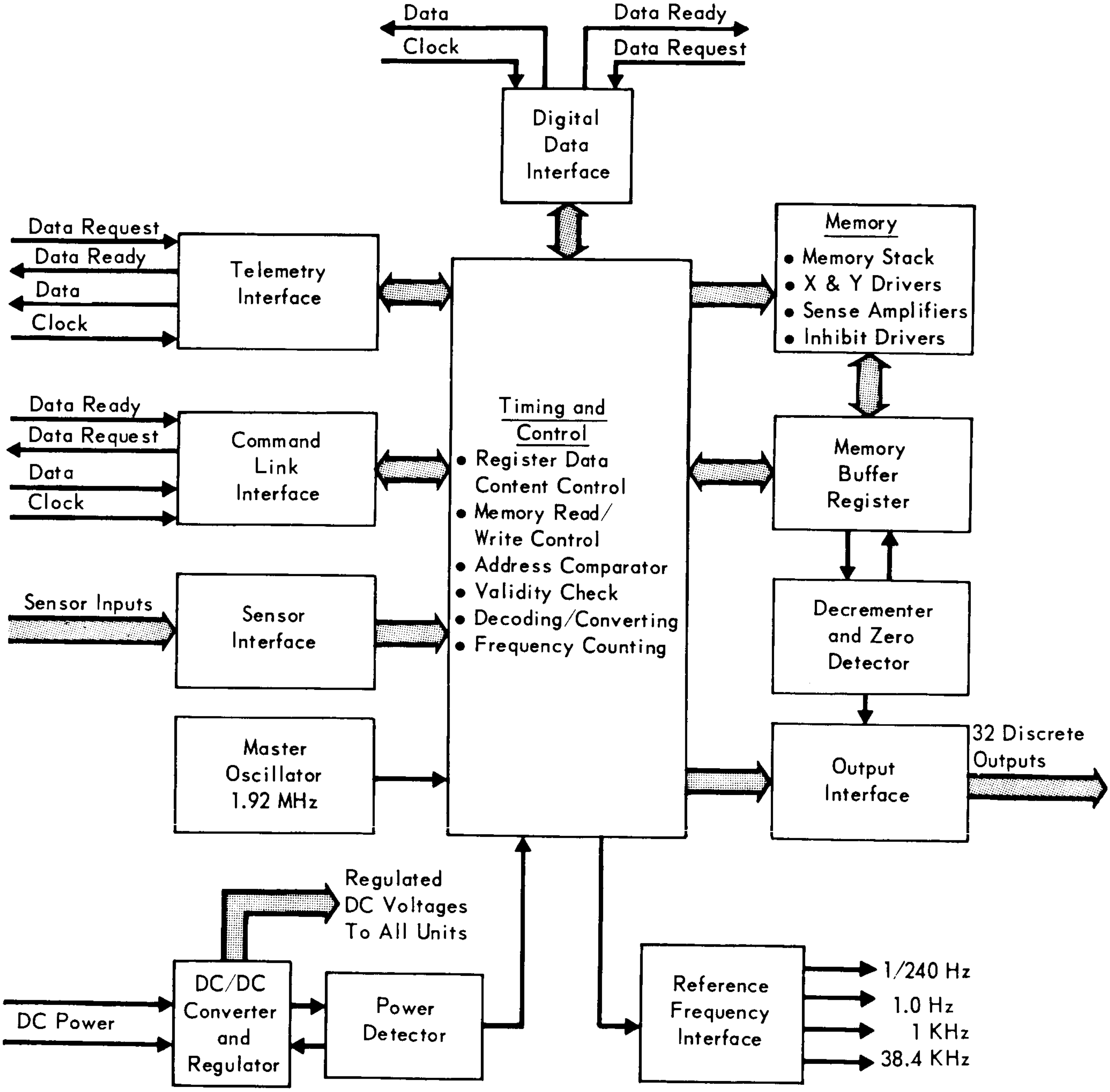


Figure 2.1-2

2.1.2 Design Requirements and Constraints - The requirements and constraints which have influenced the design of the S&T are those of mission, system and subsystem affects upon the S&T, as shown in Figure 2.1-3.

The S&T will fulfill the following known SL supporting subsystem requirements. These requirements form the basis for the corresponding memory and output sizing constraints.

Discrete outputs - The SL subsystems require 21 discrete commands subsequent to several possible mission "marks". These discretes are desired at a time of up to one diurnal cycle after a given "mark" with a resolution of ±2 seconds. A more accurate time sequence is also required for delays up to 5 hours after the "mark" with resolution of ±0.5 second. These discrete output requirements are based upon the sequence of operational events for a typical 1973 mission, shown in Figure 2.1-4.

Other S&T switching actions result from internally stored, pre-separation predicted time to sun and earth references (which may be updated after landing):

a. Predicted Earthset (5 discretes results)
b. Predicted Sunset (1 discrete results)
c. Predicted Earthrise (7 discretes results), and
d. Predicted Sunrise (1 discrete results)

Digital Data Words - The S&T must supply 7 digital words for SL supporting subsystems for the 1973 mission previously described, with 2 more envisioned for extended missions.

a. Antenna Control Subsystem (both words have ±1 pulse resolution).
   - Hour Angle (HA) word (up to 135 pulses)
   - HA Reset word (up to 180 pulses)
b. Science Data Subsystem - (all words are required each minute with a ±2 second resolution).
   - Time-from-Landing (up to 1 diurnal)
   - Time-to-Sunrise/Sunset (up to 1/2 diurnal cycle)
   - Time-to-Noon/Midnight (up to 1/2 diurnal cycle)
   - Time-to-Earthrise/Earthset (up to 1/2 diurnal cycle)
   - Days-from-Landing (up to 750 days, ±1 day, for extended missions)

TABULATION OF SEQUENCER & TIMER (S&T) DESIGN REQUIREMENTS AND CONSTRAINTS

REQUIREMENT OR CONSTRAINT	REASON
1. Stored memory sequence	SL must be entirely on-board sequenced
2. Memory alterable in flight (via FSC)	To enable post-launch mission modifications by Earth command (prior to de-orbit)
3. Memory alterable after landing	To enable post-landing mission modifications by Earth command (following initial sequence of events)
4. Built-in-self-test	To verify proper operation after cruise-storage, in a shortest inflight checkout period
5. Size limitation on S&T packaging	Lander configuration requires minimum size electronics package
6. Weight limitation	Capability of launch vehicle for interplanetary mission requires lightest possible equipment
7. Input power constraints	Must consume minimum power to conserve battery weight, must operate with fluctuating voltage levels
8. Size of memory	Number of different time marks required to sequence SDS-supporting subsystems
9. Number of outputs	Number of different discrete stimuli required by SDS-support subsystems
10. S&T provides sequencing and controls for SL subsystems supporting SDS	SL sequences all post-landing functions; SDS controls its own science equipment
11. Withstand temperature, vibration, etc., environments	Voyager Mission subjects equipment to severe environment

Abbreviations:
S&T: Sequencer & Timer
SL : Surface Laboratory
SDS: Science Data System
FSC: Flight Spacecraft

Figure 2.1-3

INTERFACE DESIGNATION	S&T INPUT (I)/OUTPUT (O)	SOURCE	S&T DESTINATION	BACKUP	MISSION TIME	S&T TIME
I-1	Apply Power to SL S&T	FS CC&S	SL Pwr (S&T)	MOS	T_{12} – 150 min	(Warmup)
I-2	Update SL S&T Parameters	MOS	SL S&T	-	T_{12} – 147 min	(Update)
O-1	Verify SL S&T Parameters	SL S&T	MOS	-	T_{12} – 117 min	(Verify)

SL SEQUENCER AND TIMER (S&T) SEQUENCE OF EVENTS

INTERFACE DESIGNATION	S&T INPUT (I)/OUTPUT (O)	SOURCE	S&T DESTINATION	BACKUP	MISSION TIME	S&T TIME
I–1	Apply Power to SL S&T	FS CC&S	SL Pwr (S&T)	MOS	T_{12} – 150 min	(Warmup)
I–2	Update SL S&T Parameters	MOS	SL S&T	–	T_{12} – 147 min	(Update)
O–1	Verify SL S&T Parameters	SL S&T	MOS	–	T_{12} – 117 min	(Verify)
I–3	Switch SL S&T to Standby	FS CC&S	SL S&T	MOS	T_{12} – 72 min	(Standby)
O–3–1	Switch SL to Internal Power	SL S&T	SL Pwr	MOS	T_{12} – 65 min	T_{es} + 7 min
I–4	Sense Touchdown	SL IS	SL S&T	CB IS	T_{26}	T_o
O–4–1	Turn on SL Command Receiver (CR) Ⓑ	SL IS	SL CR (Pwr)	SL S&T	T_{26}	+ 0 sec
O–4–2	Turn On SL Telemetry (TM) Ⓑ	SL IS	SL TM (Pwr)	SL S&T	T_{26}	+ 0 sec
O–4–3	Select TM Day/Night Mode	SL S&T	SL TM	MOS*	T_{26}	+ 0 sec
O–4–4	Turn on SL Science Data Subsystem (SDS) Ⓑ	SL IS	SL SDS (Pwr)	SL S&T	T_{26}	+ 0 sec
O–4–5	Turn on SL LRSB Transmitter	SL S&T	SL Radio (Pwr)	MOS*	T_{26}	+ 0 sec
O–4–6	Turn on SL Antenna Control Subsystem (ACS)	SL S&T	SL ACS (Pwr)	MOS*	T_{26}	+ 0 sec
O–4–7	Start High-Gain (HG) Antenna Erection Sequence	SL S&T	SL ACS	MOS*	T_{26} + 30 sec	+ 30 sec
O–4–8	LRSB Transmitter Turn on Signal	SL S&T	SL TM	MOS*	T_{26} + 30 sec	+ 30 sec
O–4–9	Begin High-Gain Antenna Gyrocompassing Ⓑ	SL ACS	SL ACS	SL S&T	T_{26} + 10 min	+ 10 min
O–4–10	End High-Gain Antenna Gyrocompassing Ⓑ	SL ACS	SL ACS	SL S&T	T_{26} + 35 min	+ 35 min
O–4–11	Transfer Hour Angle Data Word	SL S&T	SL ACS	–	T_{26} + 35 min†	+ 35 min†
O–4–12	Turn on SL HRSB Transmitter	SL S&T	SL Radio (Pwr)	MOS	T_{27}	T_o + 75 min
O–4–13	HRSB Transmitter Turn on Signal	SL S&T	SL TM	MOS	T_{27} + 30 sec	+ 30 sec
O–4–14	Transfer Time-to-Noon Data Word**	SL S&T	SL SDS	–	–	T_n – · · ·
O–4–15	Turn Off SL HRSB Transmitter or	SL S&T	SL Radio (Pwr)	MOS	T_{28} – 5 min	T_{es} – 5 min
I–5	Turn Off SL HRSB Transmitter Command	SL ACS	SL S&T	–	(at EL Limit)	–
O–4–16	HRSB Transmitter Turn Off Signal	SL S&T	SL TM	MOS	T_{28} – 5 min	T_{es} – 5 min
O–4–17	Shutdown HG Antenna Tracking	SL S&T	SL ACS	MOS	T_{28} – 5 min	T_{es} – 5 min
O–4–18	Transfer HA Reset Word	SL S&T	SL ACS	MOS	T_{28} – 4 min	– 4 min
O–4–19	Turn Off SL ACS	SL S&T	SL ACS (Pwr)	MOS	T_{28}	T_{es}
O–4–20	Turn Off SL LRSB Transmitter	SL S&T	SL Radio (Pwr)	MOS	T_{28}	T_{es}
O–4–21	LRSB Transmitter Turn Off Signal	SL S&T	SL TM	MOS	T_{28}	T_{es}
O–4–22	Transfer Time-to-Earthset**	SL S&T	SL SDS	–	–	T_{es} – · · ·
O–4–23	Switch TM to Night Mode	SL S&T	SL TM	MOS	T_{29}	T_{ss}
O–4–24	Transfer Time-to-Sunset**	SL S&T	SL SDS	–	–	T_{ss} – · · ·

Figure 2.1–4

0–4–25	Transfer Time-to-Midnight**	SL S&T	SL SDS	–	–	T_m – . . .
0–4–26	Transfer Time-to-Earthrise**	SL S&T	SL SDS	–	–	T_{er} – . . .
0–4–27 (0–4–5)	Turn on LRSB Transmitter	SL S&T	SL Radio (Pwr)	MOS*	T_{30}	T_{er}
0–4–28 (0–4–6)	Turn on SL ACS	SL S&T	SL ACS (Pwr)	MOS	T_{30}	T_{er}
0–4–29 (0–4–8)	LRSB Transmitter Turn on Signal	SL S&T	SL TM	MOS*	T_{30} + 30 sec	+ 30 sec
0–4–30	Begin Tracking Earth (HG Antenna)	SL S&T	SL ACS	MOS*	T_{30} + 1 min	+ 1 min
0–4–31 (0–4–12)	Turn on HRSB Transmitter	SL S&T	SL Radio (Pwr)	MOS	T_{30} + 75 min	+ 75 min
0–4–32	Transfer Time-to-Sunrise**	SL S&T	SLSDS	–	–	T_{sr} – . . .
0–4–33 (0–4–13)	HRSB Transmitter Turn on Signal	SL S&T	SL TM	MOS	+ 75 min, 30 sec	+ 75 min, 30 sec
0–4–34	Switch TM to Day Mode	SL S&T	SL TM	MOS	T_{31}	T_{sr}

Sequence may repeat each diurnal cycle: (0–4–14 through 0–4–34)

Notes:
ACS – Antenna Control Subsystem
EL – HG Antenna Elevation Angle
HG – High-Gain
HRSB – High Rate S-Band
LRSB – Low Rate S-Band
* – Non-real-time (delayed) backup by Earth command when possible
** – Time-to-XXX words to SDS once each minute after landing
B – Backup Signal
† – Requested by ACS at approximate time shown
SL – Surface Laboratory
S&T – Sequencer & Timer
TM – Telemetry
IS – Impact Sensor
CR – Command Receiver
SDS – Science Data System
FSC – Flight Spacecraft
CC&S – Central Computer & Timer (FSC)
MOS – Mission Operations System
Pwr – Power (Electrical)

Predicted Times:
T_{sr} – Time of Sunrise
T_{er} – Time of Earthrise
T_m – Time of Midnight
T_{ss} – Time of Sunset
T_{es} – Time of Earthset
T_n – Time of Noon
T_o – Time of Landing

Mission Times:
T_{12} – Separation (CB/FSC)
T_{26} – Touchdown
T_{27} – Begin HRSB Transmission
T_{28} – T_{es}
T_{29} – T_{ss}
T_{30} – T_{er}
T_{31} – T_{sr}

c. Telemetry Subsystem - (required each minute)

- Time-from-Landing (up to 1 diurnal cycle ±2 sec resolution)
- Days-from-Landing (up to 750 days, ±1 day, for extended missions)

Reference Frequencies - The SL subsystems in the preferred 1973 typical mission require 4 reference clock frequencies for internal counting or inter-subsystem synchronization.

a. Antenna Control Subsystem - 1/240 Hz ± .01%
- 1.0 Hz ± .01%

b. Science Data Subsystem - 1.0 Hz ± .01%
- 1.0 KHz ± .01%

c. Telemetry Subsystem - 1.0 Hz ± .01%
- 1.0 KHz ± .01%

d. Instrumentation Synchronization - 38.4 KHz ± .01%

2.1.3 Physical Characteristics - The S&T has the following physical characteristics:

a. Size - 288 in^3

b. Weight - 11 pounds

c. Power - 12 watts of 23 to 33 VDC primary power. This includes 4 watts in the memory, 4 watts in the non-memory circuitry, and 4 watts in the power supply. It does not include any power transmitted by the S&T and dissipated in its loads.

d. Alignment - Impact sensor must be aligned with local vertical.

2.1.4 Operation Description - The S&T is a special purpose digital programmer, and an associated master clock with subdividing counters to yield the required reference clock frequencies. The digital words stored in the memory may be inserted, verified, and/or updated (modified) during pre-launch checkout, prior to separation from the FSC, and after landing on the surface of Mars.

A digital word stored in the S&T memory typically represents the time delay from a specified sensor input to the corresponding line driver output. After this sensor input has occurred, this word is counted down at a rate equal to the required time resolution. The instantaneous value of the data word is the time-to-go to the desired discrete output. When the word has been decremented to zero, the associated output occurs.

The "time-to-go" data words which are periodically updated and transferred to using subsystems are similarly decremented in the memory at the required rate; following the predicted time of occurance this word is reinserted in the memory as the value corresponding to a whole diurnal cycle period and counting resumes as above. This gives the S&T an essentially unlimited daily cycle capability. In an adjacent memory word, the S&T inserts the number of times this daily cycle has occurred, yielding a "days-from-touchdown" word to TM for longer missions.

Digital data words, which are not to be decremented, are stored at constant value until transferred to the requesting subsystems at their commands.

The TM data stream time-tag represents the elapsed time from some data correlating "time-zero" mark, such as the "Touchdown" command to the S&T. This word is stored in the memory as the maximum digital time; when time counting starts (at the Touchdown command), this word is decremented at the internal 2 Hz rate. Following a time-tag request from TM, the decremented word is buffered and its complement is transferred to telemetry (representing "time-from-touchdown" instead of the usual "time-to-go" in a decrementing memory).

The S&T memory word length is assumed to be 24 bits with the following content: 16 bits of data, 3 bits to define the applicable sensor, 1 bit to define the word as "Fine" or "Coarse," 1 bit to indicate the occurence of the applicable sensor, 1 bit to indicate that the word has been decremented to zero time-to-go, 1 word-mark bit, and 1 parity bit. The bits in addition to the data bits are included to insure that, in the event of a power failure, the S&T will return to the correct state when the power returns for correct data interpretation during transmission with the interfaces and for simplification of hardware. The S&T command input word length is 32 bits; the additional 8 bits are for memory location address which signifies the action to be accomplished.

As an example of an internal operational sequence, one discrete delayed-output command (output #1 will occur 10 seconds after sensor input "A"), may be traced through the Schematic Block Diagram of Figure 2.1-2.

a. Upon application of primary power, the DC to DC Converter and Regulators, and Power Detector, are energized. Standard transformer-coupled chopper-driven converter/series regulator circuits are used, providing outputs of ±15 and +5 VDC. The Power Detector senses when the input voltage drops below a specified level and then turns off the power to the logic circuitry (+5 VDC) before allowing the ±15 VDC to decay. In this manner, the Memory content is not destroyed.

b. Prior to launch, the expected time of occurance of this example output #1 is entered into the memory: word A-1 will occur 10 seconds after sensor input "A". This word enters the S&T through the Command Link Interface module, through the Timing and Control module for address decoding and is routed to the proper memory word location.

c. The memory is detailed in Figure 2.1-5. It is a coincident current lithium-ferrite core destructive readout type.

d. The solid-state crystal stabilized Master Oscillator provides the 1.92 MHz internal timing reference, with an initial specified accuracy of 1 PPM.

e. This primary reference frequency is divided as necessary within the Timing and Control module for adjacent subsystem and for internal timing references.

f. The function of the timing and control module is as follows:
The Memory Buffer control circuits perform the task of controlling the data content of the memory buffer register which is a 24 bit flip-flop register. The memory buffer register serves as the exclusive input and output for the core memory. Data transfer to/from the core memory is in parallel. All other operations relative to changing data in the buffer register are performed serially while the contents of the register are shifted in a 24 bit shift cycle in the direction of the least sifnificant bit. As each bit is shifted out of the least significant bit position it is operated upon and then reentered into the most significant bit position of the register. After one complete shift cycle, all bits are in their respective positions and the contents of the register are written into the core memory. Typical operating sequence of the memory is shown in Figure 2.1-6. The only deviation from this sequence is for a "memory readout" cycle or a digital word request. For these operations, the word is written back into the memory prior to the shifting operation (step #5). The reason for this is that the shifting operation is controlled by an external strobe which could locate the data bit in an incorrect slot in the register if a strobe pulse is missed.

g. The logic diagram of the Decrementer and Zero Detector is shown in Figure 2.1.7. The circuit decrements the content of the memory Buffer Register by changing the Least Significant Bit (LSB) and serially checking the new word to see if any bit is not zero. If not, the zero detector sets a flip-flop and enables the Output Interface.

h. The logic diagram of the output interface is shown in Figure 2.1-8. Upon zero-detection, the appropriate line driver is energized and held in that state by a latching gate arrangement until a reset command is received. The reset command could be either a word reaching zero having been decremented, a timing module flip-flop to produce a pulse output, or a signal from the Control and Timing to protect against false triggering during power interruptions.

SEQUENCER AND TIMER MEMORY SCHEMATIC BLOCK DIAGRAM

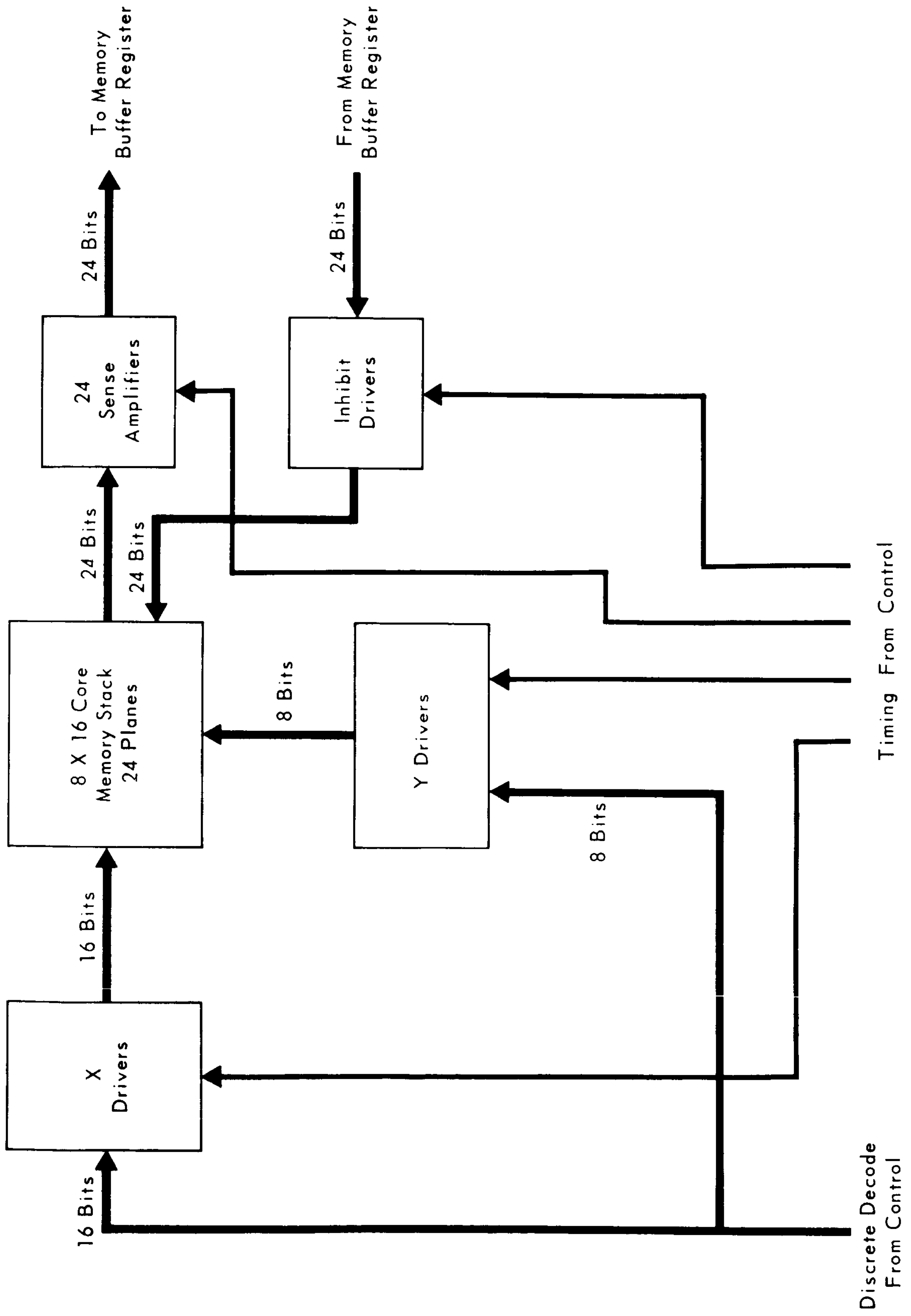


Figure 2.1-5

SEQUENCER AND TIMER (S&T) MEMORY TYPICAL OPERATING SEQUENCE

STEP	DESCRIPTION
1	Increment memory address register
2	Reset memory buffer register
3	Read word from memory specified by the address register and strobe the 24 bit word into memory buffer register in parallel
4	Prior to shifting check for the following and set mode switches accordingly: • Is this a time-to-go word as opposed to a digital data word? • Is this word to be updated from the command link system as indicated by comparison of the memory address and the address in the digital command system register? • Is the sensor for this word active? • Has this word previously reached zero? • Is this a fine or course time word? • Is this a "memory readout" cycle or a digital data word request?
5	Shift the register through 24 shift cycles and update/distribute the data as dictated by mode switches
6	Check if the time word has been decremented to zero and command discrete for this memory word address
7	Write contents of buffer register into the same core memory position from which the word was read in step 3
8	Return to step 1 and repeat sequence for next memory word

Figure 2.1–6

SEQUENCER AND TIMER DECREMENTER AND ZERO DETECTOR LOGIC DIAGRAM

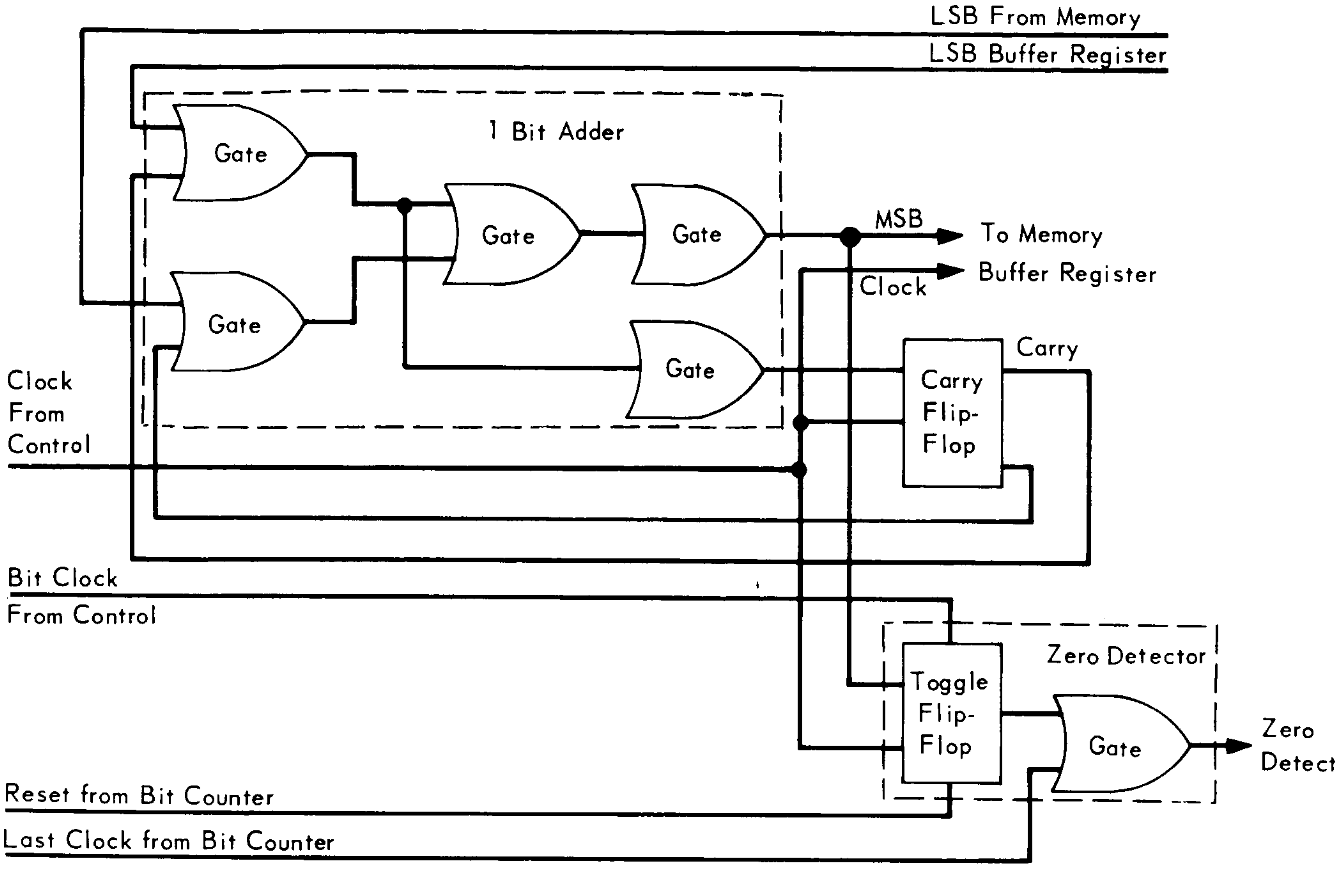


Figure 2.1-7

SL SEQUENCER & TIMER OUTPUT INTERFACE LOGIC DIAGRAM

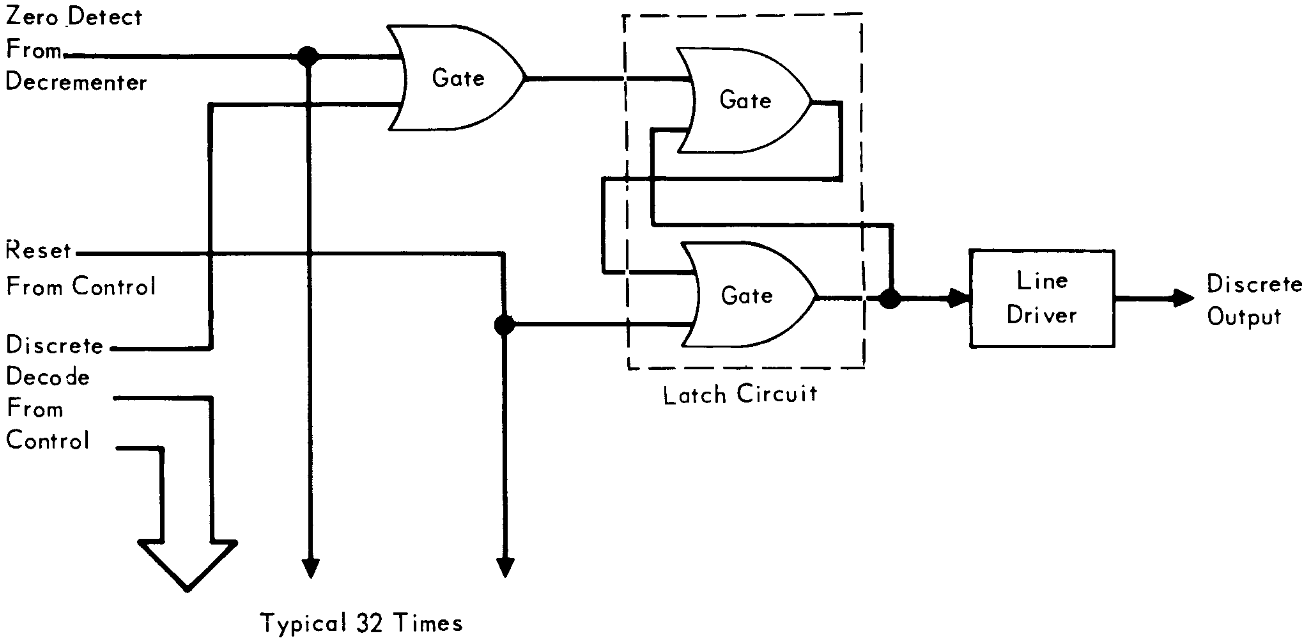


Figure 2.1-8

i. Other interface modules are merely impedance matching and data time correlation buffer units.

j. The SL impact sensor verifies that the touchdown impact has occurred (rather than thruster or decelerator jerks) by detecting that the sensed acceleration exceeds the preset threshold for a preset time period. The acceleration threshold is $0.8g_M$ to detect a static surface condition. The time delay period is 5 minutes to preclude activating while descending on the decelerator or the terminal thrusters (which have a maximum combined time duration of approximately 3 minutes). If the sensed acceleration continues for longer than 5 minutes above $0.8g_M$, the "impact" output is activated. If the sensed acceleration decreases below the $0.8g_M$ threshold within the 5 minute time-delay period, the output is not activated but is reset to start the count again when an acceleration greater than $0.8g_M$ is sensed.

2.1.5 Performance Characteristics - The S&T utilizes the 128 word storage and the 1.92 MHz internal frequency reference to produce the following output capability:

a. 32 discrete (bilevel) outputs with relay line driver capacity (switching line voltage, 23 to 33 VDC, up to 5 watts each, preferably pulsed for 1 second to latch in a remote relay in the using subsystem). These discretes may occur following any of several sensor inputs with either of the following preselected maximum time delays (and resolution) ranges: 0 to one diurnal cycle (±2 second) or 0 to 5 hours (±0.5 seconds). Because the number of stored words is over 50% greater than the number of discrete outputs, the extra memory capacity may be utilized in early flights as redundant command capability for repeated commands; nearly one-half of the discrete functions may be repeated twice.

b. Digital data word storage and transfer capability is limited only by the number of unused time word locations in the memory. These words thus have the same 16 bit capacity as the time-base data. Present requirements are (18) 16-bit data words.

c. Any sub-harmonic frequency, divided from the internal 1.92 MHz reference, may be provided for subsystem synchronization and/or basic frequency reference signals. Baseline design currently requires four output references: (1/240) Hz, ± .01%, 1.0 HZ ± .01%; 1 kHz ± .01% and 38.4 kHz ± .01%.

d. The SL impact sensor timing utilizes the S&T timing clock pulses to implement the time-delay-gating of the accelerometer output. The completion of the 5 minute delay in the presence of a sensed $0.8g_M$ initiates the SL touchdown signal, applying power to the command receiver, telemetry and science data subsystem. S&T touchdown sequences may also be initiated by this impact sensor input, or by the backup signal from the CB impact sensor. The SL impact sensor provides these discrete outputs on output lines, separate from the normal function S&T outputs, enabling redundant touchdown initiation of critical subsystems. This impact initiation is independent from the memory-timing portion of the S&T, which is also timing a touchdown backup signal from the pre-separation "standby" mark from the FSC.

2.1.6 Interface Definition - The S&T interfaces are shown on Figure 2.1-9.

In-Flight Test - The Test Programmer (TP) inputs, are test control discretes and test power as required, as defined in Section 2.1.8.

Command Link - The S&T interfaces with the SL Command Decoder (CD) with the standard digital data transfer sequence for the quantitative (delay-time) digital data words.

- Data Ready - Logic switching level input from CD.
- Data Request - Same type output from S&T to CD.
- Clock - Data transfer rate reference frequency from sending CD to S&T; the same number of pulses as bits in the data word.
- Data Word(s) - The logic switching level digital data (up to 128 words, 32 bits each, including S&T word address) from CD to S&T. Discrete (bilevel) commands are received from the CD in the same manner as the Data Ready pulse.

Sensor Inputs - The sensor inputs may be either power level or logic signal level interfaces. In addition to the SL physical sensing devices outputs, (impact sensors), these outputs also emanate from SL subsystems (elevation limit signal from the Antenna Control Subsystem).

Power - The primary electrical power input originates from the unregulated SL batteries (23 to 33 VDC). However, both ground power for pre-launch functions, and FSC power for pre-separation operations must be accepted.

Reference Frequencies - These S&T references are transferred as two-wire balanced outputs, isolated from power and signal inputs.

- 1/240 Hz ±.01% for antenna control.
- 1 kHz ± .01% for telemetry synchronization reference.
- 38.4 kHz ± .01% for instrumentation synchronization.
- 1 Hz, ±.01% for antenna control and SDS references.

Telemetry - The outputs to telemetry (TM) include the digital words, bilevel discretes and analog signals indicative of S&T internal operation. The digital data words may be transferred in the same manner as those from the Command Receiver except that the signal directions are reversed: following the request

SL SEQUENCER AND TIMER INTERFACE DIAGRAM

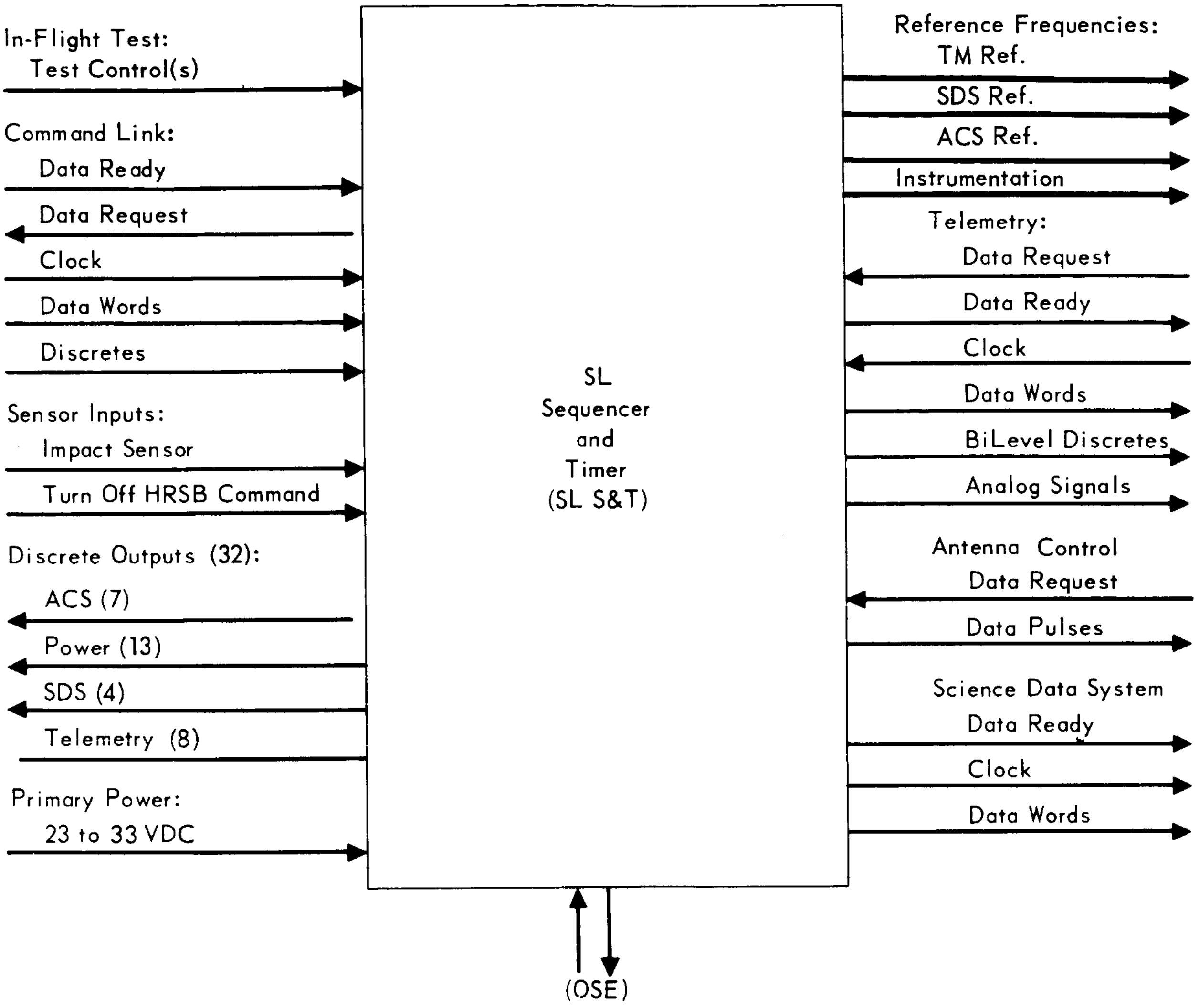


Figure 2.1-9

from TM and ready from S&T, the data flow is of course from S&T to TM. The clock reference is provided at the required TM data rate. The data words which are monitored include the following:

- Address Decoder Entry - Monitored to verify the proper acceptance of each command word from Command Receiver to S&T.
- Driver Output Counter - Sampled periodically to indicate the number of discrete outputs occurring prior to the sampling instant.
- Time-Tag Word(s) - Required by TM for data correlation, this counter starts at the pre-separation "READY" command.
- Memory Readout - A complete readout of the S&T memory to verify the total updating procedure.

The S&T bilevel discretes monitored by TM are:

- Frequency Reference Monitor - Internal rough check of S&T Master Oscillator frequency (± 10%) to assure non-harmonic operation.
- Command Receipt Parity Check - A bilevel denoting that properly coded command (correct number of bits) was received by the S&T from the CD.

The analog signals measured by TM include:

- S&T Master Oscillator Temperature - a measure of oscillator stability.
- Power Supply Voltages - monitored to indicate S&T operational trends, allowing modification of stored times to counteract degraded counting performance.

Discrete Outputs - The S&T line driver outputs are capable of activating a (latch) relay in the using subsystem. The 32 allotted S&T outputs are summarized by SL subsystems in Figure 2.1-10. These include certain backup signals to provide functional redundancy for critical SL signal sources.

Digital Data Words - The transfer of SL high gain antenna driving pulses (based upon stored digital data words) to the Antenna Control Subsystem (ACS) is accomplished at various times after landing when the antenna must be slewed. Therefore, only two functions are involved in the transfer.

- Ready or Request - HA data is requested when antenna pointing to local vertical has been accomplished; HA Reset Ready is sent to stop slow tracking prior to slewing antenna to expected Earthrise position.
- Data Word Pulse Train - Logic/switching level digital pulse train (up to 180 pulses each internally counted from stored data words) at one pulse/sec.

At present, two data words are defined:

- Hour Angle (HA), and
- HA Reset.

SL SEQUENCER AND TIMER OUTPUT SIGNAL SUMMARY

S&T OUTPUTS (TYPE) TO INTERFACING SUBSYSTEMS	LINE DRIVERS (BILEVEL) ①		DATA TRANSFER (DIGITAL) ②	DATA TRANSFER (ANALOG) ③
Antenna Control Subsystem	3 (TD) 2 (D)	(4) (3)	1 (TD) 1 (C)	2 (C)
Power	4 (TD) 3 (TD/D) 3 (D)	(5) (4) (4)		
Science Data Subsystem	0	(2) (2)	2 (TD/D) 3 (D)	1 (C)
Telemetry	2 (D) 4 (TD/D)	(3) (5)	2 (TD/D) 130 (C)	5 (C)
Totals	21	(32)	130	8

① Currently allocated outputs compared to those tentatively allotted (includes growth allowance or excess S&T output capacity).

② Memory telemetry requirement to read out entire stored sequence for Earth verification includes all digital data words transferred to other subsystems.

③ Includes clock or reference frequencies.

(TD) Based on time of touchdown (or separation) only.

(D) Occurring daily (each diurnal cycle).

(TD/D) Beginning at time of touch down and subsequently occurring daily.

(C) Continuous or "on-demand" outputs.

Figure 2.1-10

The digital data transfer to the Science Data Subsystem (SDS) is also accomplished at preselected times after landing, but is updated every minute. Hence, another function is necessary to inform the SDS that the required data is to be ' transferred so as not to use changing data, which would produce erroneous information. The three functions of the transfer are:

- o Data Ready - Logic switching level signal from S&T to SDS.
- o Clock - Same as above, to SDS.
- o Data Word(s) - Same as above, to SDS.

Typically, the SDS, receives four data words from the S&T for the 1973 mission; an additional word is required for extended missions.

- o Time-from-Touchdown - (updated each minute, 2 sec. resolution, to 1 diurnal period).
- o Days-from-Touchdown - (Updated each day, 1 day resolution, to more than 750 days for extended missions).
- o Time-to-Sunrise/Sunset - (Updated each minute, 2 sec. resolution, to 1/2 diurnal period).
- o Time-to-Noon/Midnight - (Updated each minute, 2 sec. resolution, to 1/2 diurnal period).
- o Time-to-Earthrise/Earthset - (Updated each minute, 2 sec. resolution, to 1/2 diurnal period).

The two Time-to-(Sun reference) data words are actually compilations to four S&T quantities:

- o Time-to-Noon
- o Time-to-Sunset
- o Time-to-Midnight
- o Time-to-Sunrise

These four words are decremented from their predicted touchdown values and are separately transferred to the SDS during the corresponding period:

- o For a nominal morning landing, Time-to-Noon is transferred each minute after touchdown until Noon,
- o Time-to-Midnight is then transferred over the same data lines until Midnight.
- o Time-to-Sunset word is transferred over different data lines until Sunset.
- o Time-to-Sunrise is then transferred until Sunrise, etc.

The Earth reference words similarly "share" common data lines and are sequentially transferred to the SDS in the corresponding period.

- For a nominal morning landing, Time-to-Earthset is transferred until Earthset.
- Time-to-Earthrise is then transferred over the same Earth-time data lines until Earthrise, etc.

2.1.7 <u>Reliability Consideration</u> - Evaluation of the Sequencer and Timer selected design indicates this design can be implemented for the 1973 Mars mission utilizing state-of-the-art components and conservative design techniques consistent with the VOYAGER Mars reliability requirements.

2.1.7.1 <u>Reliability Model</u> - The Reliability Model for the Surface Lab Sequencer and Timer is presented in Figure 2.1-11. This model is representative of the selected design approach. A model modified to show redundancies considered for incorporation in the Surface Lab Sequencer and Timer is presented in Section 2.1.7.4.

2.1.7.2 <u>Reliability Estimates</u> - The reliability estimate for the Surface Lab Sequencer and Timer, for a nominal 1973 Mars mission, as shown in Figure 2.1-11, is

P_s (probability of success) = .9918

<u>Reliability Estimate by Mission Phase</u> - The estimate of Surface Lab Sequencer and Timer probability of success (P_s) for each of the four mission phases is:

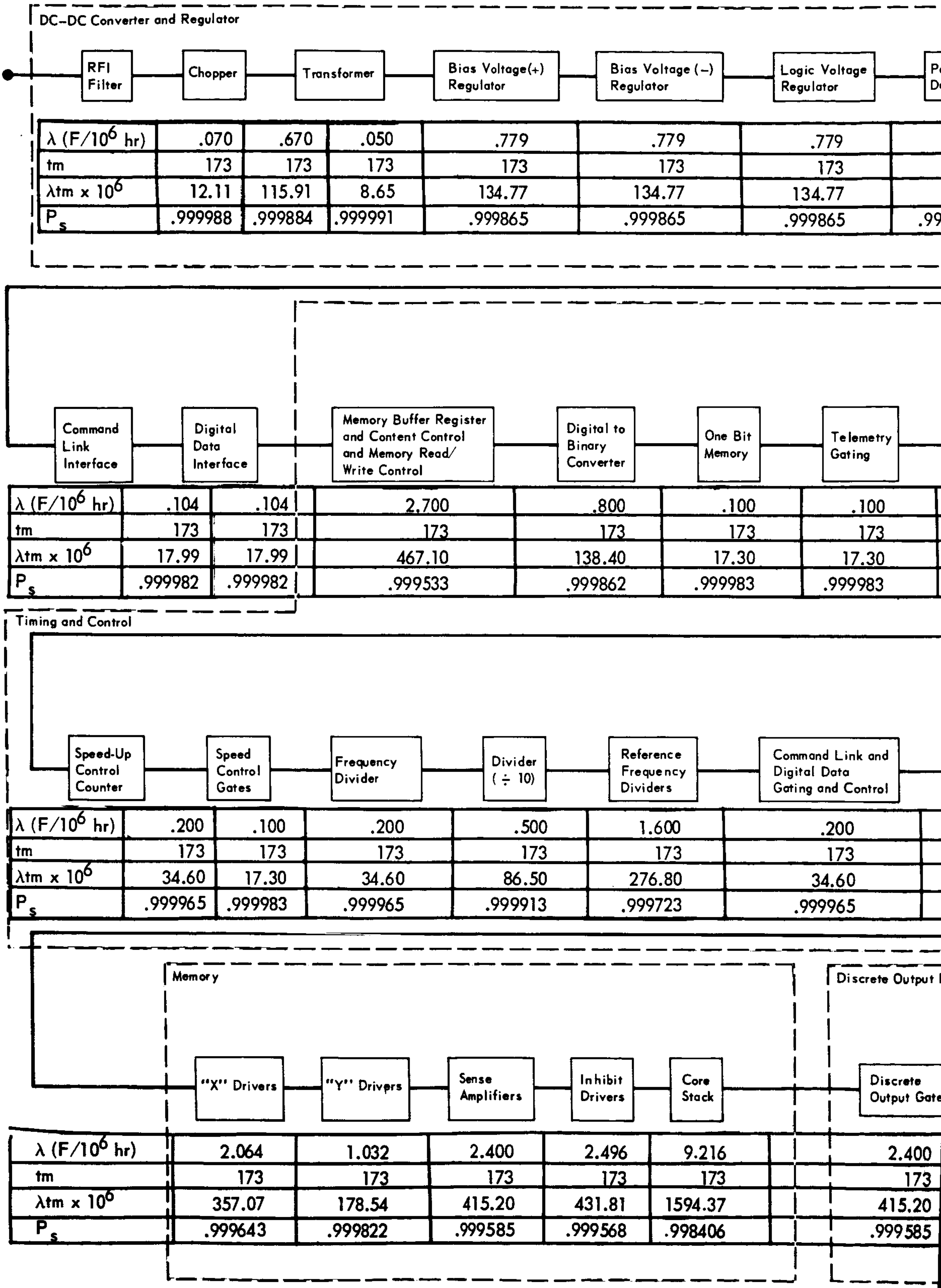
Phase 1 (Launch to Deorbit Maneuver) $P_s = .9958$
Phase 2 (Deorbit Maneuver to Entry) $P_s = .9998$
Phase 3 (Entry to Landing) $P_s > .9999$
Phase 4 (Landing to Mission End) $P_s = .9962$

<u>Major Assenbly Reliability Estimates</u> - The component type, quantity of components and probability of assembly mission success were estimated for each block of the reliability model to obtain the overall Sequencer and Timer mission success probability.

These estimates are as follows:

	Phase P_s				Mission
Major Assembly	(1)	(2)	(3)	(4)	P_s
DC-DC Converter and Power Regulator	.999723	.999984	.999997	.999746	.999452
Memory	.998501	.999913	.999987	.998622	.997024
Timing and Control	.998411	.999908	.999986	.998543	.996855
Output Interface	.999645	.999980	.999997	.999675	.999297
Remaining Assemblies	.999549	.999974	.999996	.999586	.999106

SURFACE LABORATORY SEQUENCER & TIMER RELIABILITY MODEL



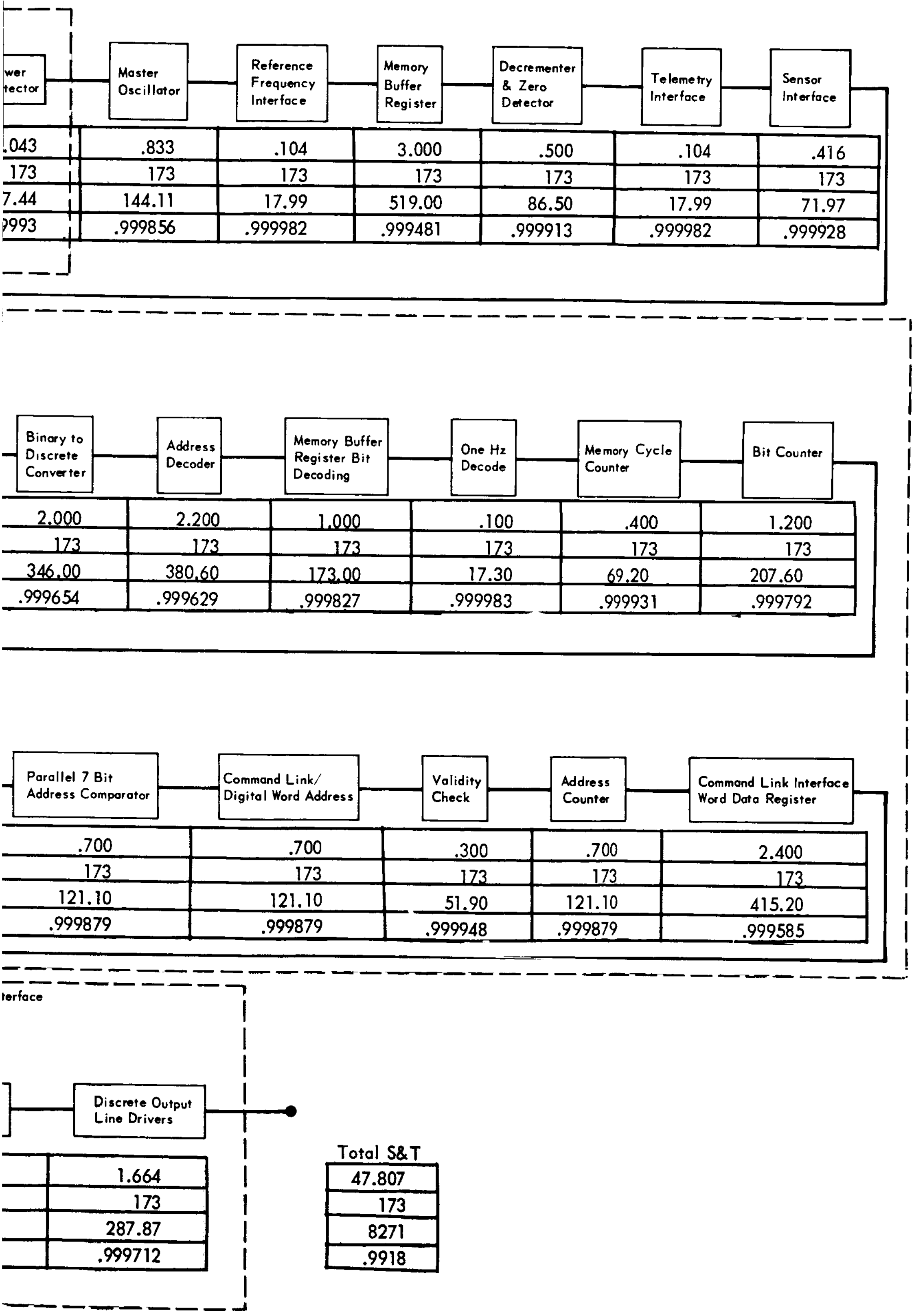
	RFI Filter	Chopper	Transformer	Bias Voltage(+) Regulator	Bias Voltage (–) Regulator	Logic Voltage Regulator
λ (F/10^6 hr)	.070	.670	.050	.779	.779	.779
tm	173	173	173	173	173	173
λtm x 10^6	12.11	115.91	8.65	134.77	134.77	134.77
P_s	.999988	.999884	.999991	.999865	.999865	.999865

	Command Link Interface	Digital Data Interface	Memory Buffer Register and Content Control and Memory Read/ Write Control	Digital to Binary Converter	One Bit Memory	Telemetry Gating
λ (F/10^6 hr)	.104	.104	2.700	.800	.100	.100
tm	173	173	173	173	173	173
λtm x 10^6	17.99	17.99	467.10	138.40	17.30	17.30
P_s	.999982	.999982	.999533	.999862	.999983	.999983

	Speed-Up Control Counter	Speed Control Gates	Frequency Divider	Divider (÷ 10)	Reference Frequency Dividers	Command Link and Digital Data Gating and Control
λ (F/10^6 hr)	.200	.100	.200	.500	1.600	.200
tm	173	173	173	173	173	173
λtm x 10^6	34.60	17.30	34.60	86.50	276.80	34.60
P_s	.999965	.999983	.999965	.999913	.999723	.999965

	"X" Drivers	"Y" Drivers	Sense Amplifiers	Inhibit Drivers	Core Stack	Discrete Output Gate
λ (F/10^6 hr)	2.064	1.032	2.400	2.496	9.216	2.400
tm	173	173	173	173	173	173
λtm x 10^6	357.07	178.54	415.20	431.81	1594.37	415.20
P_s	.999643	.999822	.999585	.999568	.998406	.999585

2.1-21-1


wer
tector
.043
173
7.44
9993
Master Oscillator
.833
173
144.11
.999856
Reference Frequency Interface
.104
173
17.99
.999982
Memory Buffer Register
3.000
173
519.00
.999481
Decrementer & Zero Detector
.500
173
86.50
.999913
Telemetry Interface
.104
173
17.99
.999982
Sensor Interface
.416
173
71.97
.999928
Binary to Discrete Converter
2.000
173
346.00
.999654
Address Decoder
2.200
173
380.60
.999629
Memory Buffer Register Bit Decoding
1.000
173
173.00
.999827
One Hz Decode
.100
173
17.30
.999983
Memory Cycle Counter
.400
173
69.20
.999931
Bit Counter
1.200
173
207.60
.999792
Parallel 7 Bit Address Comparator
.700
173
121.10
.999879
Command Link/ Digital Word Address
.700
173
121.10
.999879
Validity Check
.300
173
51.90
.999948
Address Counter
.700
173
121.10
.999879
Command Link Interface Word Data Register
2.400
173
415.20
.999585
terface
Discrete Output Line Drivers
1.664
173
287.87
.999712
Total S&T
47.807
173
8271
.9918

re 2.1-11

2.1.7.3 Failure Mode, Effect and Criticality Analysis (FMECA) - A failure mode, effect and criticality analysis was performed on the selected design to highlight its possible deficiencies and point up those areas requiring additional effort. The analysis performed is reflected in Figure 2.1-12 and identifies those failure modes which could have catastrophic or degraded effect on the mission. This analysis was used to determine single point failure and, additionally, as a guide in applying the redundancies discussed in Section 2.1.7.4. A need for continuing effort is indicated to assure that as many of the identified catastrophic and degraded failure modes as possible are eliminated.

2.1.7.4 Redundancy Considerations - As a part of the overall reliability evaluation of the Surface Lab, each major subsystem design was reviewed for potential application of redundancies which would improve the mission success probability and eliminate single failure modes which have catastrophic mission effect. Since Surface Lab weight is constrained, one major consideration used in determining the efficiency of redundancy alternates has been the reliability improvement (ΔR) obtained for the additional weight (ΔW) required to implement the redundancy being considered. This analysis was performed for the Surface Lab Sequencer and Timer. Figure 2.1-13 depicts the redundancies selected, of the various forms considered, for comparison with other subsystem potential redundancies on the basis of their ΔR to ΔW ratios.

Using the $\Delta R/\Delta W$ critiera, the priority of redundancy incorporation for the Surface Lab Sequencer and Timer is:

- Provide active redundant crystal controlled oscillators.
- Provide duplex memories and memory buffer registers with error detection switching logic.
- Incorporate triple redundant frequency dividers with majority voters at each use point.
- Incorporate triple redundant decrementers and zero detectors with majority voters.
- Provide active redundant discrete output line drivers.
- Incorporate triple redundant control logic with majority voters.
- Provide active redundant telemetry, command link, reference frequency and digital data interfaces.
- Provide active redundant sensor interfaces.
- Incorporate triple redundant discrete output gates with majority voters.
- Provide active redundant bias voltage and logic voltage regulators.

FAILURE MODE EFFECT AND CRITICALITY ANALYSIS
SURFACE LABORATORY SEQUENCER AND TIMER

FAILURE CATEGORY DEFINITION
1 – No Effect on Mission Objective
2 – Degrading Effect on Mission Objective
3 – Possible Catastrophic Effect on Mission Objective

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	FAILURE CATEGORY				REMARKS
			Landing	Entry Science	Landed Science	Eng. Data	
DC–DC Converter	No output	S&T fails to function	1	1	2	2	No S&T initiated events will occur. Redundant regulators lower the probability of occurrence best from effectiveness vs. weight standpoint.
Master Oscillator	No output	S&T fails to function	1	1	2	2	No S&T initiated events will occur. Active redundant oscillators would prevent a single oscillator failure from causing S&T failure.
	Frequency instability	Inaccuracy in timing of functions	1	1	2	2	Adequate design should minimize this as a problem. (Mariner 4 had only slight drift.)
Reference Frequency Interface	No output	Fails to provide synch for using units	1	1	2	2	Design of using units will provide for free-running operation (unsynched) at frequencies slightly below the synch frequencies so that loss of synch only results in degraded operation.
Power Detector	Fails to detect power loss	Possible alteration of data in memory	1	1	2	2	When bias voltage is removed before logic voltage, a possibility exists that the memory will be altered by the shutfown transients. If significant digits are altered can cause events to occur too early or too late. Small probability of occurence.
	False Shutdown	Loss of down time in time count	1	1	1	1	No problem created if this occurs prior to final update. After that time only effect is a \delay in event times equal to the time during which power was lost.
Memory Buffer Register	Failure to allow data transfer from or to memory.	Loss of all functions other than as frequency generator for synch. use.	1	1	2	2	All data enters and leaves the memory buffer register. Loss of all or part of the memory buffer register can prevent all timed

Figure 2.1-12

							events from occuring. Duplexed memory registers used with the duplexing of memories would preclude this as a single point failure.
Decrementer and Zero Detector	Failure to decrement memory time word	All time functions fail to occur	1	1	2	2	All timed events are initiated by the DZD decrementing of the time word and detection of zero. Triple redundant decremeters and zero detectors with voters would reduce probability but already low probability of occurence.
	Failure to detect zero	No output discretes will occur	1	1	2	2	(Same as above)
Telemetry Interface	Failure to allow telemetry read-out of the S&T memory	Uncertainty as to correctness of memory content	1	1	2	2	Failure to obtain telemetry read-out of the memory would necessitate either accepting the data already in the memory in an unverified state or attempting to write new words in the memory without being able to verify these words were correctly written into the memory. Redundant telemetry interface would reduce the probability of this occurence, however probability is already small.
Sensor Interface	Fails to recognize sensor activation	Events timed from sensor occurence will fail to occur	1	1	2	2	All events which are timed from a sensor activation will fail to occur unless backup by MOS is available. Redundant sensor interface would reduce the probability of this occurence however probability is already small.
	False indication that sensor has activated	Events timed from sensor occurence will occur at improper time	1	1	2	2	False indication might occur by virtue of a transient of by chatter in a relay acting as a sensor element. This failure mode requires triple redundant interface with majority voters to reduce likelihood of occurence.
Command Link Interface	Fails to allow memory up-date	Events will occur at nominal times programmed prior to command link interface failure.	1	1	2	2	Readout of memory during the test sequence will establish memory contents. If mission can be performed utilizing nominal times, separate command will be sent by MOS. Can be made redundant, however probability of failure is low.

FAILURE MODE, EFFECTS AND CRITICALITY ANALYSIS

SEQUENCER AND TIMER (Continued)

FAILURE CATEGORY DEFINITION
1. No Effect on Mission Objective
2. Degrading Effect on Mission Objective
3. Possible Catastrophic Effect on Mission Objective

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	FAILURE CATEGORY Landing	Entry Science	Landed Science	Eng. Data	REMARKS
Digital Data Interface	Fails to allow transfer of digital data words stored in S&T memory to using units.	Units will retain nominal words stored prior to failure and operate as for a nominal mission	1	1	2	2	Digital data interface can be made redundant, however, probability of failure is already low. Using units have pre-programmed nominal words and would operate on those words instead of allowing update.
Memory Drivers	Fail to drive.	Loss of row driven by failed driver	1	1	2	2	Criticality is based on which time word is failed by memory driver loss. Duplex of memories or programming of redundant time words in different "X" – "Y" locations would reduce the probability of this occurrence.
Memory Sense Amplifiers	Fail to perform sensing function.	Loss of memory plane associated with failed sense amplifier	1	1	2	2	Criticality is based on which "bit" of all time words is failed by memory sense amamplifier loss. Triple redundant sense amplifiers with majority voter or duplex memory would reduce the probability of this occurrence.
Inhibit Drivers	Fails to drive	Loss of plane driven by failed inhibit driver	1	1	2	2	Criticality is based on which "bit" of time words may be incorrect. Duplexing of memories would reduce the probability of this failure mode.
Core Stack	Broken core	Loss of bit for storage purposes	1	1	2	2	Criticality dependent on word or "bit" associated with failure. Duplex memories would reduce the probability of this failure mode, however probability of occurrence is extremely small.
	Broken drive, sense or inhibit functions associ-	Loss of drive, sense or inhibit functions associated with	1	1	2	2	Criticality dependent on word or "bit" associated with failure. Duplex memories would reduce

Figure 2.1-12 (Continued)

	ated with failed wire	failed wire					the probability of this failure mode, however probability of occurrence is extremely small.
Discrete output drivers	Fails to actuate output	Loss of function controlled by output.	1	1	2	2	Criticality dependent on function controlled by output. Use of two outputs to actuate one function **will prevent this from** occurring.
	Fails to reset	Failure to turn off function controlled by output	1	1	2	2	Criticality dependent on function controlled by output. Triple redundant gates with majority voter would reduce the probability of this failure mode.
	False actuation	Enables function at improper time – possible mission abort	1	1	2	2	Criticality dependent on function controlled by output. Triple redundant gates with majority voter would reduce the probability of this failure mode.
Timing and Control Sensor Recognition	Fails to recognize sensor activation	Fails to command associated event at Δtime after sensor occurence.	1	1	2	2	All events which are timed from a sensor activation will fail to occur unless backup by some other means exists. Triple redundacizing of this function with majority voters will reduce probability of occurrence.
	False recognition of sensor	Commands associated event at Δtime after false sensor indication.	1	1	2	2	All events which are timed from the falsely recognized sensor activation will occur at the preprogrammed Δtime. Triple redundacizing of this function with majority voters will reduce probability of this failure mode.
Telemetry readout	Fails to transfer data from memory buffer register to telemetry interface	Failure to readout S&T memory content to MOS.	1	1	2	2	Failure to obtain telemetry readout of the memory would necessitate either accepting the data already in the memory in an unverified state or attempting to write new words in the memory without being able to verify these words were correctly written into the memory. Triple redundacizing of this function with majority voters would reduce probability of this failure mode.
Discrete Decoding	Failure to properly decode output address	Actuation of incorrect output and failure to actuate proper output when time word reaches zero.	1	1	2	2	Criticality is dependent upon function mistakenly activated and function not activated. Triple redundacizing of this function with majority voters would reduce the probability of this failure mode occurring.

2.1-24-2
Part 1

2.1-24-2

2.1-24-2
Part 2

FAILURE MODE EFFECT AND CRITICALITY ANALYSIS
SURFACE LABORATORY SEQUENCER AND TIMER (Continued)

FAILURE CATEGORY DEFINITION
1 – No Effect
2 – Degrading Effect on Mission Objective
3 – Possible Catastrophic Effect on Mission Objective

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	FAILURE CATEGORY Landing	Entry Science	Landed Science	Eng. Data	REMARKS
Memory Driver Decoding	Failure to actuate proper "X" and "Y" memory drivers.	"Write" or "read" of data in incorrect memory location causing incorrect output and failure to actuate proper output when time word reaches zero.	1	1	2	2	Criticality is dependent upon function controlled by word mistakenly written. Triple redundacizing of this function with majority voters would re-reduce the probability of this failure mode occurring.
Frequency Dividers	Fails to divide	Probable failure of entire timing and control function	1	1	2	2	No S&T initiated event will occur Triple redundant frequency dividers with majority voters would reduce probability of this failure mode occurring.
Speed-Up Control	Fails to speed-up "clock" rate to compensate for time taken to read out telemetry.	Time error of time taken to read out memory	1	1	1	1	No problem created if this occurs prior to final update. After that time only effect is a delay in event times equal to the time required to read out the memory. Triple redundant speed-up control with majority voters would reduce probability of this failure mode occurring.
External Clocking Gates	Fails to clock memory at externally supplied rate.	Either does not supply digital data to TM or using unit or supplies it at an unusable rate.	1	1	2	2	Memory cannot be read out and or digital data cannot be transferred. Nominal times in S&T can be used or attempt made to read in new words without verification. Using units of digital words will use nominal data words. Triple redundant clocking gates would reduce probability, how-

Figure 2.1–12 (Continued)

						ever probability is already small and does not **warrant** redundancy.
Bit Decoding	Incorrectly reads bit	Initiates Incorrect operation on word in memory buffer register	1	1	2	2	Criticality is dependent upon nature of operation initiated by the erroneous bit. Triple redundant bit decoding with majority voters would reduce probability of failure mode, however, probability of occurrence is low and redundancy is not warranted.
Address Decoding	Reads address location incorrectly	Initiates incorrect output when word decrements to zero	1	1	2	2	Criticality is dependent upon output incorrectly initiated. Triple redundant address decoders with majority voters would reduce probability of occurrence, however, probability of failure mode is small.
Address Comparator	Fails to correctly address words being inserted via command link or selects incorrect word for digital data read out.	Data words are read from or inserted into incorrect memory locations.	1	1	2	2	Criticality is dependent upon function controlled by memory location. Triple redundant address comparators would reduce probability of occurrence.
Command Link – Digital Data Register	Fails to allow the transfer of data from or to memory buffer register.	Fails to allow digital data readout causing those using units to use nominal pre-launch inserted data and fails to allow up-date of S&T memory causing discrete commands to occur at nominal pre-launch inserted times	1	1	2	2	Amount of degradation will depend on variation from nominal values. Triple redundant command link/digital data registers with majority voters would reduce probability of failure mode occurrence.

CAPSULE BUS SEQUENCER & TIMER REDUNDANCY CONSIDERATION MODEL

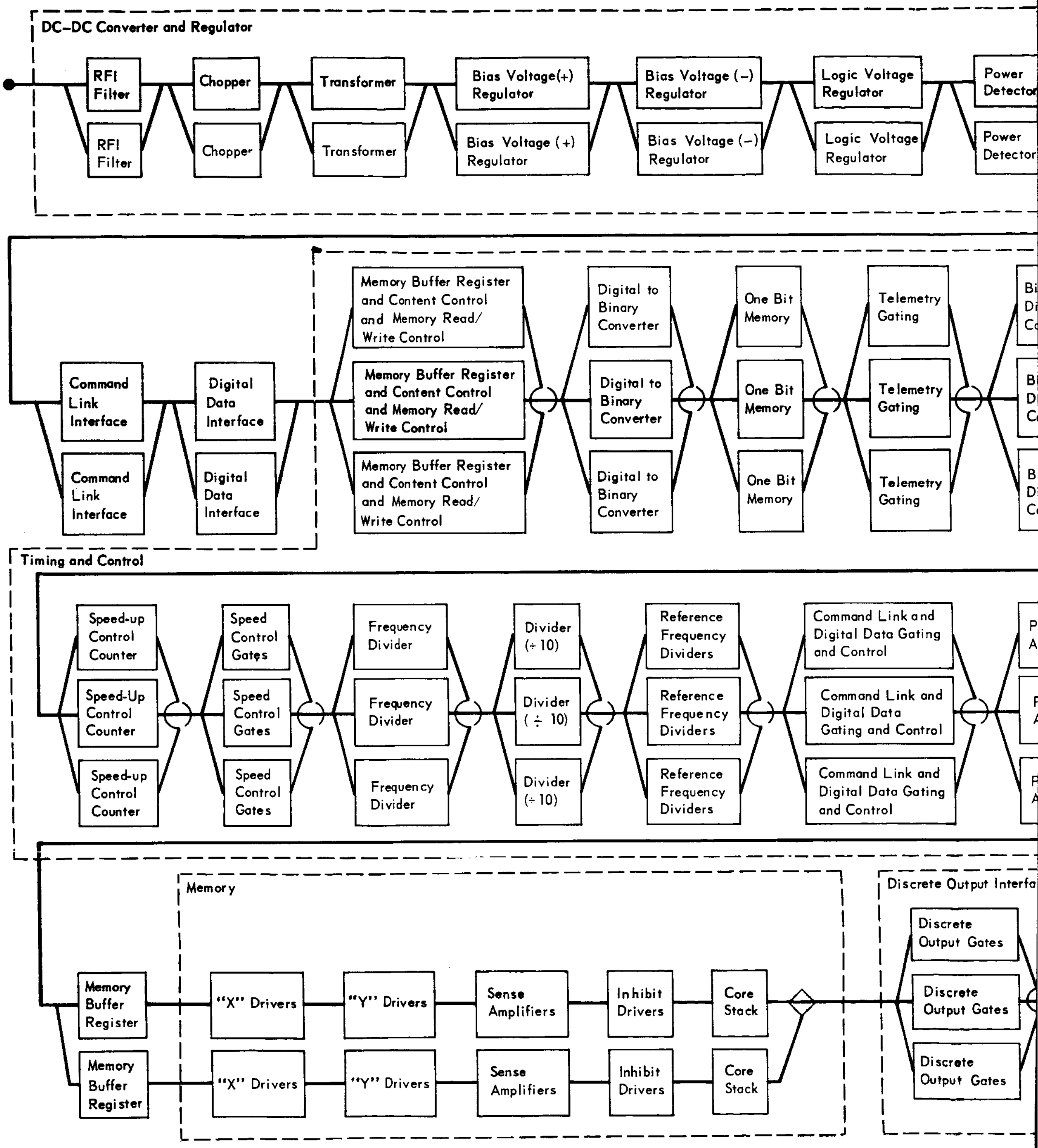
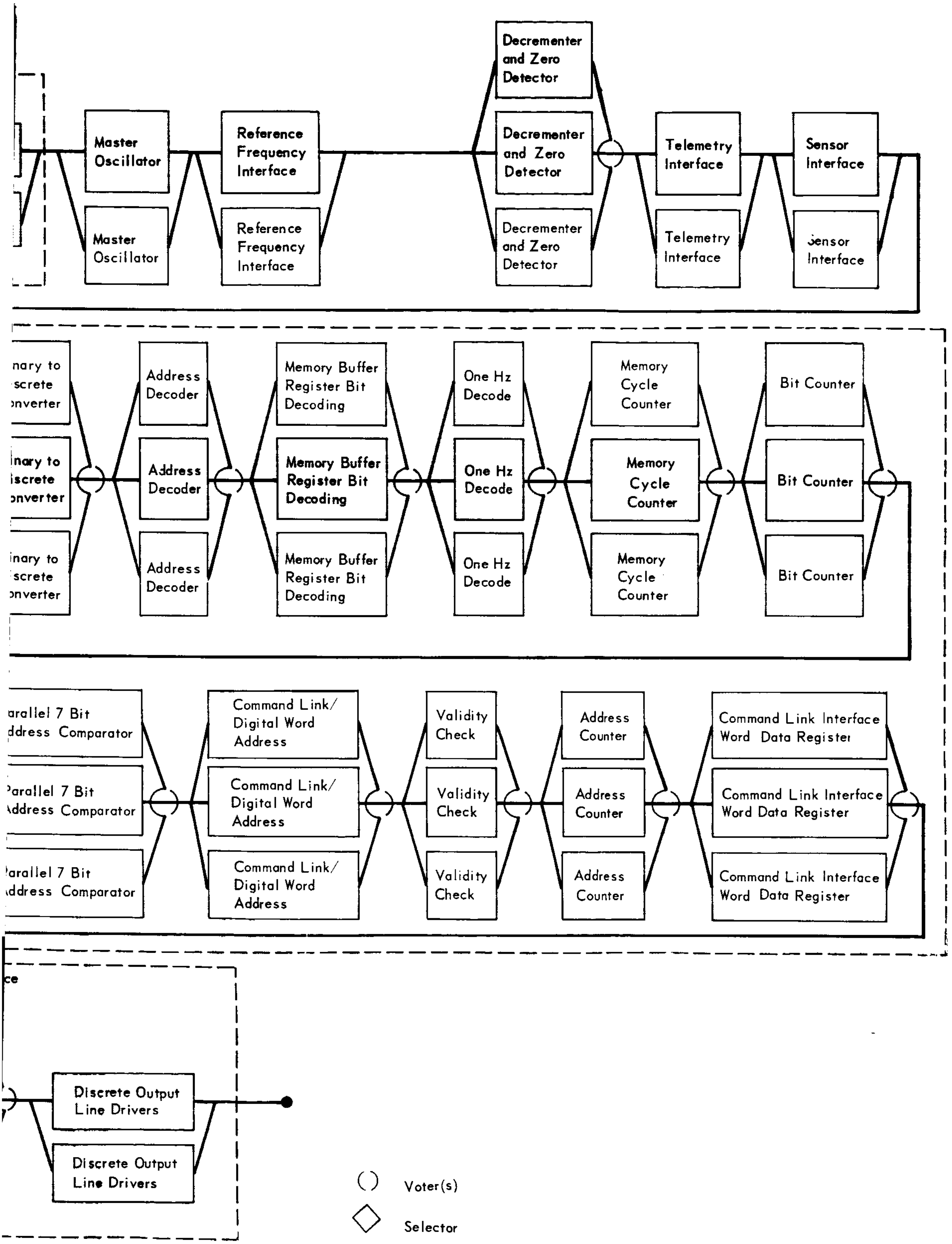


Figure 2.1–13



Decrementer and Zero Detector
Decrementer and Zero Detector
Decrementer and Zero Detector
Master Oscillator
Master Oscillator
Reference Frequency Interface
Reference Frequency Interface
Telemetry Interface
Telemetry Interface
Sensor Interface
Sensor Interface
nary to screte onverter
inary to iscrete onverter
inary to screte onverter
Address Decoder
Address Decoder
Address Decoder
Memory Buffer Register Bit Decoding
Memory Buffer Register Bit Decoding
Memory Buffer Register Bit Decoding
One Hz Decode
One Hz Decode
One Hz Decode
Memory Cycle Counter
Memory Cycle Counter
Memory Cycle Counter
Bit Counter
Bit Counter
Bit Counter
arallel 7 Bit ddress Comparator
arallel 7 Bit ddress Comparator
arallel 7 Bit ddress Comparator
Command Link/ Digital Word Address
Command Link/ Digital Word Address
Command Link/ Digital Word Address
Validity Check
Validity Check
Validity Check
Address Counter
Address Counter
Address Counter
Command Link Interface Word Data Register
Command Link Interface Word Data Register
Command Link Interface Word Data Register
ce
Discrete Output Line Drivers
Discrete Output Line Drivers
Voter(s)
Selector

The projected effect of incorporation of these redundancies, in the above order, on the Surface Lab Sequencer and Timer reliability and weight is illustrated in Figure 2.1-14.

The reliability objective for the Surface Lab is to provide protection against as many as possible of the single point failure modes which have catastrophic effect on the mission while optimizing the system probability of success. Incorporation of redundancies is therefore not determined on a subsystem basis but on an overall system basis and incorporation of Surface Lab Sequencer and Timer redundancies will depend on their relative ΔR - ΔW ratios and effectiveness in protection against single point failure when viewed from a system standpoint.

2.1.8 Test -

Pre-Flight Checkout - Sufficient access exists via the OSE connector to allow Sequencer and Timer subsystem testing and anomaly isolation to the modular level even after being installed in the vehicle. Provisions for a "fast-clock" simulated mission test is also included to reduce test time. Following terminal sterilization, preflight checkout will consist of monitoring the SL TM parameters when the Command Receiver is exercised. Once fully connected in the SL, test of the Sequencer and Timer must be carefully accomplished to prevent inadvertent activation of irreversible devices (i.e., pyrotechnics). To aid in prevention of such an occurrence following Sequencer and Timer installation, the OSE must latch the Safe/Arm pyrotechnic power relay(s) in the Safe position. The S&T may then be checked throughout the entire simulated SL mission sequence without unsafe activation of pyrotechnic devices.

In-Flight Checkout - Following the long interplanetary cruise and Mars orbit period, the SL subsystems are activated and tested to determine their operational readiness. The Test Programmer (TP) provides an on-board test control to decrease the number of Earth commands for such testing. The TP outputs to the Sequencer and Timer include test power (if from other than normal operational power source) and test control discretes to govern the test sequence by simulating the various sensor inputs. The test outputs are monitored by TM indicating the Sequencer and Timer internal operation and flight readiness.

2.1.9 Development Requirements - At present, no advanced state-of-the-art devices appear to be required in the Sequencer and Timer design. Verification through testing is desired to assure that the components (memory cores, crystals, capacitors, etc.) will withstand terminal sterilization without permanent damage or effective change in operating characteristics. Circuits of Lunar Orbiter and advanced Mariner sequencer design are envisioned to fulfill the functional requirements of the Sequencer and Timer.

SURFACE LABORATORY SEQUENCER AND TIMER RELIABILITY VS. WEIGHT

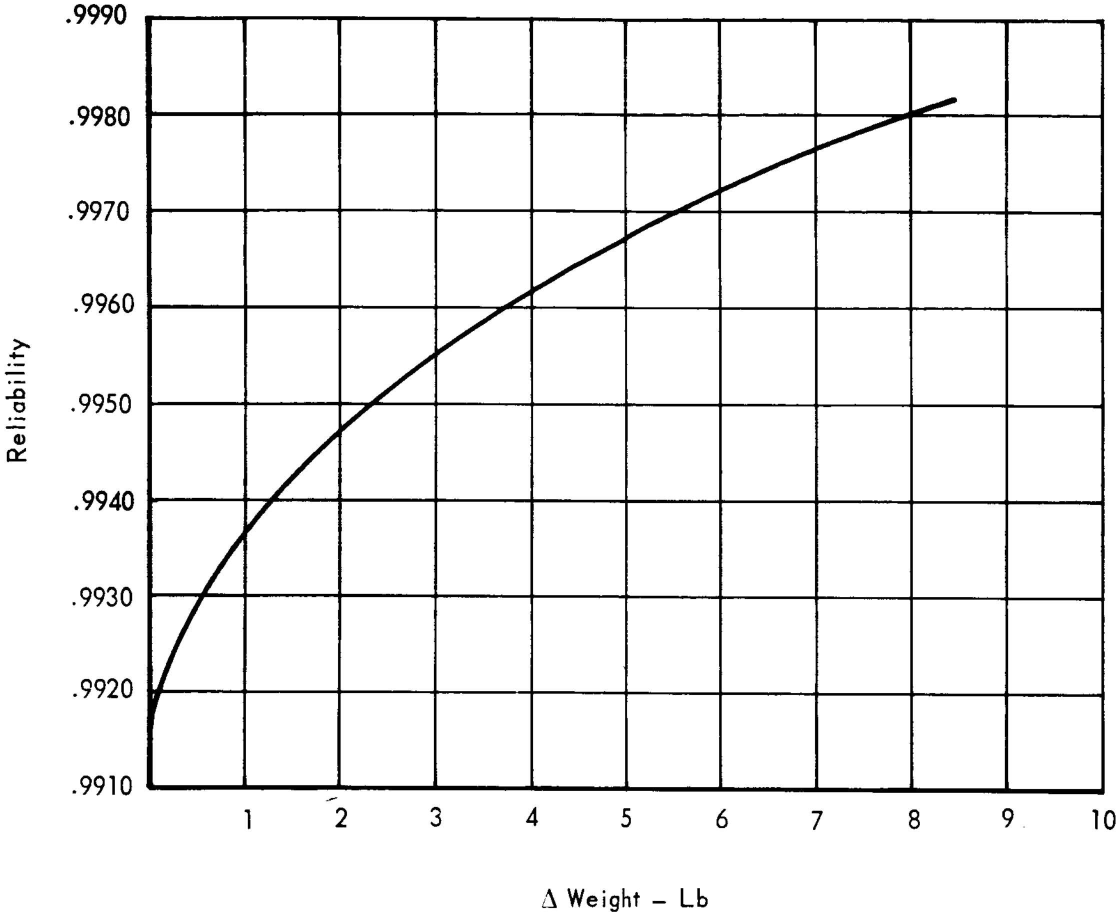


Figure 2.1–14

2.2 TEST PROGRAMMER

2.2.1 Equipment Identification and Usage - The Test Programmer establishes the operational readiness of the Surface Laboratory equipments prior to their utilization in the VOYAGER mission. The prolonged interplanetary cruise period when the Surface Laboratory equipment is inactive in the environment of deep space necessitates an in-flight check on operational readiness. Subsystems designed for deep space missions of long duration include functional redundancy, and in-flight check-out by the Test Programmer determines what functionally redundant capability the subsystems still possess so the mission can be run using the functional path most likely to succeed.

2.2.2 Design Requirements and Constraints - In-flight check-out will be performed during Mars orbit. It is the last time prior to separation that a closed loop check-out via Earth command and telemetry can be performed. After landing the capability for a closed loop check-out will again be available and the science program may be changed. The test programmer will accept quantitative data from the command subsystem to provide for changes in the check-out sequence that may result from Earth analysis of telemetry data. The programmer's outputs will be discretes for instructing the built-in test section of subsystems under test. The Test Programmer will utilize the operational drivers of the Sequencer And Timer and the Science Data subsystem when unwarranted duplication can be eliminated.

2.2.3 Physical Characteristics - The Test Programmer requires five watts of power for operation. Maximum weight is five pounds and volume is 150 cubic inches.

2.2.4 Operation Description - The functional block diagram, Figure 2.2-1, shows that the Test Programmer will generate a check-out sequence from the test program stored in its memory. This sequence will be transmitted to the subsystems under test in the form of discrete instructions to the subsystem's built-in-test section. The program stored in the Test Programmer is alterable via radio commands from earth to provide for changes in the check-out sequence, such as rerunning a given test. The subsystem's reaction to the perturbations of the check-out sequence will be monitored by telemetry and transmitted to earth to provide a closed loop check-out.

The Test Programmer Functional Schematic Block Diagram, Figure 2.2-2, shows the method by which in-flight check-out is controlled. The Test Programmer is activated by the Spacecraft Central Computer and Sequencer. Its self-contained clock will begin a systematic read-out of the memory to run through a self-test

TEST PROGRAMMER FUNCTIONAL BLOCK DIAGRAM

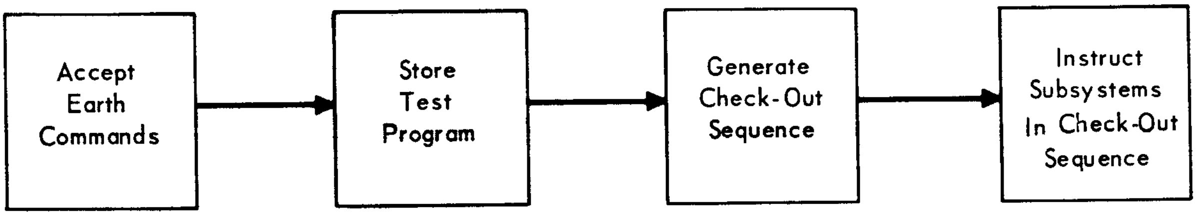


Figure 2.2-1

TEST PROGRAMMER FUNCTIONAL SCHEMATIC BLOCK DIAGRAM

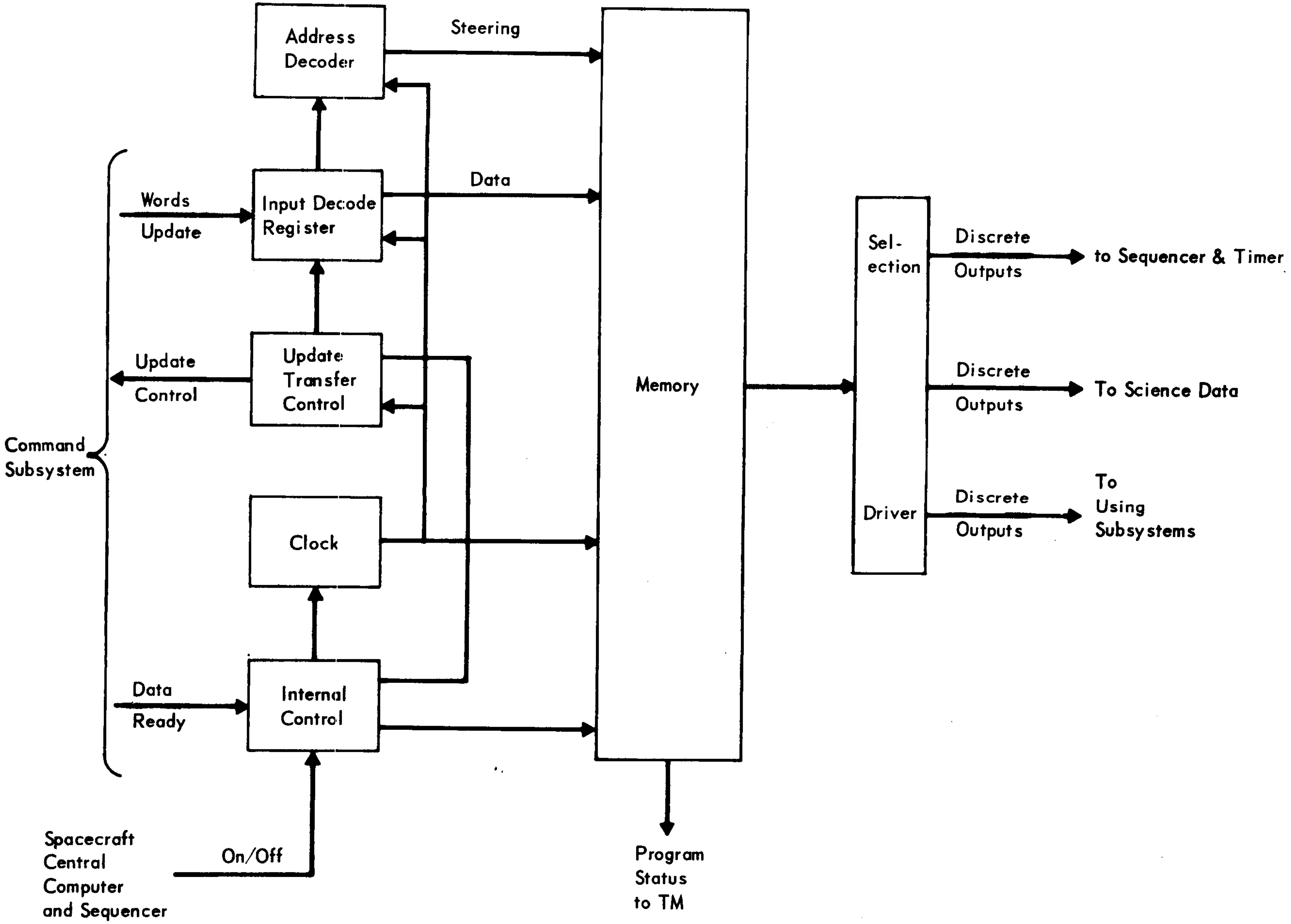


Figure 2.2-2

followed by the Surface Laboratory test sequence. Any updating, of the programmer's memory is accomplished between discrete events in the test sequence in synchronization with the programmer's clock. The status of the test sequence will be telemetered to Earth for use in evaluating test data. Control of the subsystem under test is through the relay drivers of the Sequencer And Timer, the Science Data Subsystem, or the selection - driver section of the Test Programmer.

2.2.5 Performance Characteristics - The Test Programmer provides 52 output test discretes to the Surface Laboratory subsystems and 3 to the Spacecraft Mounted Support Equipment. One 63 bit digital test word is provided to the Surface Laboratory Command Subsystem. The Test Programmer has a total capacity for 64 discretes. Using a 16 bit time tag for each discrete word and adding sufficient memory for all internal programming, the programmer memory magnitude is 1500 bits.

2.2.6 Interface Definition - The Test Programmer interfaces with the Command Subsystem, the Telemetry Subsystem, and the various subsystems under test. The Command Subsystem interface consists of quantitative commands to the Test Programmer to reprogram it. The Telemetry Subsystem interface consists of the transfer of program status data to the Telemetry Subsystem for transmission to Earth. Test program outputs to Surface Laboratory subsystems under test are:

- Radio - 4 discretes
- Command - 2 discretes, 1 digital word
- Antenna - 4 discretes
- Telemetry - 5 discretes
- Sequence and Timer - 10 discretes
- Science Data - 17 discretes
- Science Instruments - 10 discretes

For a detailed interface definition see Figure 2.2-3.

2.2.7 Reliability Considerations - The primary reliability consideration in the design of the Surface Laboratory Test Programmer has been to ensure that the programmer does not induce failure of any of the subsystems under test. Continued strict attention must be given to the design of all interfaces with systems to be tested to assure a "Fail-Safe" condition should a failure of the Test Programmer occur.

As a result of a preliminary evaluation, the reliability estimate for the Capsule Bus Surface Laboratory test programmer, for a nominal 1973 Mars mission, is estimated to be .99970.

TEST PROGRAMMER INTERFACE DIAGRAM

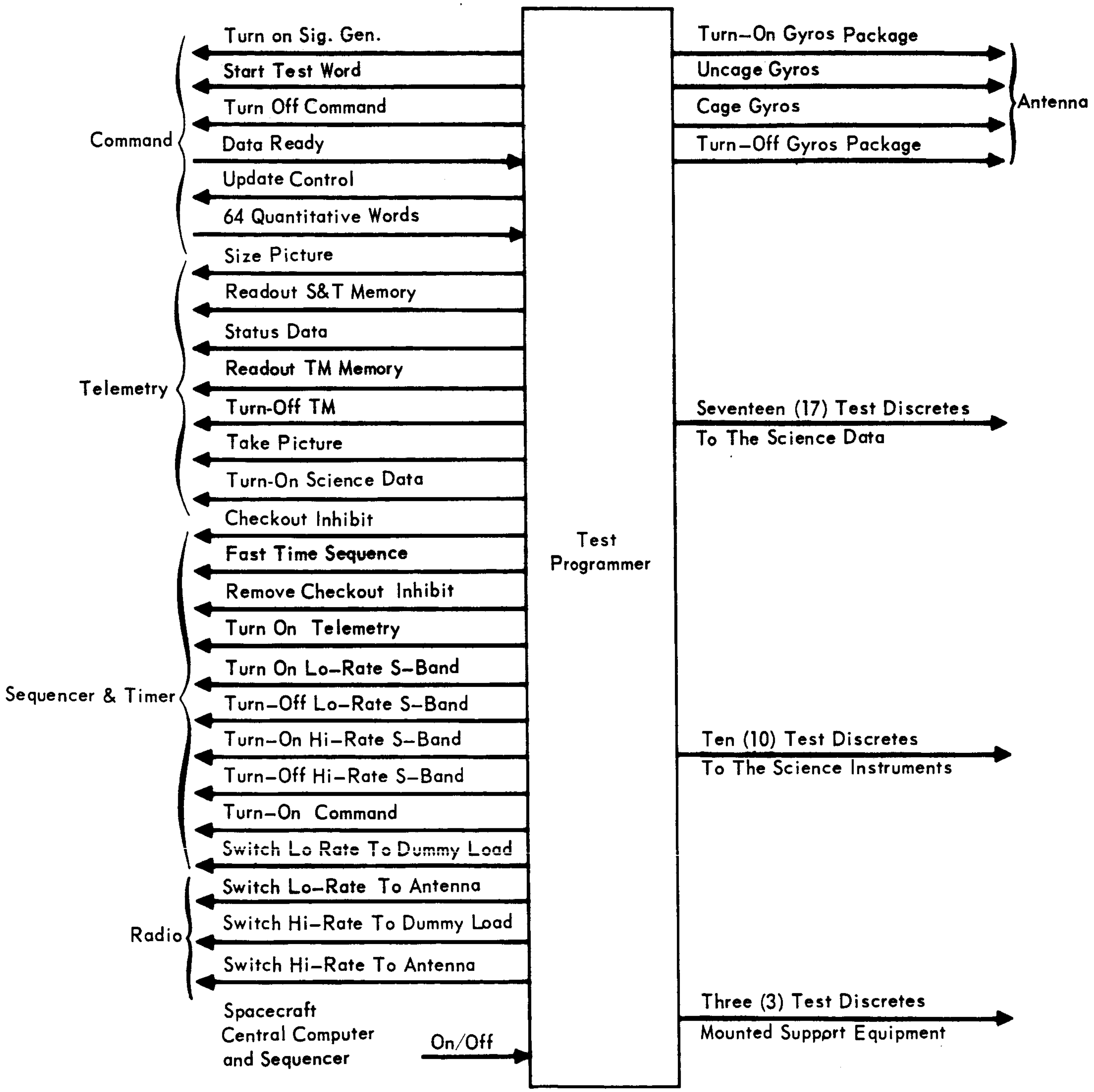


Figure 2.2-3

2.2.8 Test Requirements - Pre-flight testing will consist of a check-out of the Test Programmer counting circuitry memory and driver circuitry. One or more positions in the memory will be set aside for test words that will exercise all circuitry. The same approach will be taken for check-out of the counting circuitry during in-flight testing.

2.2.9 Development Requirements - No advanced state-of-the-art devices are required for the Test Programmer. However, verification that components such as memory cores will withstand sterilization without permanent damage or effective change in operating characteristics is necessary.

SECTION 3

CONTROL SUBSYSTEM

The Control Subsystem includes the sensors and control electronics which provide drive commands to the antenna mechanism of Section 5.2.1 to erect and orient the high gain antenna.

3.1 EQUIPMENT IDENTIFICATION AND USAGE - The control circuitry of the subsystem directs the high gain antenna continuously toward the Earth while it is above the local horizon. Figure 3-1 shows the functional configuration of the subsystem. Rate integrating gyros are used as references to initially align an hour angle axis with the Mars polar axis using an elevation over azimuth configuration. Following completion of this erection procedure the control circuitry commands antenna motion about the hour axis to a reference position defined by a pendulum or sun sensor. From this point the control circuits step command the antenna mechanism subsystem drive motors in synchronism with pulses provided by an external timer. Should the tracking receiver AGC output indicate that a beacon signal has been acquired, this subsystem can switch operation to an optional autotrack mode for fine pointing the antenna.

The Control Subsystem includes servo electronics, gyros, and logic networks. All control loops and functions are designed such that any single failure can be corrected by an alternate procedure without significantly affecting the scope of the program. The antenna will enter an alternate mode only by Earth command.

3.2 DESIGN REQUIREMENTS AND CONSTRAINTS - The Control Subsystem must operate:

- Without assistance from Earth.
- With 3 degree differences between actual and predicted landing site latitude and longitude.
- Within the latitude range of plus 10 to minus 40 degrees.
- With the Surface Laboratory tilted from the local vertical by as much as 40 degrees, which is the maximum expected terrain slope plus a six degree allowance for deformation of the crushable attenuator.
- Without dependence on the Sun.
- With an initial beam pointing error of less than 7.4 degrees.

3.3 PHYSICAL CHARACTERISTICS - The servoelectronics and control logic are contained within the Surface Laboratory and the gyros are mounted on the antenna mechanism. The four gimbals of the antenna mechanism, starting at the laboratory, are arranged in the following order: azimuth, elevation, hour axis, and declination. The

CONTROL SYSTEM BLOCK DIAGRAM

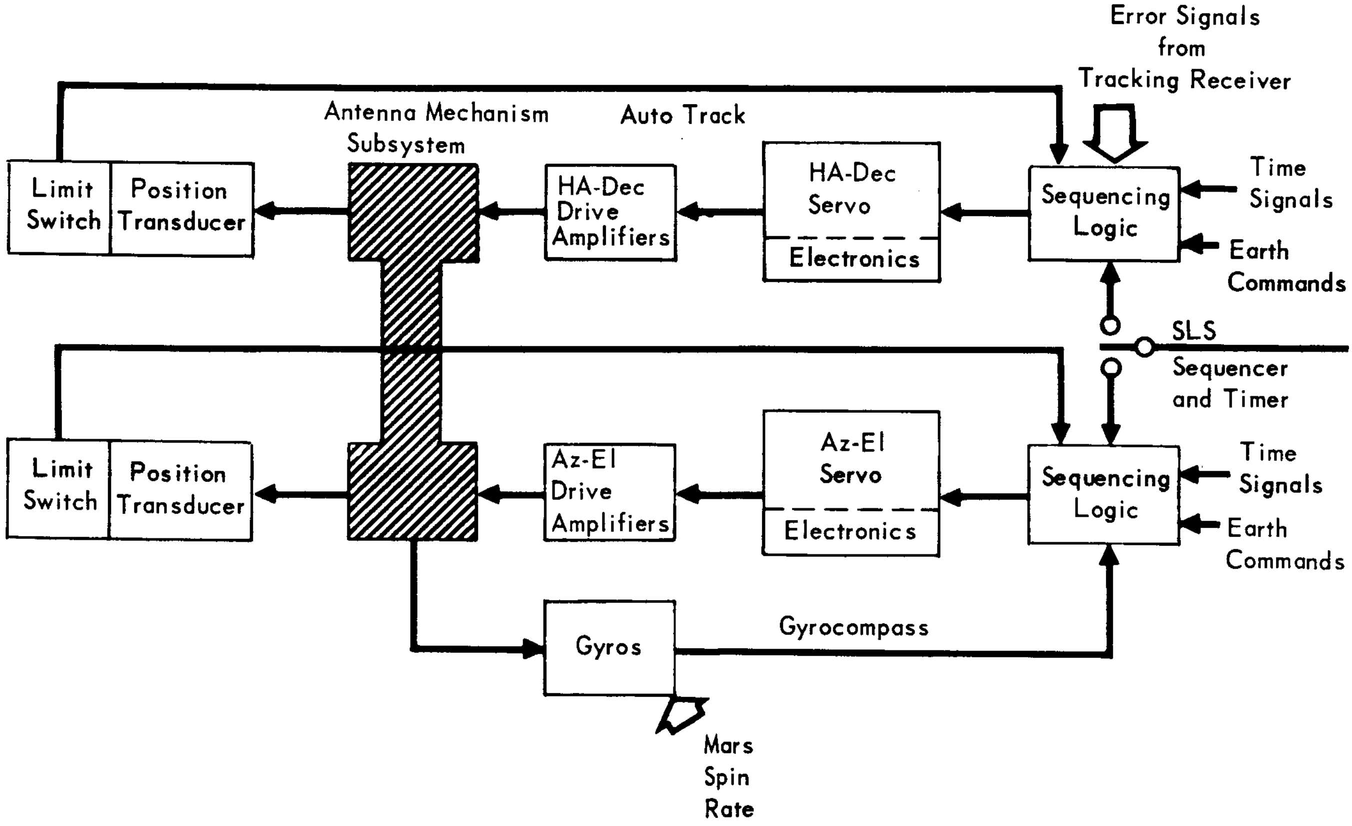


Figure 3–1

azimuth and elevation gimbals each carry a gyro, and all four gimbals have an individual, reduction geared stepper motor, and a gimbal position pickoff. A sun sensor and a pendumlum, which are attached to the hour axis gimbal, are free to rotate about this axis with the two outer gimbals. A detailed breakdown of size, weight, and power estimates is presented in Figure 3-2.

3.4 OPERATION DESCRIPTION - The Control Subsystem is functionally organized, as shown in Figure 3-1 in two parts that separately implement the erection and tracking capabilities. The hour axis is aligned to the Mars spin axis by azimuth and elevation gyrocompasses. The antenna is then pointed at Earth by preprogrammed movement of the hour axis and declination gimbals. The autonomous method of Earth tracking is to rotate the antenna about the hour axis with a uniform clock rate that cancels the Mars spin rate. However, the option exists to reduce the pointing error by selecting the autotrack mode. The decision to select this option is based on the results of the pre-separation checkout, and is made before commiting the Capsule to flight. Autotrack may be engaged by Earth command at any time during Earth visibility.

The subsystem operates until the end of an operational day is indicated by a signal from either the Sequencer and Timer or an axis limit switch. The antenna then moves back to the position where it will acquire the Earth on the following morning.

Several points within the control network are monitored from Earth. These include axis position sensors, gyro outputs, tracking receiver AGC, tracking receiver error channels, output of the servo electronics, and the axis limit switches. Information conveying the status of these points is transmitted at regular time intervals. Earth has real time access to the gyros, erection drives, tracking drives, electronics, and sequencing logic.

3.4.1 Servo System Operation - The azimuth and elevation gimbals are controlled by gyrocompass servo loops, and the hour axis and declination gimbals are controlled by position servos using data from the Sequencer and Timer or, optionally, autotrack error signals.

3.4.1.1 Gyrocompass Servo Operation - The azimuth and elevation gyrocompass servos are functionally identical. They differ only in specific gain values. The outer, or elevation gyrocompass loop is shown schematically in Figure 3-3.

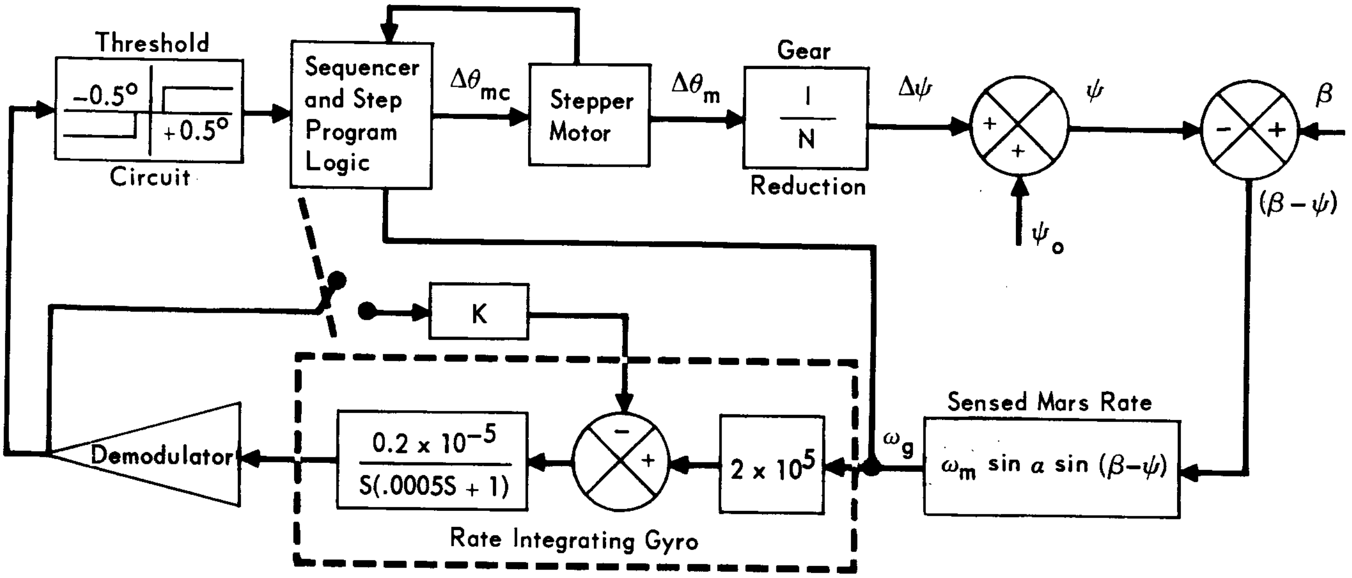
Eight minutes after the system is placed in the erection mode, the outputs of the rate integrating gyros are connected to the appropriate axis servo networks. Because the signal to be sensed by the gyro (angular velocity of Mars)

PHYSICAL CHARACTERISTICS OF THE ANTENNA CONTROL ELECTRONICS

FUNCTION	WEIGHT (LB)	VOLUME (IN^3)	POWER (WATTS)
Servo Electronics (Each Axis)			
Integrator	0.02	0.6	0.10
Integrator Dump	0.03	0.7	0.05
Threshold Sensor (Controller)	0.04	1.0	0.13
Compensation Network	0.02	0.6	0.02
Command Pulse Generator	0.10	2.5	0.10
Servo Amplifier	0.20	4.0	2.0
Drive Motors (Each)			
DC Stepper	0.38	7.2	25.0
Position Potentiometer	0.13	2.0	0.04
Gyros (Each)			
Electronics Package	0.20	3.5	0.7
Gyro	1.00	10.7	–
Warm Up Heater			55.0
Control Heater			7.0
Spin Motor			3.0
Sequencing Logic	1.00	25.0	1.2
Total	7.08 Lb	127.8	

Figure 3-2

OUTER GIMBAL GYROCOMPASS LOOP



α = $\cos^{-1} (\sin \lambda \cos \sigma + \cos \lambda \sin \sigma \cos \tau)$

λ = Landing Point Latitude

α = Angle Between Local Vertical and Lander Vertical

τ = Bearing From North to Plane Containing Local Vertical and Lander Vertical

ψ = Outer Gimbal Angle About Lander Vertical with Respect to Lander Axes

β = Angle About Lander Vertical Between Lander Axes and Mars Fixed Axes Parallel to Equatorial Plane.

ω_g = Rate Sensed by Gyro Input Axis

$\Delta\theta_m$ = Incremental Motor Shaft Displacement

N = Gear Reduction Ratio Between Motor Shaft and Outer Gimbal

Figure 3-3

is expected to be small compared to random noise effects caused by wind deflections of the gyro mount, the error signal is integrated in the gyro before it is applied to the control system. After a period of integration, normally 30 seconds, the polarity of the gyro output will be sensed and sequencer logic output will drive the controlled axis 45 degrees in the direction of the error signal.

During the command execution time the gyros will be caged to prevent saturation when the antenna is moving. Once the command has been executed by the system, the process is repeated.

After the second integration period, if the gyro output has changed polarity indicating the null has been passed, the next motion will be one-half as many steps. If the polarity changes each time the gyro output is integrated, the subsequent motion will be halved. If the gyro polarity does not change between two samplings, indicating that the null has not yet been reached, the number of steps on the subsequent motion will remain unchanged. If the motion were always halved after each sampling, one error in polarity interpretation could place the antenna in a position where subsequent half motions would never permit reaching the null. Maintaining motion length for unchanged signal polarity causes each angular sector to be traversed twice so that single errors can be tolerated. The gyro controlled axes would be aligned in a time not less than 10 minutes nor more than 20 minutes by this method. The preferred design concept envisions the free running of this system for a clocked period of 30 minutes.

The azimuth axis could initially be as much as 180 degrees from north alignment. To prevent the elevation gyro from driving the elevation axis in the wrong direction its output will be delayed six minutes to allow the azimuth axis to move into the correct quadrant. It is possible for the elevation axis to be driven the wrong way if the landing is in the southern hemisphere. In this event, the gyro error signal drives the elevation axis into the upper limit switch, the azimuth gyro output will be reversed, and the elevation servo will be delayed another six minutes before its operation resumes.

3.4.1.2 Clock Track Servo System - The Earth's apparent motion relative to Mars is approximately 15 degrees per hour, or one degree every four minutes. After erection of the hour axis, the Sequencer and Timer will gate one pulse each 4 minutes to a command pulse generator. The generator then sends a pulse to the hour axis drive motor which steps the antenna one degree in hour angle.

3.4.1.3 Autotrack Servo System Operation - Autotrack operation is an option whereby the tracking receiver error outputs are switched into the hour axis and declination servos. Threshold circuits determine if the error signal is large enough to warrant moving the antenna. If the signal is large enough, the control system is activated and the axis drive motor stepped one degree. The control system drive is then deactivated to conserve power. These functions are shown in the autotrack servo block diagram, Figure 3-4.

3.4.1.4 Scan Mode Servo System - A simplified scan program is included, which by a command from Earth, causes the antenna to scan the sky above the horizon until Earth acquisition is indicated by the tracking receiver AGC circuit or an Earth command turns it off. This mode, when used with autotracking, provides a functional back-up to the gyrocompass mode with clock tracking. The scan logic applies a signal to the servo electronics input, which steps the hour axis drive until the gimbal limit is reached. The output of the limit switch causes a pulse generator to step the declination axis once and reverses the hour axis step signal polarity. This procedure produces a raster scan that continues until the error voltage is removed by the acquisition signal or by Earth command. The scan time is 30 minutes.

3.4.2 Sequence of Events - The sequence of operations carried out by the Control Subsystem is summarized in Figure 3-5.

3.5 PERFORMANCE OBJECTIVES - Studies to determine the performance of the Control Subsystem are presented in Section 5.3, Part B of this Volume. These studies indicate the following performance can be achieved:

o Beam pointing error after gyrocompass erection (3 sigma)	hour angle	6 degrees
	declination	2.4 degrees
o Beam pointing error after fine alignment by autotracking (3 sigma total)		1 degree

3.6 INTERFACE DEFINITION - The Control Subsystem interfaces with the Sequencer and Timer, Command Link, Tracking Receiving, High Gain Antenna Mechanism and Electrical Power Subsystems. A description of the interface parameters is shown in Figure 3-6.

3.7 RELIABILITY AND SAFETY CONSIDERATIONS - The Control Subsystem has an assessed reliability of 0.99953 probability of successfully performing its mission of antenna erection and aiming tracking. Probabilities of specific functional paths are as follows:

P_I	- Pedestal erection	0.9937
P_{II}	- Alignment, hour axis and local vertical	0.9778

AUTOTRACK SERVO BLOCK DIAGRAM

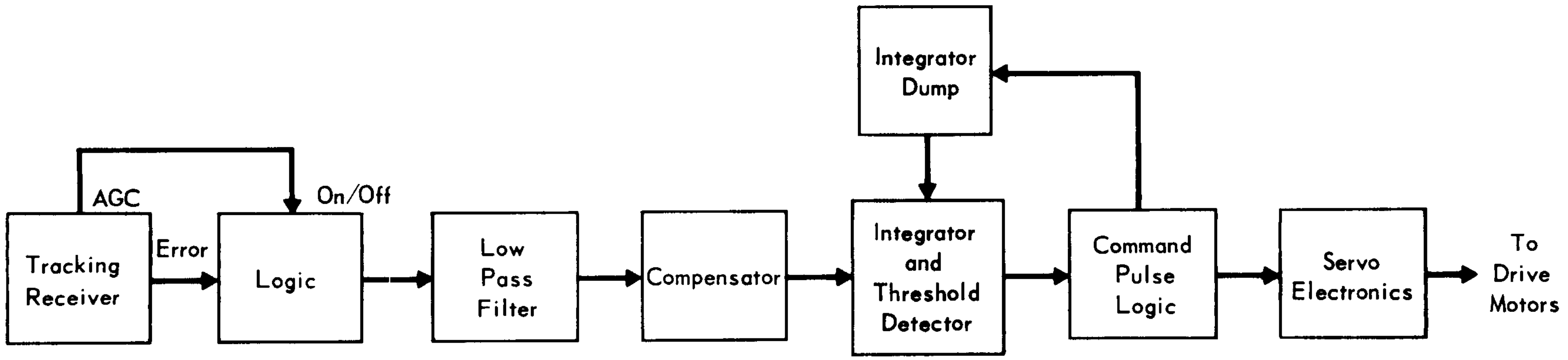


Figure 3–4

SEQUENCE OF OPERATION CONTROL SUBSYSTEM

EVENT	PRIMARY COMMAND SOURCE	ALTERNATE COMMAND SOURCE	EVENT DURATION
Start erection sequence	S & T		Discrete
Warm up gyros	Internal		8 Minutes
Start azimuth gyrocompass	Internal		30 Minutes
6 Minute delay	Internal		
Start elevation gyrocompass	Internal		24 Minutes
Stop gyrocompasses	Internal	S&T	Discrete
Null hour axis pendulum	Internal		4 Minutes
Position hour axis gimbal	S & T	Earth	1 Minute
Position declination gimbal	S & T	Earth	
Start clock track mode	Internal		Continuous
Inhibit clock track mode – Start autotrack mode (option)	Earth		Continuous
Inhibit clock track mode – Start scan mode (option)	Earth		Continuous
End of day	S & T	Internal	Discrete
Return to morning position	Internal	S & T	2 Minutes
Shut down	Internal	S & T	Discrete
Start track	S & T	Earth	Discrete

Figure 3–5

FIGURE 3-6

SIGNAL NAME	DESCRIPTION
Sequencer and Timer	
Start	Bilevel voltage, initiates the erection sequence.
HA Position Data	Pulse train drives HA axis at 1 degree/second.
Start Drive	Bilevel voltage, starts HA axis drive.
Clock Train	Pulse train drives HA axis at 1 degree/second.
End-of-Day	Bilevel voltage, indicates end of first day (HA drive stop)
Request HA Return	Bilevel voltage, indicates start of HA position return.
Stop Return	Bilevel voltage, inhibits HA position return drive.
Start Second Day	Bilevel voltage, starts HA drive (second day).
Reposition Az Axis	Pulse train drives Az axis at 1 degree/second.
Reposition El Axis	Pulse train drives El axis at 1 degree/second.
Reposition HA Axis	Pulse train drives HA axis at 1 degree/second.
Reposition Dec Axis	Pulse train drives Dec axis at 1 degree/second.
Command Subsystem	
Scan Sequence Command	Bilevel voltage, starts scan sequence.
Scan Axis Selection	Bilevel voltage, selects scan axes.
Start	Bilevel voltage, back-up for S&T erection initiation.
Az Gyro On/Off	Bilevel voltage, back-up control.
El Gyro On/Off	Bilevel voltage, back-up control.
Servo Electronics On/Off	Bilevel voltage, back-up control.
Time Share Servo Electronics	Bilevel voltage, switch electronics between axes - back-up.
Radio Subsystem	
AGC	Bilevel voltage, indicates tracking receiver acquisition.
HA Error Signal	Analog, tracking receiver error voltage - hour axes channel.
Dec Error Voltage	Analog, tracking receiver error voltage - declination channel.
Telemetry	
TM Power Supply	± 5 volt reference for position potentiometer.
Power	Laboratory direct current power bus.
Antenna Mechanism	
Electrical	Servo outputs to drive motors.
Mechanical	Gyro and servo mounting.

Figure 3-6

P_{III}	- Pointing, hour angle and declination	0.9882
P_{IV}	- Scan mode	0.99943
P_{V}	- Clock track mode	0.99953

The reliability assessment matrix and the reliability success flow model are shown in Figure 3-7.

3.7.1 Failure Modes and Effects Analysis - The fault tree, Figure 3-8, shows that the design has a large amount of mode and control flexibility to bypass failed functions. Erection failure is bypassed by the capability to track with the hour and declination axes from the stowed position. Pendulum indexing of the hour axis is backed up by the sun sensor, and by direct command. The positioning servos operate with a 50 percent duty cycle so that one of the azimuth-elevation or hour axis-declination sets can do the work of both by operating 100 percent of the time, while alternately being switched between axes. Clock tracking back-up is provided by the autotrack circuits.

The significant failure states identified in the fault tree are:

- No erection.
- No gyrocompass alignment.
- No azimuth, elevation, hour axis or declination drive.
- No scan mode.
- No autotracking mode.
- No scan or tracking modes.

The DC/DC converter is serial to all functions and requires special emphasis in reliability assurance. Active redundancy can be incorporated without incurring significant power and weight penalties.

3.7.2 Complexity Estimate - The control subsystem is estimated to have 964 piece parts excluding hardware and connectors. The total parts count is listed in Figure 3-9, which also includes failure rate data. The parts requiring special emphasis in reliability assurance are the gyros, stepper motors, gimbal position potentiometers and sun sensor cells.

3.8 TEST REQUIREMENTS - Through the command system, the DSIF can at any time turn on or off any piece of equipment in the control chain and connect the modules into any normal or alternate functional order. Because the antenna is mechanically restrained from moving during transit, it is not possible to conduct a complete end-to-end checkout before separation. Electronics can be checked at this time, and after landing the full checkout capability can be exercised. A

A. RELIABILITY ASSESSMENT MATRIX

	DC/DC Conv	Erection Control & Drive	Sun Sensor & Elect	AZ Gyro	EL Gyro	Scan Control	Axis Select	AZ/EL Servo 1 Elect	AZ/EL Servo 2 Elect	AZ/EL Servo Sharer Control	AZ Drive Motor	EL Drive Motor	HA/DEC Servo 1 Elect	HA/DEC Servo 2 Elect	HA/DEC Servo Sharer Control	HA Drive Motor	DEC Drive Motor	Track Control
$\lambda F/10^8$ Hr	285	5070	307	7100	7100	182	160	269	269	26	5000	5000	269	269	26	5000	5000	120
2Kt Hr	117	117	118	118	118	167	167	167	167	167	142	142	167	167	167	142	142	167
λ2 Kt	.000336	.00594	.000362	.00838	.00838	.000304	.000268	.000450	.000450	.000044	.00710	.00710	.000268	.000268	.000044	.00710	.00710	.000201
P_s	.999664	.99406	.999638	.99162	.99162	.99696	.999732	.999550	.999550	.94956	.99290	.9929	.999732	.999732	.94956	.99290	.99280	.999799

B. RELIABILITY SUCCESS MODEL

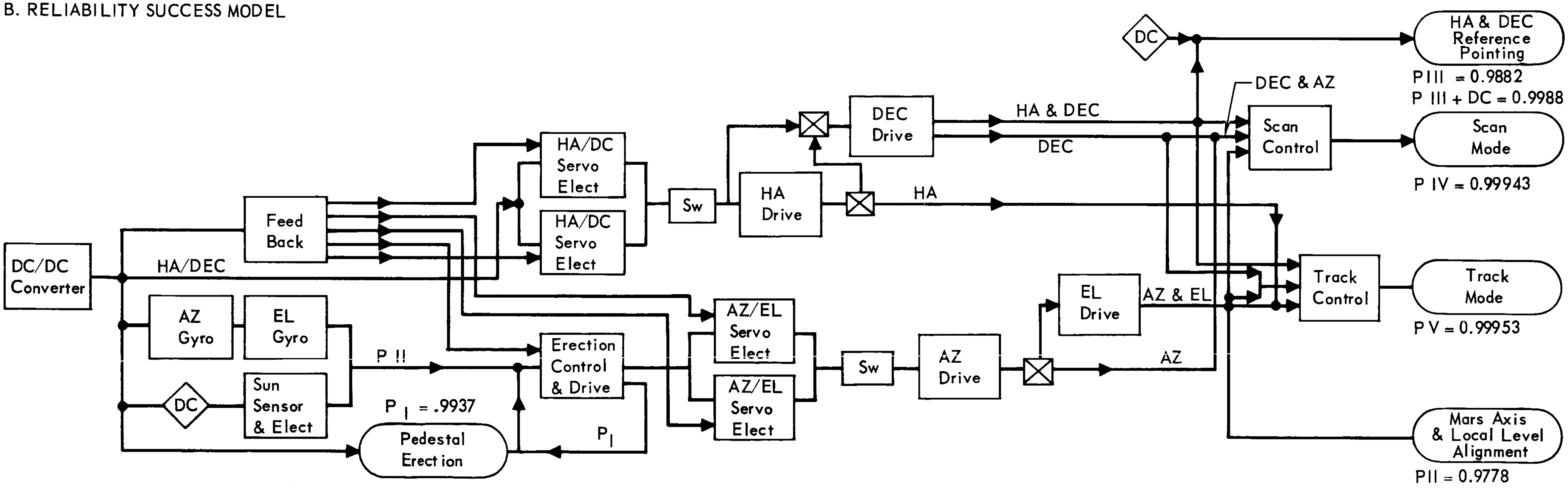


Figure 3–7

CONTROL SYSTEM FAULT TREE

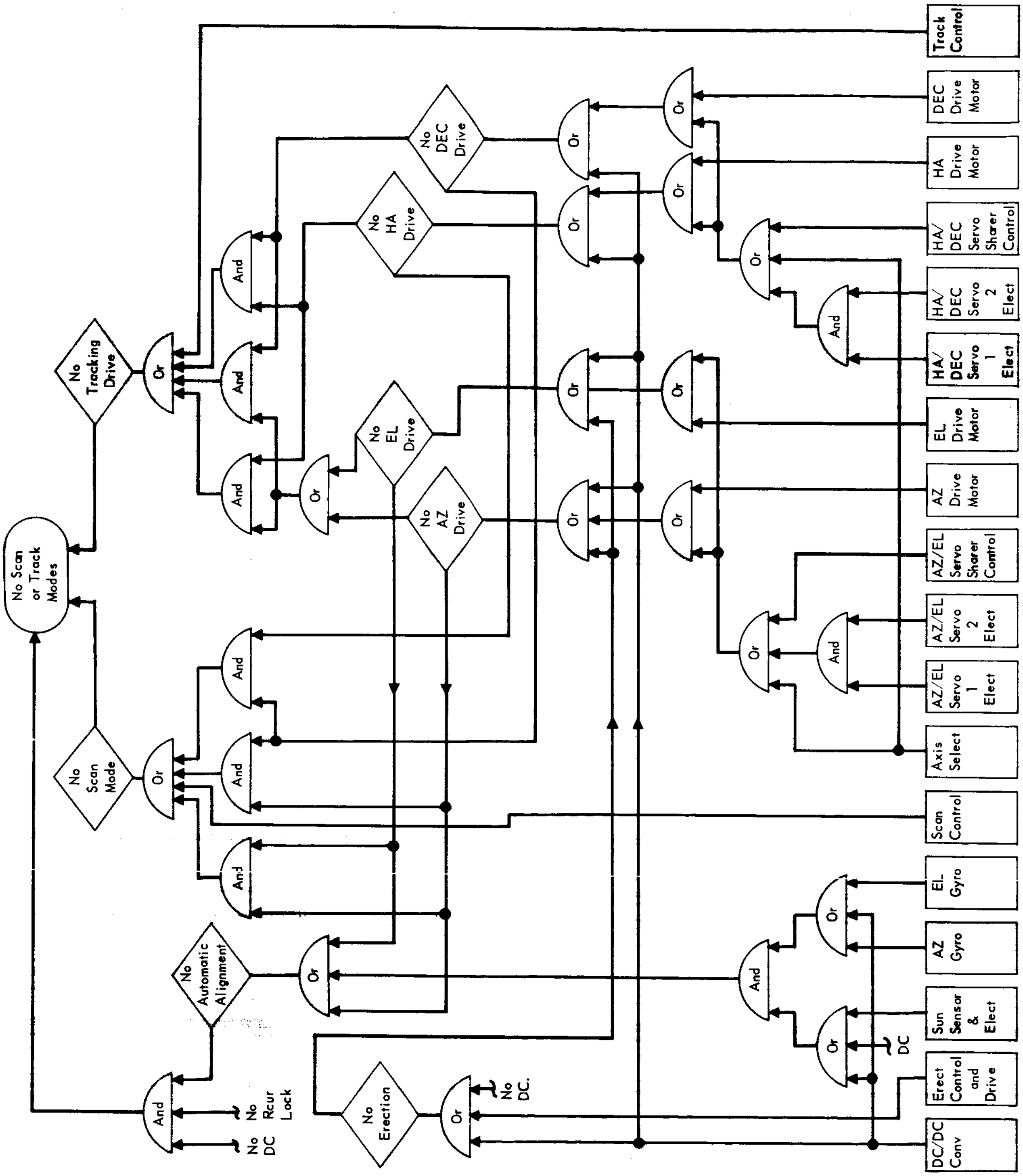


Figure 3-8

CONTROL SUBSYSTEM COMPLEXITY ESTIMATE

PART TYPE	FAILURE RATE, $F/10^8$ HK	QUANTITY n	TOTAL CONTRIBUTION FAILURE RATE
I.C. Dual Transistor	10	20	200
Transistor, Gen. Purpose	5	39	195
Transistor, Power	50	10	500
Transistor, Field Effect	5	4	20
Diodes, Gen. Purpose	1.1	25	28
Diodes, Zener	10	5	50
I.C., Op. Amp.	30	19	570
I.C., Flip Flop	10	26	260
Resistor, M.F.	0.3	159	48
Resistor, C. C.	0.1	428	43
Capacitor, CC/G.	1	197	197
Capacitor, Solid Tant.	2	3	6
Inductor, D.C.	10	5	50
Transformer, Power	50	1	50
Heater	50	2	100
Thermoswitch	60	2	120
Stepper Motor	5000	5	25,000
Potentiometer, Precision	12	4	48
Gyro with Spin Motor	7000	2	14,000
Limit Switch	25	5	125
Sun Sensor	50	3	150
Totals:		964	41,760 $F/10^8$ Hr

Figure 3-9

matrix of tests by mission phase is shown in Figure 3-10.

Gyro tests confirm gyro wheel speed, and float freedom. Servo drive loops are checked by inserting a test signal into the error channel and observing the response of the loop electronics. After erection, the motors and gimbals are included in the loop checkout by observing the response of the gimbal position transducers.

The input test point of the autotracking control circuitry is the antenna feed horn. Electronic circuit and gimbal response is observed as in the gyrocompass servo loops.

In all tests, the error signal will consist of a positive error followed by an identical negative error, to provide a bipolar check which restores the system to its original state at the end of the test.

3.9 DEVELOPMENT REQUIREMENTS - All items used in forming the Control Subsystem can be developed using existing techniques. However, additional testing should be conducted to establish long-range effects of vacuum environment on potentiometer performance.

CONTROL SUBSYSTEM TEST MATRIX

TEST	NON-OPERATIVE TEST	ANTENNA	IMPEDANCE/VSWR	BORESIGHT	ERECTION SEQUENCE	SERVO ELECTRONICS	DRIVE VOLTAGE	RESPONSE TIME	TRACKING ERROR VOLTAGE	POWER SUPPLY VOLTAGE	CURRENT	COMMAND OPERATION	GYRO PACKAGE	GYRO OPERATION	REFERENCE VOLTAGE	AXIS POSITION VOLTAGE	POWER SUPPLY VOLTAGE	POWER SUPPLY CURRENT	POWER SUPPLY FREQUENCY	GYRO SPIN-UP SEQUENCE	MOUNT	MECHANICAL TORQUE	GIMBAL POSITION	INPUT VOLTAGE	INPUT CURRENT	SUN SENSOR/ELECTRONICS	SENSOR ALIGNMENT	SENSOR ACTUATION	SENSOR OUTPUT	INPUT VOLTAGE	INPUT CURRENT
Telemetry							X		X	X	X	X			X	X	X	X					X	X	X				X	X	X
System Test (Pre-Canister)			X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X
System Test (With Canister)							X		X	X	X	X		X	X	X	X	X		X				X	X				X	X	X
Pre-Launch							X		X	X	X	X		X	X	X	X	X		X				X	X				X	X	X
Inflight Checkout							X		X	X	X			X	X	X	X	X		X				X	X				X	X	X

Figure 3-10

SECTION 4

RADIO SUBSYSTEM

The Radio Subsystem consists of the High Rate Radio, Low Rate Radio and the Tracking Receiver. The High Rate Radio contains both a high power transmitter and a command receiver. The transmitter is used with the High Gain Antenna to transmit high rate data directly to the Deep Space Network (DSN). The command receiver is used with the Low Gain Antenna to receive commands from the DSN. The Low Rate Radio, also used with a low gain antenna, transmits low rate data directly to the DSN. The Tracking Receiver provides error signals to the Control Subsystem to allow a refinement of the High Gain Antenna inertial pointing accuracy.

4.1 SL HIGH RATE RADIO

4.1.1 Equipment Identification and Usage - The Surface Laboratory (SL) High Rate Radio is shown schematically in Figure 4.1-1. The radio consists of two major components; a phase-lock command receiver and a high data rate transmitter. The transmitter is normally coherently driven by the command receiver. The radio is compatible with the Deep Space Instrumentation Facility (DSIF) utilizing the nominal transmit and receive frequencies of 2295 and 2113 5/16 MHz, respectively.

The SL High Rate Radio provides a direct S-Band communications link between the Surface Laboratory and the DSIF during landed operations. The S-Band link transmits data from the engineering and scientific instrumentation on the laboratory to the DSIF, and receives command signals from the DSIF for the various SL subsystems. The radio also provides either one-way or two-way coherent Doppler tracking capability to the DSIF.

4.1.2 Design Requirements and Constraints - The communication link analysis indicates the transmitter power must be +43 dBm (20 watts) and that the command receiver carrier threshold must be less than -150 dBm.

The High Rate Radio design must be compatible with the DSIF. This establishes the receive/transmit frequency ratio as 221/240 and the transmit and receive frequencies as 2295 ± 5 and 2113 5/16 ± 5 MHz, respectively.

4.1.3 Physical Characteristics - The physical characteristics of the SL High Rate Radio are summarized in Figure 4.1-2. All the characteristics listed are well within the current state-of-the-art.

4.1.4 Operation Description - Figure 4.1-3 is a functional block diagram of the High Rate Radio. The functional operations are:

SL HIGH RATE RADIO FUNCTIONAL SCHEMATIC

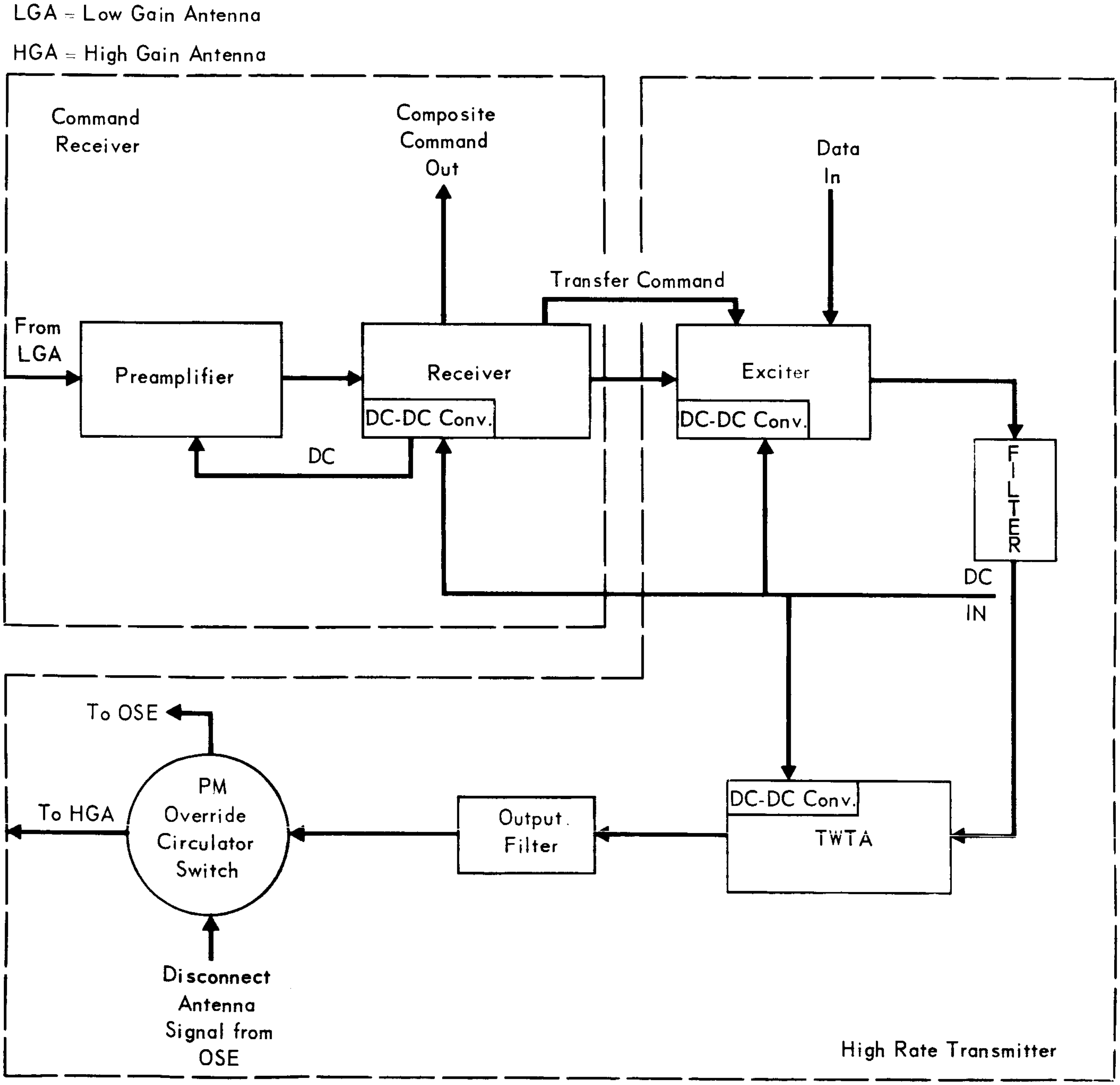


Figure 4.1-1

SL HIGH-RATE RADIO PHYSICAL CHARACTERISTICS

TRANSMITTER	SIZE (CU. IN)	WEIGHT (LBS)	DC POWER INPUT (W)	POWER DISSIPATED (W)
Transmitter				
Exciter	125	3.5	18.1	17.9
Filter	30	0.5	--	0.1
TWTA	195	10.5	98.5	77.5
Output Filter	25	0.8	--	1.3
RF Circulator Switch	45	1.6	--	1.4
Command Receiver				
Preamplifier	75	2.2	0.3	0.3
Receiver	200	4.4	9.2	9.2
RF Cables	--	1.0	--	2.4
Total	695	24.5	126.1	110.1

Figure 4.1-2

SL HIGH RATE RADIO DETAIL SCHEMATIC BLOCK DIAGRAM

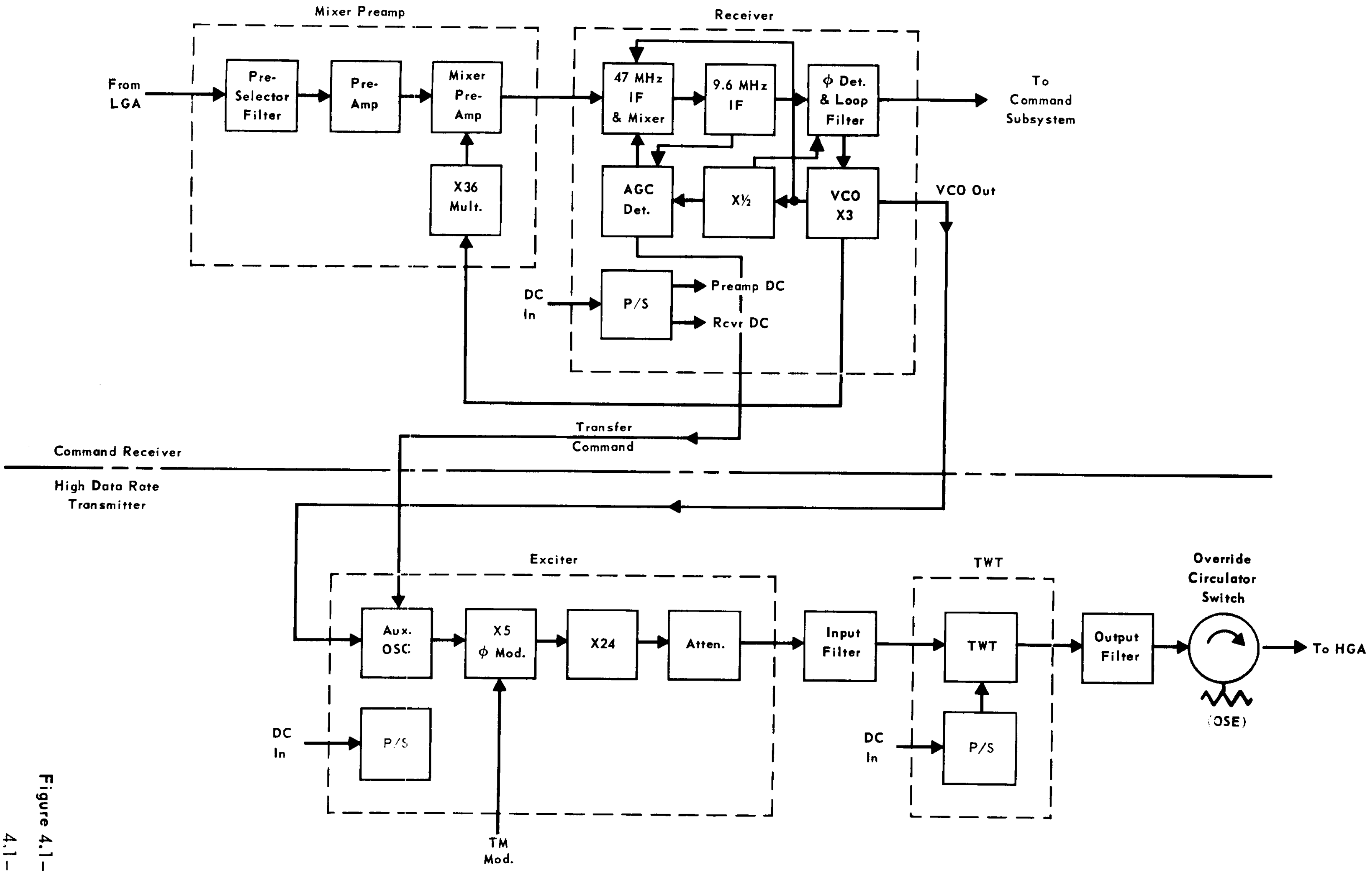


Figure 4.1-3

a. Transponder primary D.C. power is turned on by the SL S&T when the SL is in view of the DSIF.

b. The transmitter and command receiver have separate primary D.C. power inputs so that either may be turned off independently by command in case of failure.

c. Traveling wave tube amplifier (TWTA) heater power is applied when primary D.C. power is turned on, but application of TWTA high voltage is delayed 120-210 seconds by a switching function in the TWTA subassembly.

d. The transmitter is excited by the receiver VCO when the receiver is "in-lock"; two-way Doppler tracking capability is enabled.

e. The transmitter is excited by the auxilliary oscillator when the receiver is "out-of-lock"; one-way Doppler tracking capability is enabled.

Referring to Figure 4.1-3, the radio operation is as follows. The up-link command signal received by the low gain antenna is fed to the preamplifier in the command receiver. The low-noise preamplifier achieves a noise figure of 5 dB. The amplified signal is then passed to the receiver.

The receiver is a narrow band, double superheterodyne automatic phase-tracking type with a loop bandwidth of 20 Hertz. The receiver phase demodulates the up-link signal and provides the command signal to the SL Command Subsystem. The receiver includes a coherent AGC which, when the receiver is in-lock, provides a transfer command signal to the exciter. This causes the exciter to take its RF drive from the receiver VCO providing phase coherence between the received and transmitted signal. When the receiver is out-of-lock the exciter is driven by an internal auxiliary oscillator.

In the exciter, the data signal from the SL Telemetry Subsystem is phase modulated on the RF carrier. The receiver VCO operates at approximately 19 MHz or 2/221 of the received signal. The exciter contains a total frequency multiplication of 120 yielding the required 240/221 frequency translation ratio.

The exciter output (about 100 millivolts) is fed to the TWTA through a band-pass filter to remove any spurious signals generated in the exciter multiplier chain.

The TWTA consists of a traveling wave tube and its associated power supply to raise the power level to 20 watts. A bandpass/band-reject filter is placed at the TWTA output to supress spurious signals generated in the TWTA and to prevent tube noise from degrading the receiver sensitivity.

A permanent magnet override ferrite circulator switch permits switching the output of the TWTA to a dummy load/power monitor during ground testing.

High Rate Transmitter - The high data rate transmitter consists of five subassemblies:

a. Exciter
b. Input Filter
c. TWTA
d. Output Filter
e. Circulator Switch

A detailed block diagram of the exciter is shown in Figure 4.1-4. The unit is configured in four modules; auxiliary oscillator, phase modulator, X24 frequency multiplier and a power supply.

A 19.1 MHz crystal controlled oscillator in the auxiliary oscillator module is the source of the exciter drive when the transfer command is not present. This signal is amplified, passed through an isolating pad and then through a switchable amplifier. The transfer command controls this amplifier and selects either the VCO input or the auxiliary oscillator. The signal at a level of about 10 dBm is then fed to the phase modulator module where it is frequency multiplied by 5 in a transistor-amplifier-multiplier (TAM). The signal is passed through a bandpass filter, an isolation pad and is then phase modulated with the data signal from the Telemetry Subsystem.

After further isolation padding and amplification, the modulated signal is passed to the X24 module. At this point the signal is at 95.5 MHz and a level of 3 dBm. In the X24 module, the signal is passed through a bandpass filter and amplified in two transistor amplifiers. A TAM stage doubles the frequency to 191 MHz and then final amplification is achieved in a power amplifier stage. A varactor frequency quadrupler multiplies the frequency to 765 MHz and then a varactor tripler provides final frequency multiplication to the 2295 MHz output frequency.

Miniature ferrite isolators are inserted after each Varactor multiplier stage to enhance stability. The output power level variation of the exciter is less than ± 1 dB.

The input filter consists of a bandpass/low pass filter and an attenuator. The filter supresses spurious signals by at least 25 dB and thus provides a clean signal to the TWTA. The attenuator is selected at test and serves to set the proper drive level to the TWTA.

EXCITER SCHEMATIC DIAGRAM

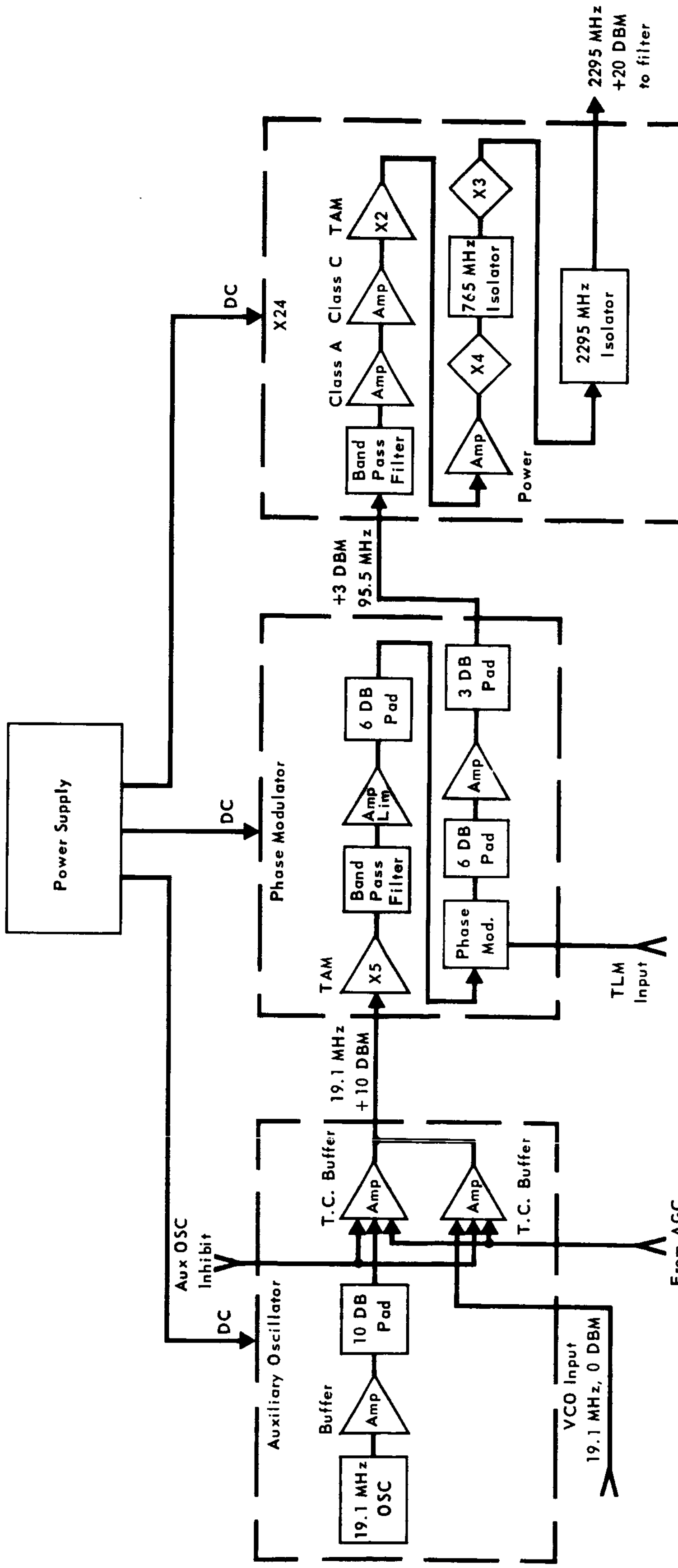


Figure 4.1-4

The TWTA design selected is that used in the Mariner-Mars 1969 Radio Subsystem. This unit delivers a nominal power output of 21 watts at 30% overall tube efficiency. The nominal drive level is between 40 and 70 milliwatts. TWTA power output variation under transponder design conditions is -0.0 dB to + 0.9 dB. The unit is designed for operation over a temperature range of -20 to + 75°C. The primary thermal interface is the bottom surface of the unit which is attached by bolts to the primary spacecraft radiator/cold plate. This surface is designed for a filled thermal joint using silver-filled RTV to keep the joint thermal resistance low.

The output filter contains a band elimination and low pass filter elements to suppress spurious signals and noise in the receiver bandpass and image spectrum

The RF Switch is a three port ferrite circulator. The direction of power circulation is, under normal conditions, controlled by a permanent magnet. The unit contains a coil which, when energized, overrides the permanent magnet and reverses the direction of RF energy flow. This switch enables the transmitter to be disconnected from the high gain antenna during ground tests and connected instead to a dummy load or power monitor.

Command Receiver - This unit is almost identical to the Mariner Mars 1969 receiver except for the power supplies, a few deletions, and the insertion of the low noise S-Band preamplifier module between the receiver filter and the preamplifier modules.

The preamplifier shown in Figure 4.1-5 consists of the following cascaded stages: narrow band bandpass filter, low noise S-band preamplifier, first mixer, IF preamplifier and the X36 frequency multiplier which supplies the local oscillator injection signal. The narrow band filter suppresses unwanted spurious signals, including the IF image frequency, and also serves to protect the low noise S-Band preamplifier.

Nominal gain and noise figure of the overall preamplifier are 61 dB and 5.0 dB, respectively. The receiver together with the preamplifier comprise the Command Receiver. The receiving system is an automatic phase control (APC) device, essentially identical to its Mariner series prototype. The receiver is configured in seven modules.

a. 47.8 MHz IF Amplifier

b. 9.6 MHz IF Amplifier

c. Phase detector and Loop filter

d. AGC detector

PREAMPLIFIER SUBASSEMBLY SCHEMATIC DIAGRAM

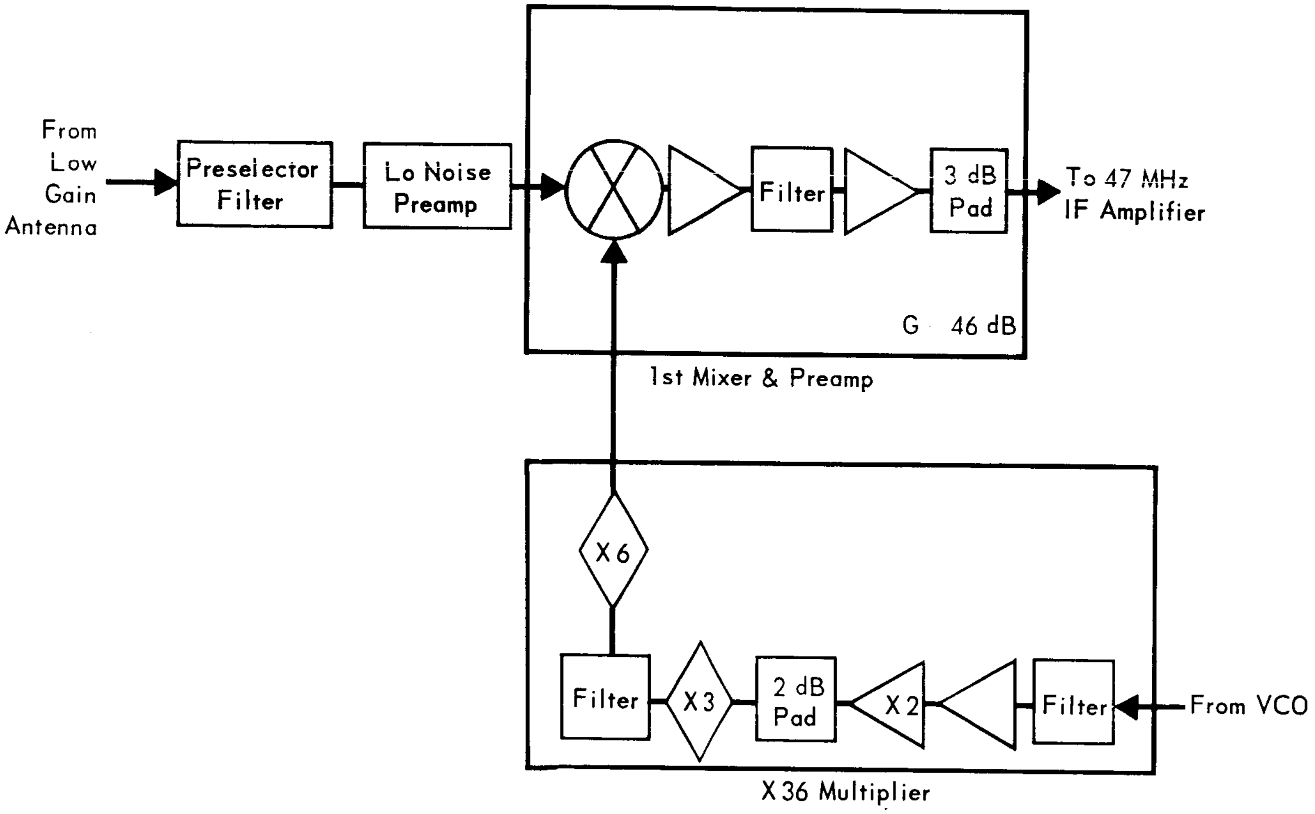


Figure 4.1-5

e. Voltage Controlled Oscillator
f. Frequency Divider
g. Power Supply

Figure 4.1-6 is a detailed block diagram of the receiver. The 48 MHz first IF signal from the preamplifier is amplified in a gain-controlled IF amplifier. A dynamic range of over 100 dB is achieved. The signal is then heterodyned to the 9.6 MHz second IF frequency and passed through a 4 KHz BW crystal filter. The signal is amplified further and split into two channels. One channel is maintained linear and fed to the AGC detector. The second channel is passed through limiter stages and fed to the main phase detector.

In the phase detector module the 9.56 MHz IF signal is phase compared with a 9.56 MHz reference signal and the resulting phase error voltage is passed through the loop filter and used to control the VCO. The phase detector output contains the demodulated command information which is video amplified and sent to the SL Command Subsystem for processing.

The VCO operates at a frequency twice the second IF frequency or at about 19.1 MHz. The VCO is a crystal controlled oscillator whose phase and frequency are controlled by the application of the error signal to a varactor in the oscillator feedback loop. The oscillator output is amplified and split into three channels. Two of these channels are frequency tripled and one of them is used as the LO signal for the second mixer and the other is fed to the X 36 multiplier module in preamplifier and serves ultimately as the first mixer LO signal.

The third VCO output is fed to the frequency divider module where it is amplified and the frequency divided by two to 9.56 MHz. From this point the signal is sent to the phase detector and the AGC detector modules to serve as reference signals for the phase detectors.

4.1.5 Performance Characteristics - The detailed performance characteristics of the SL High Rate Radio are summarized in Figure 4.1-7.

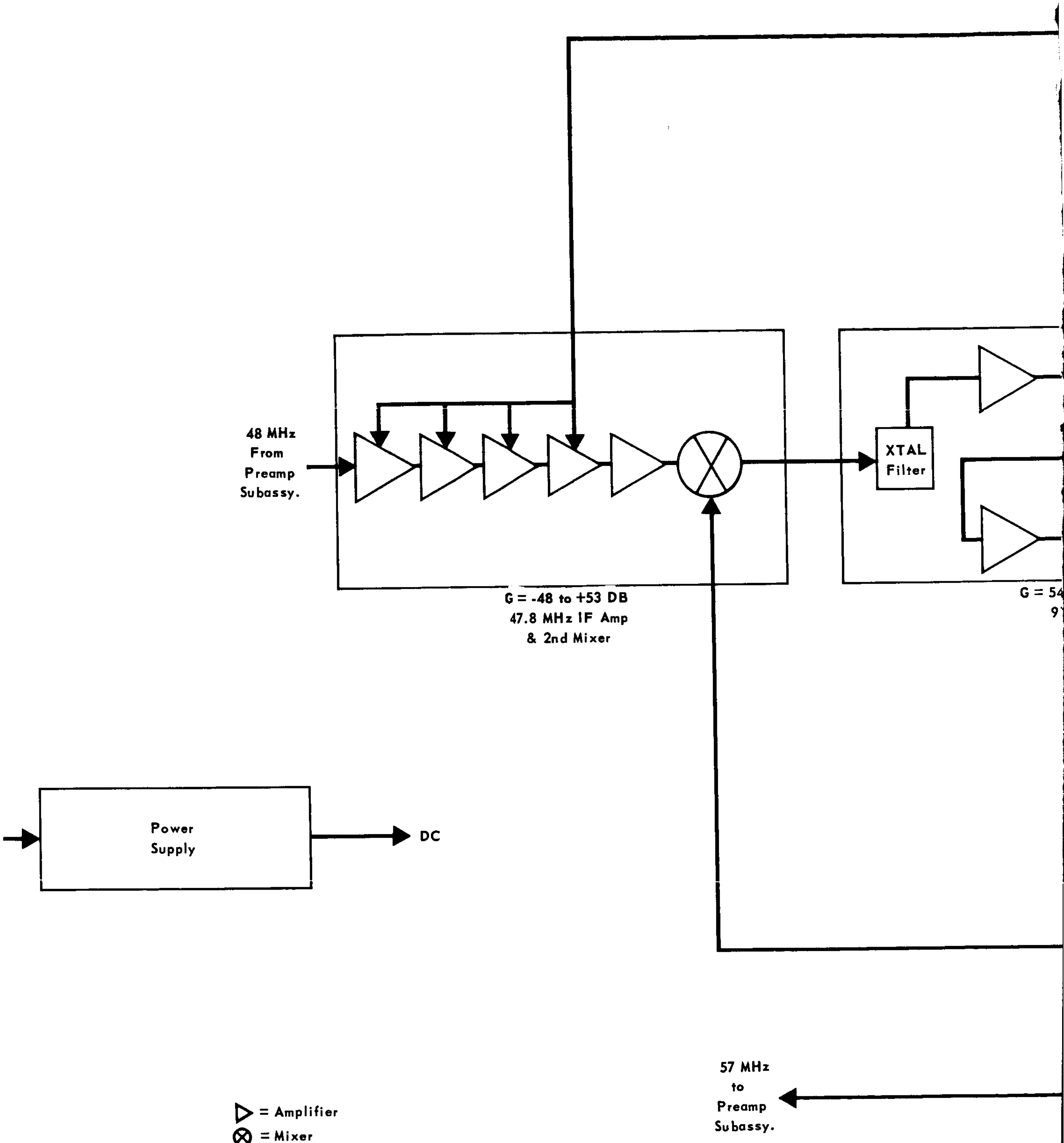
4.1.6 Interface Definition - Interfaces of the SL High Rate Radio are listed in Figure 4.1-8.

4.1.7 Reliability & Safety Consideration -

4.1.7.1 Reliability Assessment Model - The SL High Rate Radio has assessed reliability of a 0.9934 probability of success for total functional capability. The breakdown by major functions is as follows:

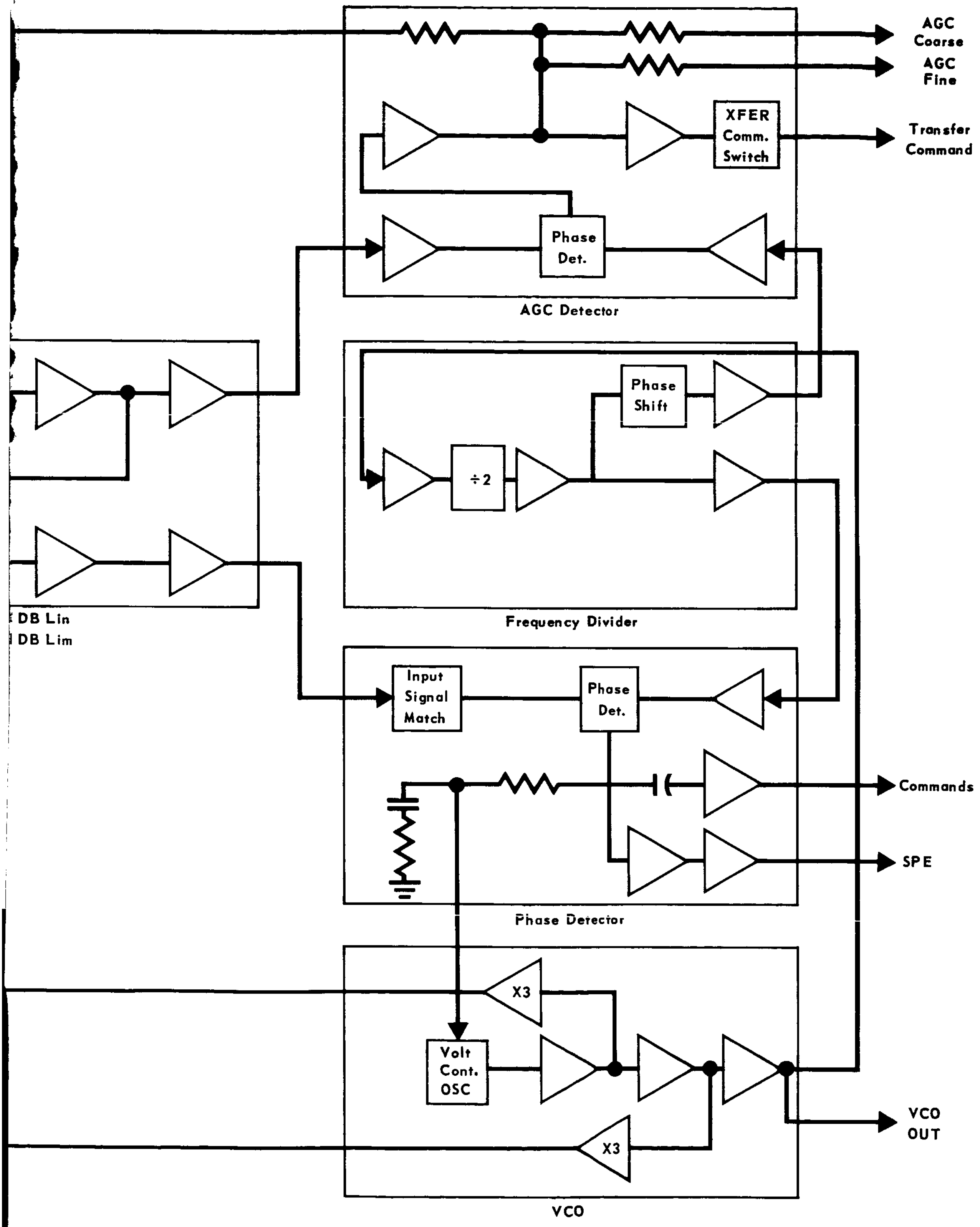
o Command Reception: Ps = 0.9976

COMMAND RECEIVER BLOCK DIAGRAM



▷ = Amplifier
⊗ = Mixer
◇ = Varactor Multiplier

Figure 4.1-6


AGC Coarse
AGC Fine
XFER Comm. Switch
Transfer Command
Phase Det.
AGC Detector
Phase Shift
÷2
DB Lin
DB Lim
Frequency Divider
Input Signal Match
Phase Det.
Commands
SPE
Phase Detector
X3
Volt Cont. OSC
X3
VCO OUT
VCO

4.1-11-2

SL HIGH RATE RADIO PERFORMANCE CHARACTERISTICS

Overall

Transmit Frequency	2295 MHz ± 5 MHz
Receive Frequency	2113 5/16 MHz
Transmit/Receive Ratio	240/221
Coherent Spurious Rejection	30 dB min
Operating Temperature	–20°C to +75°C
Primary DC Input Voltage	28 Vdc
Power Output	42.7 dBm ± 0.6 dB
Spurious Output Signals	–60 dB max
Modulation Characteristics	
Bandwidth (2 dB)	DC to 3.0 MHz
Sensitivity	1.0 rad/volt
Linearity at 2 radians	2.5%
Phase Deviation Capability	4.0 rad
Deviation Stability	± 3%
Output S-band Phase Deviation Sense for Positive Input Voltage	Positive
Carrier Phase Stability	
Nominal	5° RMS
Vibration	1.5° RMS/g
Long Term Frequency Stability	
–20°C to +75°C	12 pts/10^6
–0°C to + 55°C	6 pts/10^6
Short Term Frequency Stability	2 pts/10^{10}
Receiver Nose Figure	4.9 dB $^{+0.5}_{-0.2}$ dB
Preselector Loss	0.8 dB ± 0.1 dB
Output Filter Loss	0.2 dB ± 0.05 dB
RF Circulator Switch Loss	0.3 dB ± 0.05 dB

Figure 4.1–7

SL HIGH RATE RADIO INTERFACE DEFINITION

INTERFACE DESCRIPTION	SIGNAL FLOW TO	SIGNAL FLOW FROM	INTERFACING SUBSYSTEM
RF Power Output	X		High Gain Antenna
RF Power Input		X	Low Gain Antenna
High Rate TLM		X	SL Telemetry Equipment
Transponder Engineering TLM	X		SL Instrumentation Equipment
Command Signals	X		SL Command SS
Primary DC Power		X	SL Power Subsystem
Backup Operational and Failure Mode Commands		X	SL Command SS
Test Checkout			
Prelaunch		X	SL Telemetry SS and In-flight Checkout SS
Cruise (Not Required)			
In-flight		X	Same as above

Figure 4.1-8

- o Data Transmission: Ps = 0.9958
- o Coherent Two Way Doppler: Ps = 0.9934

The functional flow block diagram, the reliability assessment model, and the reliability flow model for functional or total success are shown in Figure 4.1-9 No block redundancy is utilized in the design. Overcurrent protection is provided to assure that the power bus is not pulled down by a short failure mode, therefore preventing failure mode propagation from disabling the back-up transmitter. To restore the system if the overload is temporary, the overload current protection logic can be reset by a direct command or a periodic reset pulse from the Sequencer And Timer.

4.1.7.2 Failure Modes and Effects - Figure 4.1-10 shows the fault tree for the SL High Rate Radio Subsystem. There is inherent redundancy in the data transmission function since the exciter auxiliary oscillator can be bypassed by the receiver VCO in the coherent two way mode. The alternate for command reception is the automatic operational capability via the Sequencer And Timer. Critical data can also be transmitted via the Low Rate Radio Subsystem in case of the no-subsystem-output failure mode.

4.1.7.3 Complexity Estimate - The SL High Rate Radio is estimated to have a complexity in the order of 1135 piece parts excluding hardware and connection system parts. Figure 4.1-11 breaks down the subsystem by generic part types. To summarize, the following is a listing by part category:

422 Capacitors
124 Diodes
376 Resistors
96 Transistors
76 Chokes & Coils

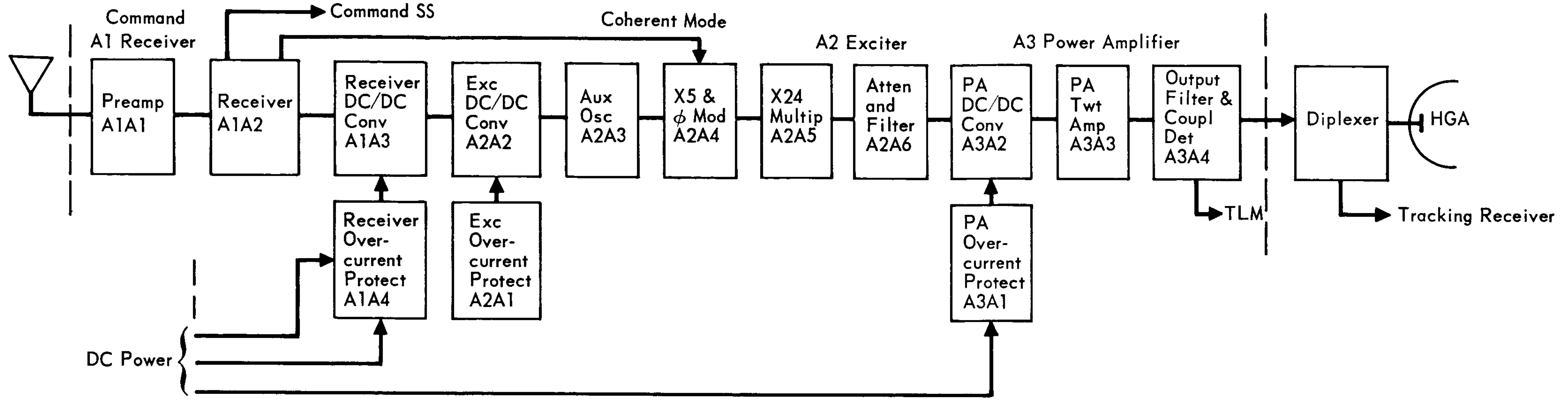
26 transformers
1 I.C. Op. Amps.
3 Relays
10 Miscellaneous
1131 Total

Critical part applications are the power amplifier high voltage circuits, the P.A. DC/DC converter input regulator, the crystal oscillator, and the preamp. The hazards of high voltage breakdown, ripple current power dissipation, crystal fracture, and signal to noise deterioration have been reviewed and analyzed in depth. Design techniques to reduce the risk of catastrophic failure have been used in developing the design concept.

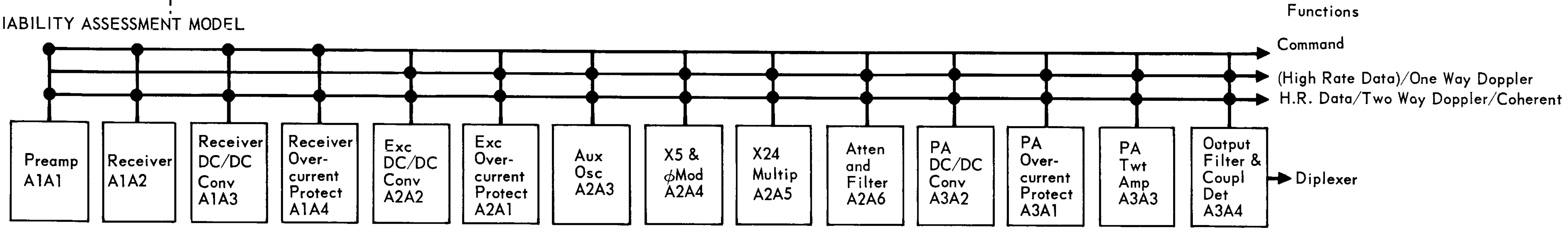
4.1.7.4 Safety Considerations - Due to power amplifier voltages up to 2500 Vdc standard high voltage safety precautions are necessary in the design operation and test of the unit.

SL HIGH RATE RADIO RELIABILITY MODEL

A. FUNCTIONAL FLOW MODEL, SL HIGH RATE RADIO

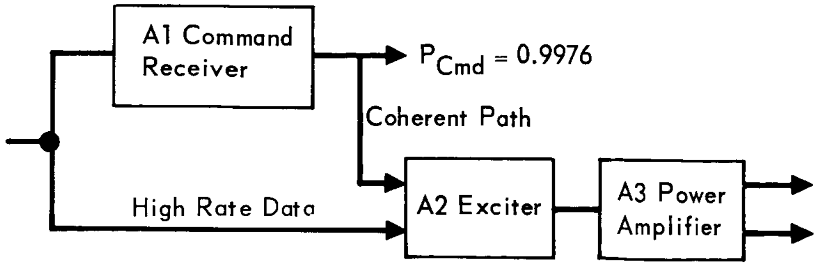


B. RELIABILITY ASSESSMENT MODEL



λ	415	1377	251	37	301	37	291	209	358	120	404	37	1750	120
Σkt	122	122	122	122	122	122	122	122	122	122	122	122	122	122
λΣkt	.0005	.00167	.00028	.000045	.00037	.000045	.00035	.00025	.00044	.00015	.00049	.000045	.00212	.00015
P_s	.9995	.9983	.99972	.999955	.99963	.999955	.99965	.99956	.99956	.99985	.99951	.999955	.99788	.99985
	$P_{Rcvr (A1)} = 0.9976$				$P_{Exciter (A2)} = 0.9984$						$P_{PA (A3)} = 0.9974$			

C. RELIABILITY FLOW MODEL



$P_{Cmd} = 0.9976$

Total Success $P_s = P_{A1} \cdot P_{A2} \cdot P_{A3} = 0.9934$

$P_{Coherent\ Two\ Way\ Doppler} = P_{A1} \cdot P_{A1} \cdot P_{A3} = 0.9934$

$P_{High\ Rate\ Data} = P_{A2} \cdot P_{A3} = 0.9958$

Figure 4.1-9

SL HIGH RATE RADIO FAULT TREE

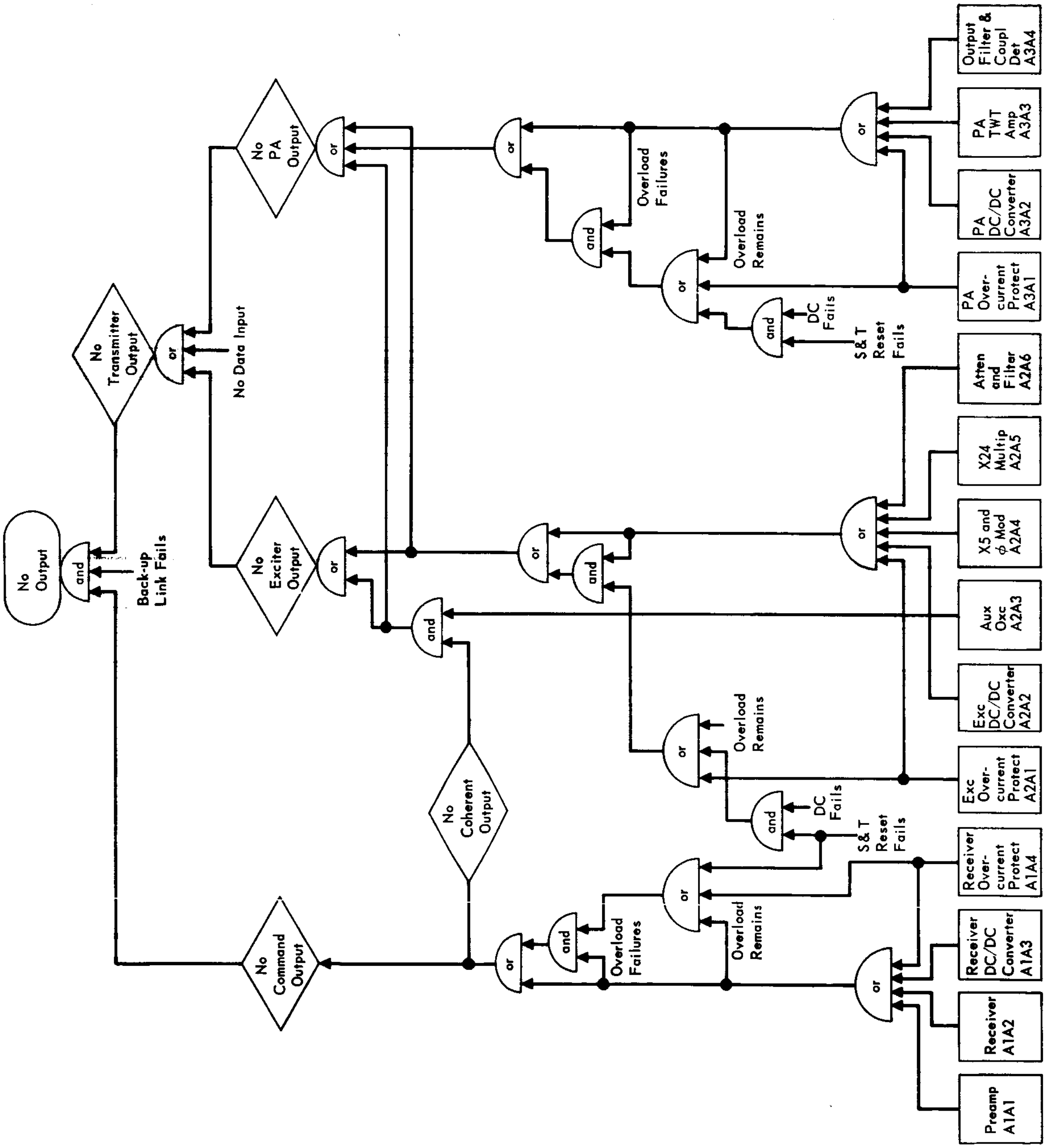


Figure 4.1-10

SL HIGH RATE RADIO SUBSYSTEM COMPLEXITY ESTIMATE
(NO BLOCK REDUNDANCY)

PART TYPE	FAILURE RATE	RECEIVER NO.	EXCITER NO.	POWER AMPLIFIER NO.	TOTAL NO.	TOTAL FAILURE RATE
Capacitors						
Ceramic/Glass	1	180	41	5	226	226
Solid Tantalum	2	12	14	14	40	80
Variable Piston	10	51	26	–	77	770
Feed Thru	5	45	28	–	73	365
Mylar	1	1	–	5	6	6
Diodes						
General Purpose	1.1	22	40	42	104	114
Zener	10	1	1	1	12	120
Varactor VHF	25	–	2	–	2	50
Varactor UHF	50	–	2	–	2	100
Mixer	50	4	–	–	4	200
Resistors						
Metal Film	0.3	52	24	35	111	33
Carbon Composition	0.1	195	54	3	252	25
W.W. Power	0.5	3	3	3	9	4
Thermistors	30	–	1	3	4	120
Transistors						
General Purpose	5	40	17	20	77	385
Power	50	5	4	4	13	650
R.F. Power	50	–	3	–	3	150
Chokes/Coils						
R.F. Chokes	7.5	41	14	8	63	472
Coils/Inductors	10	3	3	7	13	130
Transformers						
RF/IF/Signal	5	8	8	–	16	80
L.V./Power	5	1	1	6	8	40
High Voltage	50	1	1	2	2	100
Miscellaneous						
Relay, 2A, DPDT	10	1	1	–	2	20
Relay, 10A, DPDT	20	–	–	1	1	20
Crystal	65	2	1	–	3	195
Crystal Filter	65	1	–	–	1	65
TWT, 20 watt	1750	–	–	1	1	1750
IC OP Amplifier	30	1	–	–	1	30
Filter, RF Mech.	60	–	1	1	2	120
Coupler, Stripline	60	–	–	1	1	60
Isolator, Ferrite	25	–	1	–	1	25
Attenuator RF	60	–	1	–	1	60
Totals	–	678	291	162	1131	6465

Figure 4.1-11

The 20 watt S-Band output of the power amplifier is of sufficient level to require standard safety precautions in energizing the unit in the vicinity of pyrotechnic devices.

4.1.8 Test - Testing will be conducted as listed in the test matrix shown in Figure 4.1-12 in accordance with the Integrated Test Plan.

Tests will be performed prior to canister enclosure, after enclosure prior to final sterilization, after sterilization and during pre-launch operations. In-flight-checkout will be performed thru the DSIF. In-flight-checkout (pre-separation) is initiated by the SL Test Programmer upon command from the DSIF and monitored through the SL Telemetry Subsystem. DSIF compatibility tests will also be performed.

4.1.9 Development Requirements - Significant development effort may be necessary to realize the performance required of the low noise S band transistor preamplifier. Flight and design experience has been amassed with the 20-Hertz phase-lock receiver developed by the Jet Propulsion Laboratory and the cost and risk implications of developing a receiver with a smaller loop bandwidth form a strong constraint to utilize this bandwidth in the command receiver. Retaining the 20-Hertz loop bandwidth requires the use of a low-noise preamplifier in the receiver in order to meet the -150 dBm sensitivity constraint. This low-noise preamplifier is the only developmental item contained in the design.

The most critical element is the TWT. The TWT's are nearly identical to the Apollo 394H tubes which have had over 10,000 life test hours. The TWT's are designated as the 242H with a life requirement of 10,000 hours minimum, 50,000 design goal.

LABORATORY HIGH RATE RADIO TEST MATRIX

In-Flight Checkout	Pre-Launch	System Test (With Canister)	System Test (Pre-Canister)	Telemetry Points	TEST	ACCY REQ
					Non Operative Test	
					RF Exciter	
×	×	×	×	×	Power Supply Voltage	1%
			×		RF Power Output	0.2 dB
×	×	×	×	×	Power Supply Current	2%
×	×	×	×	×	Auxiliary Osc. Temperature	2%
	×	×	×		Auxiliary Osc. Frequency	1×10^{-8}
×	×	×	×	×	Detected RF Power Output	0.5 dB
	×	×	×		Spurious Output	1 dB
					Hi-Rate Transmitter (TWTA)	
	×	×	×		RF Power Output	0.2 dB
	×	×	×		Collector Current	2%
×	×	×	×	×	Helix + Anode Current	2%
×	×	×	×	×	Regulator Voltage	1%
×	×	×	×	×	Collector Temperature TWTA	2%
×	×	×	×	×	Case Temperature	2%
×	×	×	×	×	Detected Power Output	0.5 dB
			×		Modulation Test	5%
	×	×	×		Spurious Output	1 dB
	×	×	×		Transmitter Frequency	1×10^{-8}
					Command Receiver	
	×	×	×	×	AGC Course	2%
	×	×	×	×	AGC Fine	2%
	×	×	×	×	Static Phase Error	2%
×	×	×	×	×	VCO Temperature	2%
×	×	×	×	×	Power Supply Voltage	1%
×	×	×	×	×	Power Supply Current	2%
			×		APC Loop Bandwidth	5%
	×	×	×		Dynamic Range	1 dB
			×		Modulation/Video Test	5%
			×		VCO Frequency	1×10^{-11}
	×	×	×		Sensitivity (Threshold)	0.2 dB
	×	×	×		Image Rejection	1 dB
					RF Switch Operation	

Figure 4.1-12

4.2 SL LOW RATE RADIO

4.2.1 Equipment Identification and Usage - The SL Low Rate Radio is used for transmitting engineering data to Earth from landing on Mars until completion of the mission. The SL Low Rate Radio block diagram is shown in Figure 4.2-1.

4.2.2 Design Requirements and Constraints - The most significant design constraint imposed upon the Low Rate Radio is the requirement that the unit generate and transmit 16 FSK signals at S-Band with a frequency separation between the signals of 6.25 Hz and a spacing stability within 0.23 Hz. This stability is needed to gain full advantage of the low bit rate MFSK communications system.

Other design constraints on the low data rate radio are:

- The unit must provide a 5 watt RF power output at approximately 2292 MHz
- The unit must accept the low bit rate digital information from the telemetry equipment and select, via a frequency synthesizer or equivalent, the correct one of sixteen tones

4.2.3 Physical Characteristics - The physical characteristics of the SL Low Rate Radio are shown in Figure 4.2-2.

4.2.4 Operation Description

4.2.4.1 Operation Sequence - The Low Rate Radio is controlled by the Sequencer And Timer (S & T).

4.2.4.2 Functional Operation - When the Low Rate Radio is supplied a data stream from the telemetry equipment, the MFSK generator generates one of 16 discrete frequencies in the 30 KHz region with separations of 3.125 Hz. The MFSK frequencies are then translated up to the 1146 MHz region by the frequency translator. The translator output power is approximately one milliwatt.

The solid state amplifier increases the 1146 MHz RF power to 10 watts and then doubles the frequency to achieve the 2292 MHz 5 watt output. The spacing of the S-Band MFSK frequencies will be 6.25 Hz.

The power converter accepts dc power from the Flight Capsule Power Subsystem and produces two regulated 28 Vdc power sources. One is used to operate the solid-state power amplifier while the other is used to operate the MFSK generator and the frequency translator. The two 28 Vdc sources can be turned on or off independently. To insure stable operation it is necessary to turn on the MFSK generator and the translator for a 6 hour warm up before applying dc power to the solid-state power amplifier.

MFSK Generator - The MFSK generator is a frequency synthesizer. The frequency synthesizer functional schematic is shown in Figure 4.2-3.

SLS LOW RATE RADIO BLOCK DIAGRAM

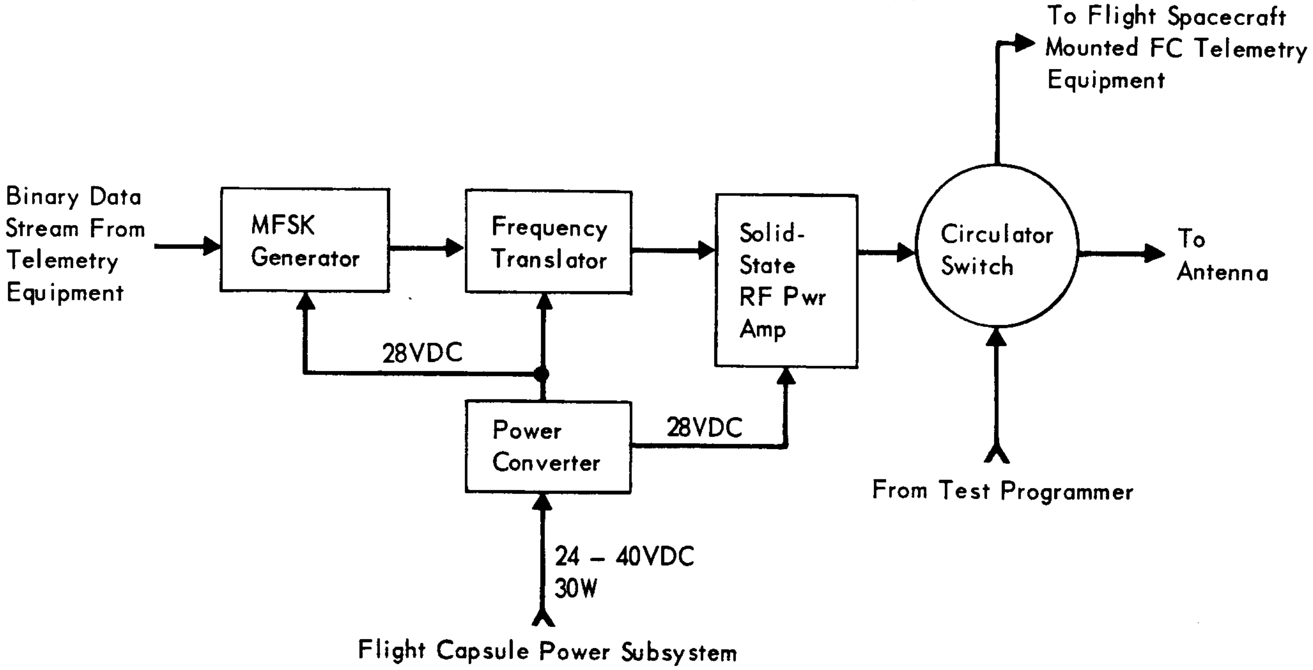


Figure 4.2–1

SLS LOW RATE RADIO PHYSICAL CHARACTERISTICS

ASSEMBLY	MFSK GENERATOR	FREQUENCY TRANSLATOR	POWER AMPLIFIER	POWER CONVERTER	CIRCULATOR SWITCH	TOTAL
Size (Inches)	6 x 6 x 2 (72 in^3)	2 x 6 x 2 (24 in^3)	4 x 5 x 1 (20 in^3)	2 x 4 x 2 (16 in^3)	2 x 2 x 1 (4 in^3)	136 in^3
Weight (Pounds)	3	1.4	1.1	.8	.3	6.6
DC Input Power (Watts)	1.5	1.0	24	30	–	30
Power Dissipation (Watts)	1.5	1.0	19	3	–	24.5

Figure 4.2-2

FREQUENCY SYNTHESIZER FUNCTIONAL SCHEMATIC

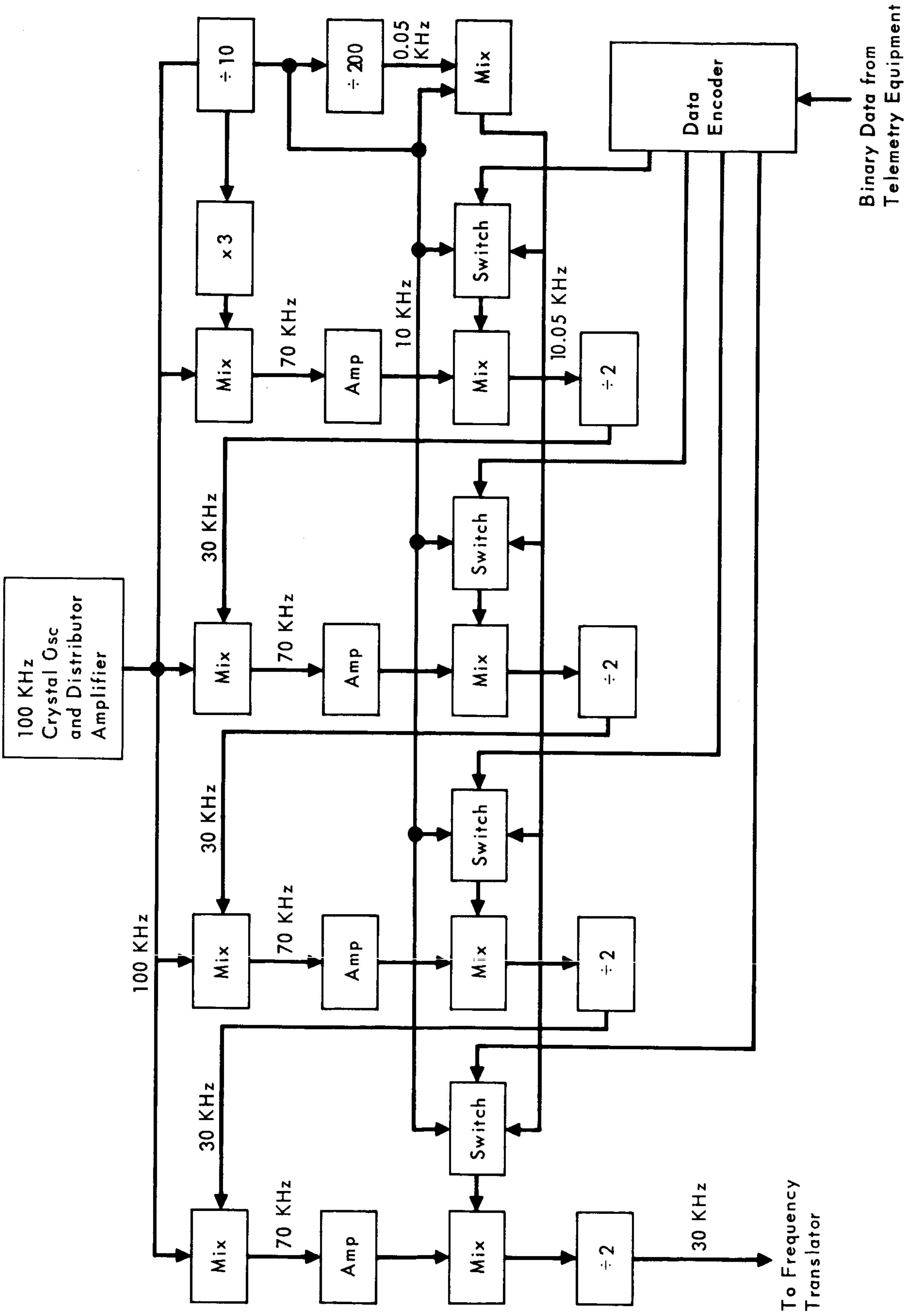


Figure 4.2-3

The data from the SL TM Equipment to the Low Rate Radio is in the form of a NRZ serial bit stream. The MFSK generator translates each group of four successive bits into one of 16 frequencies by use of a four bit shift register controlling the switches shown in Figure 4.2-3.

The synthesizer frequency scaling diagram is shown in Figure 4.2-4. The spacing between frequencies is determined by the spacing between the two frequencies in the first tier.

Frequency Translator - The frequency translator translates the 30 KHz MFSK frequencies up to the 1146 MHz region. It consists of an ultra stable crystal oscillator, a multiplier chain and three mixers. The functional schematic is shown in Figure 4.2-5.

The crystal oscillator must have a short term stability of 1 x 10^{-11} per one second average, and a long term stability of ± 5 x 10^{-7} per year. Such high stability requires a proportional oven which regulates the crystal temperature within 0.01°C.

Solid-state Power Amplifier - The solid-state power amplifier consists of the following: (The schematic is shown in Figure 4.2-6.)

- 1146 MHz driver - The driver accepts the 1146 MHz signal from the frequency translator and amplifies the power up to +23 dBm. It utilizes high gain, MT1070 L-Band Transistors.
- 1146 MHz power amplifier - The power amplifier utilizes TA-7003 transistors. Each transistor can produce 3.4 watts RF power with 0.5 watt RF input. The collector efficiency is 50%. An input power of approximately 1.7 watt at the input hybrid will deliver 11 watts to the varactor doubler. The amplifier and the hybrids are combined on a single circuit board.
- 1146 MHz - 2292 MHz varactor doubler - The 1146 MHz doubler utilizes a 1N5153 varactor diode, and has a conversion efficiency of greater than 50%.
- 3-way hybrids - The 3-way hybrids provide over 20 dB isolation between points. The insertion loss is less than 0.5 dB.
- RF coupler/power detector - The RF coupler/power detector samples and detects a small percentage of the RF output power, and provides a dc feedback voltage to control the gain of the 1146 MHz driver for maintaining a constant power level to the antenna.

FREQUENCY SYNTHESIZER SCALING DIAGRAM

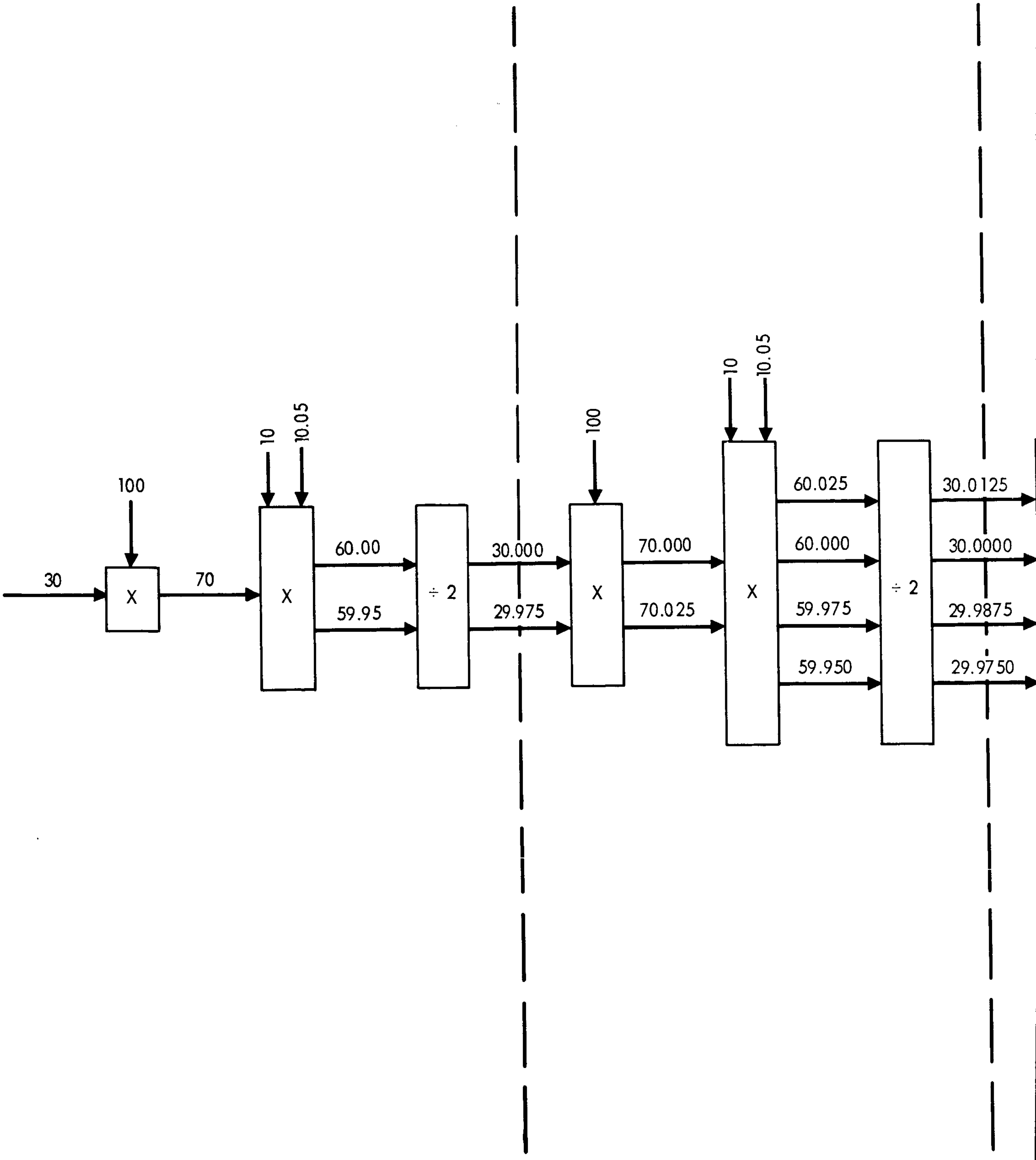
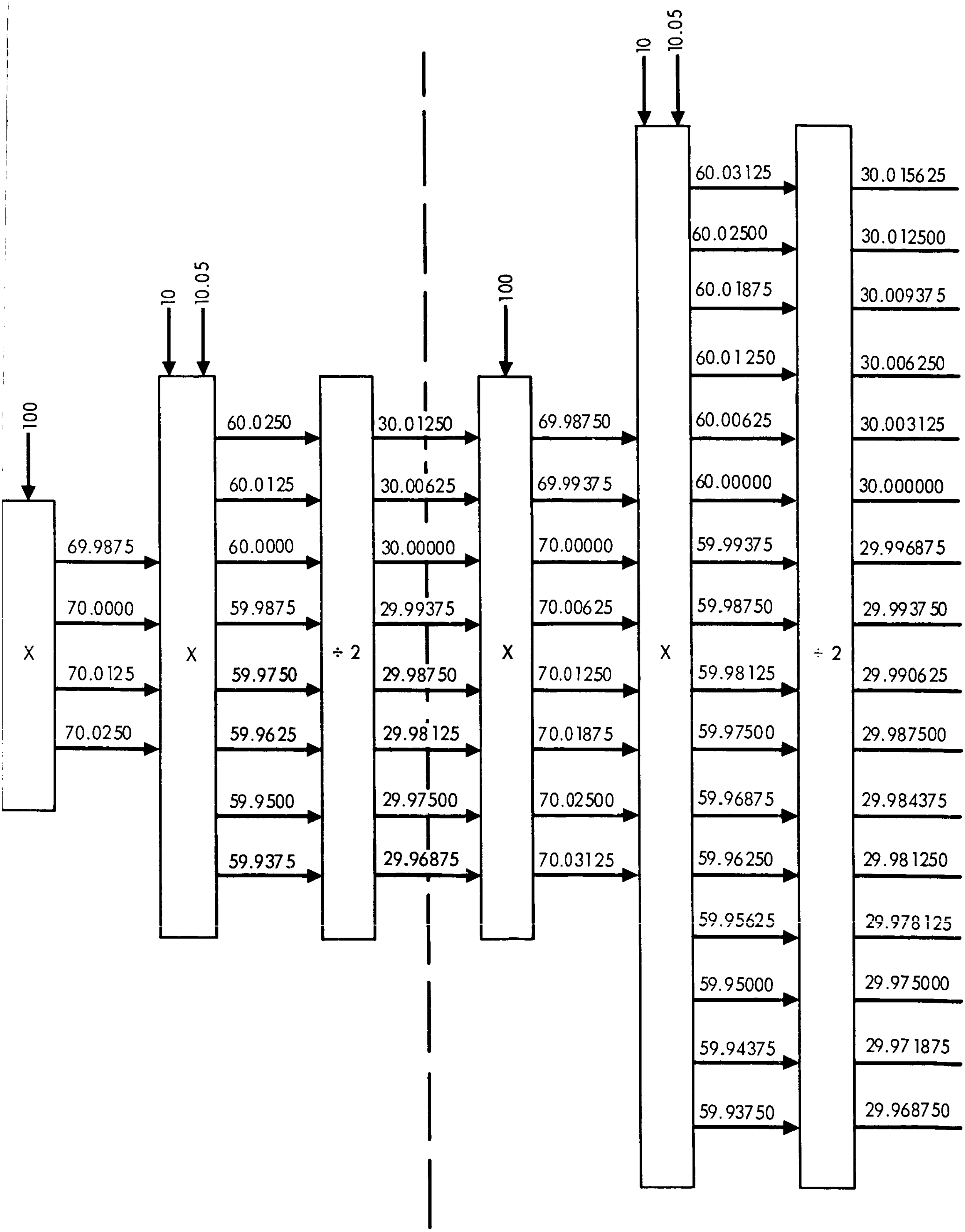


Figure 4.2-4


100
X
69.9875
70.0000
70.0125
70.0250
10
10.05
X
60.0250
60.0125
60.0000
59.9875
59.9750
59.9625
59.9500
59.9375
÷ 2
30.01250
30.00625
30.00000
29.99375
29.98750
29.98125
29.97500
29.96875
100
X
69.98750
69.99375
70.00000
70.00625
70.01250
70.01875
70.02500
70.03125
10
10.05
X
60.03125
60.02500
60.01875
60.01250
60.00625
60.00000
59.99375
59.98750
59.98125
59.97500
59.96875
59.96250
59.95625
59.95000
59.94375
59.93750
÷ 2
30.015625
30.012500
30.009375
30.006250
30.003125
30.000000
29.996875
29.993750
29.990625
29.987500
29.984375
29.981250
29.978125
29.975000
29.971875
29.968750

4.2-6-2

FREQUENCY TRANSLATOR FUNCTIONAL SCHEMATIC

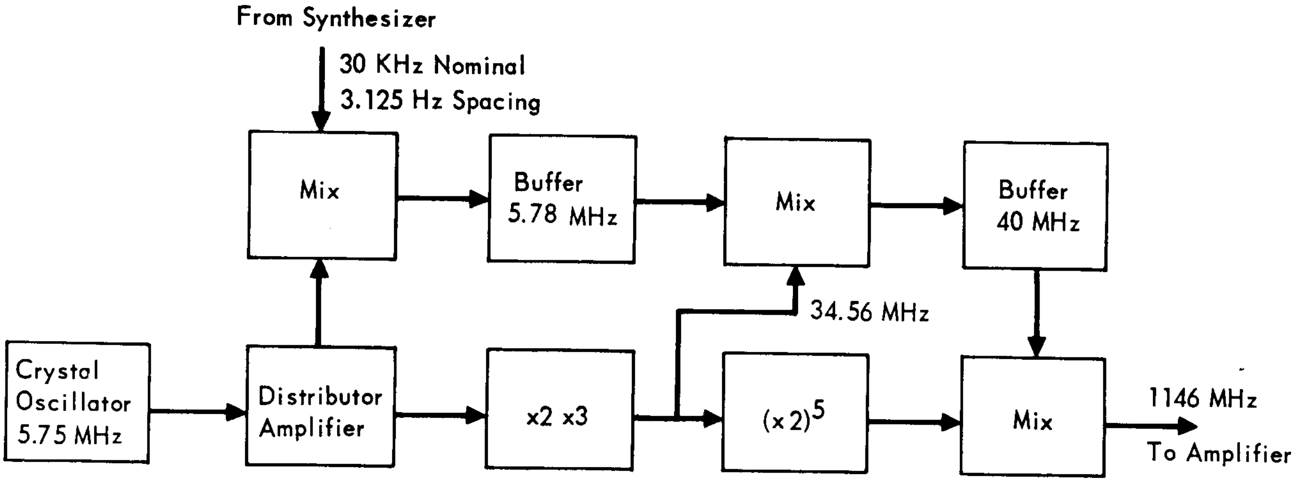
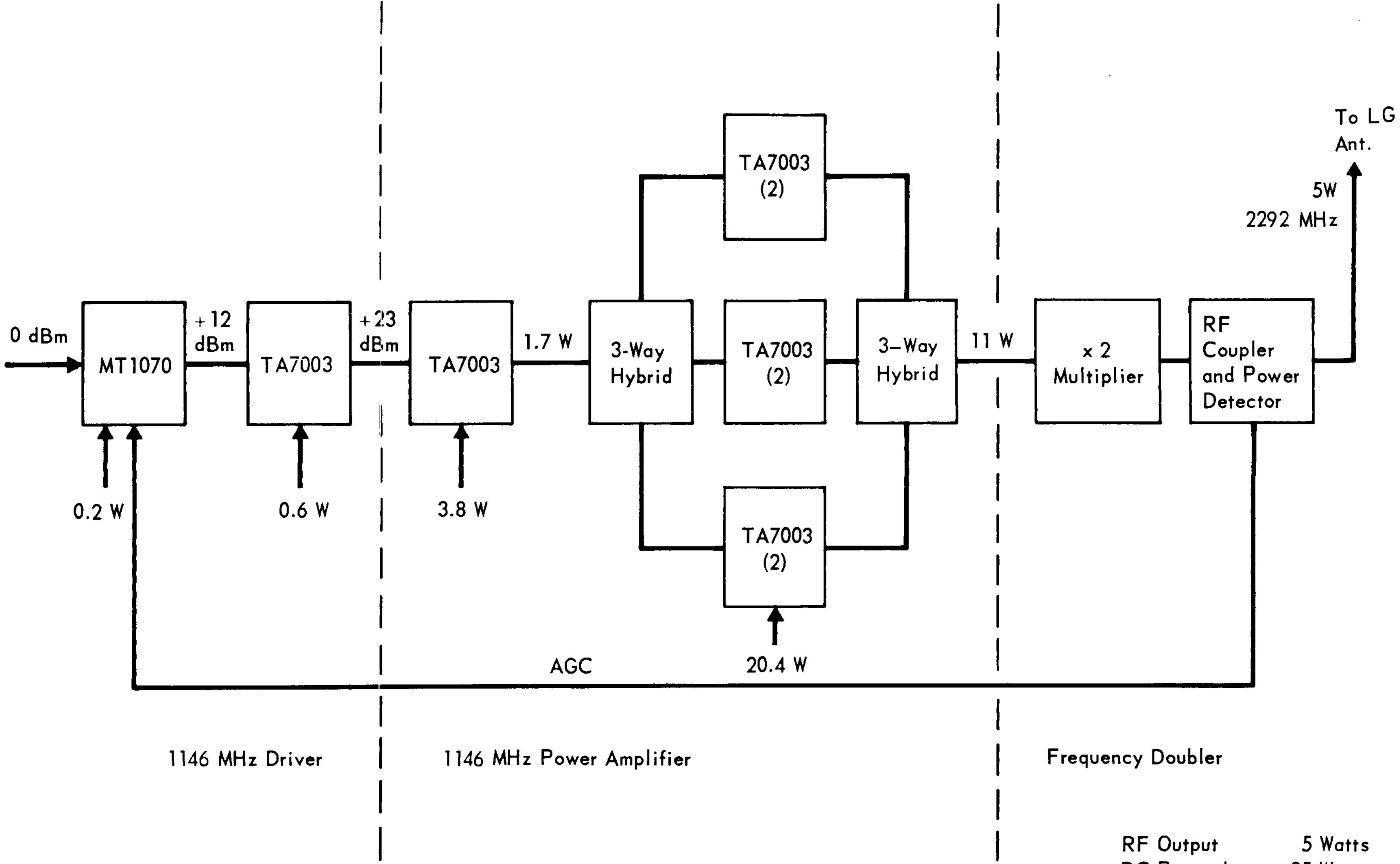


Figure 4.2–5

S-BAND SOLID-STATE TRANSMITTER

(LOW RATE RADIO)



RF Output	5 Watts
DC Power Input	25 Watts
Efficiency	20%

Figure 4.2–6

- Circulator switch - The circulator switch facilitates measurements of low rate radio RF power and frequency during prelaunch test and in-flight checkout.
- Power Converter - The power converter accepts dc power from the Flight Capsule Power Subsystem and produces two 28 Vdc regulated power sources for the SLS Low Rate Radio assemblies. The power converter characteristics are as identified in Figure 4.2-7.

4.2.5 Performance Characteristics - The Low Rate Radio performance characteristics are as listed in Figure 4.2-8.

4.2.6 Interface Definition - The Low Rate Radio interfaces are listed in Figure 4.2-9.

4.2.7 Reliability and Safety Considerations - The following paragraphs describe the reliability and safety considerations of the Surface Laboratory Low Rate Radio Subsystem.

4.2.7.1 Mission Success Definition - The SL Low Rate Radio Subsystem mission is to successfully survive environmental stresses prior to operation and provide direct transmission to Earth capability of engineering data. The SL Low Rate Radio Subsystem is required to operate successfully from post landing turn-on until landed operation termination.

4.2.7.2 SL Low Rate Radio Reliability - The SL Low Rate Radio has an assessed reliability of 0.997 probability of successfully performing its required mission. The functional flow model, the functional reliability assessment matrix and the mission success flow model appear in Figure 4.2-10.

4.2.7.3 Mission Failure Modes and Effects - Figure 4.2-11 shows the mission fault tree for the SL Low Rate Radio. The separate power converter provided for the Frequency Converter is to assure reliable performance and frequency stability.

The major failure modes identified are denoted in Figure 4.2-11.

4.2.7.4 Complexity Estimate - The SL Low Rate Radio is estimated to have a complexity in the order of 586 piece parts. Figure 4.2-12 presents the breakdown of generic parts by Frequency Synthesizer, Frequency Converter, Power Amplifiers, and Power Supplies.

4.2.7.5 Safety Considerations - No special safety considerations are necessary since the voltages of the unit are in the 28 Vdc region.

4.2.8 Test Requirements - Tests (Figure 4.2-13) shall be performed prior to canister enclosure, after enclosure prior to final sterilization, after sterilization and during pre-launch operations. All ground testing shall be performed with the

LOW RATE RADIO POWER CONVERTER CHARACTERISTICS

PARAMETERS	SOLID-STATE RF AMP SUPPLY	MFSK GEN & TRANSLATOR SUPPLY
Input Voltage	24 – 40 vdc	24 – 40 vdc
Output Power	24 watts	2.5 watts
Output Voltage	28 vdc	28 vdc
Regulation	0.1%	0.1%
AC Ripple	0.05%	0.05%
Efficiency	90%	90%
Short and Overload Protection	Yes	Yes

Figure 4.2–7

LOW RATE RADIO PERFORMANCE CHARACTERISTICS

Power Output	5 watts
Frequency	2292 MHz
DC Input	30 watts
Frequency Stability:	
Short Term	1×10^{-10}/second avg.
Temperature	$\pm 2 \times 10^{-9}$
Long Term	$\pm 5 \times 10^{-7}$/year
Initial Accuracy	$\pm 1 \times 10^{-8}$
Change in Spacing Between Any Two Carriers Under All Conditions	0.23 Hz
Temperature Range	–20°C to +75°C

Figure 4.2–8

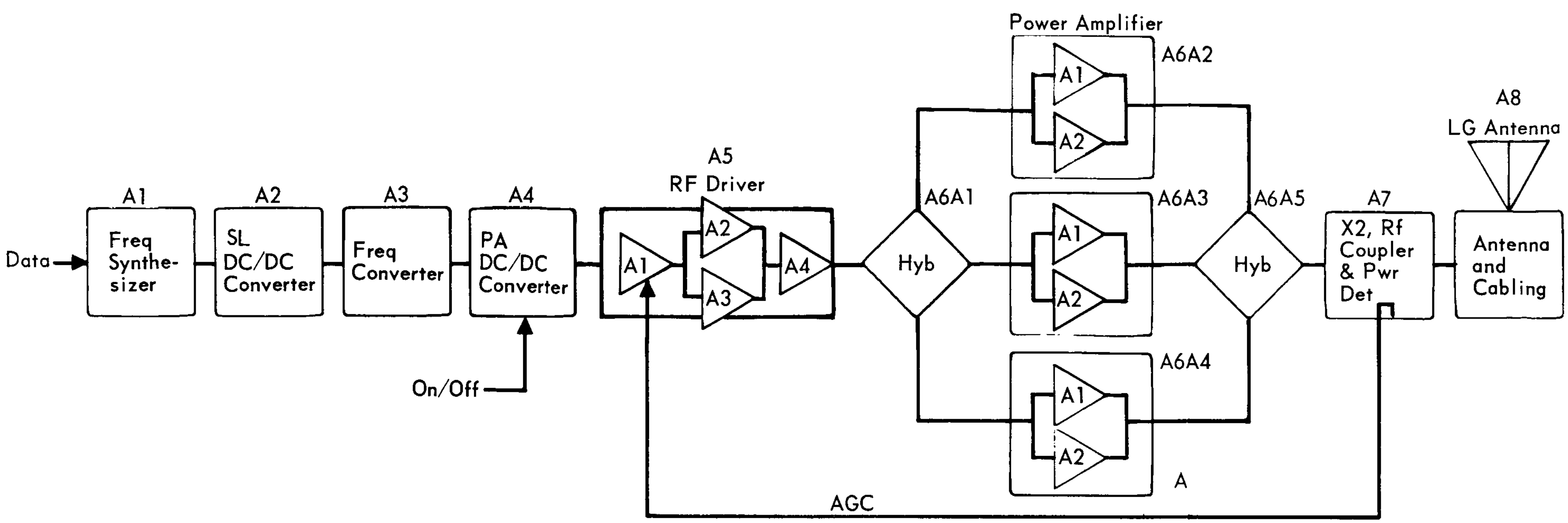
LOW RATE RADIO INTERFACE DEFINITION

INTERFACING EQUIPMENT	INTERFACE DESCRIPTION
Flight Capsule Power Subsystem	Supplies 30 watts DC Power
SL Telemetry Equipment	Provides Modulation Data to Low Rate Radio
SL Low Gain Antenna	Radiates Low Radio Power, 5 watts, 2292 MHz
FSC Mounted FC Telemetry Support Equipment	Facilitates RF Power and Frequency Measurements

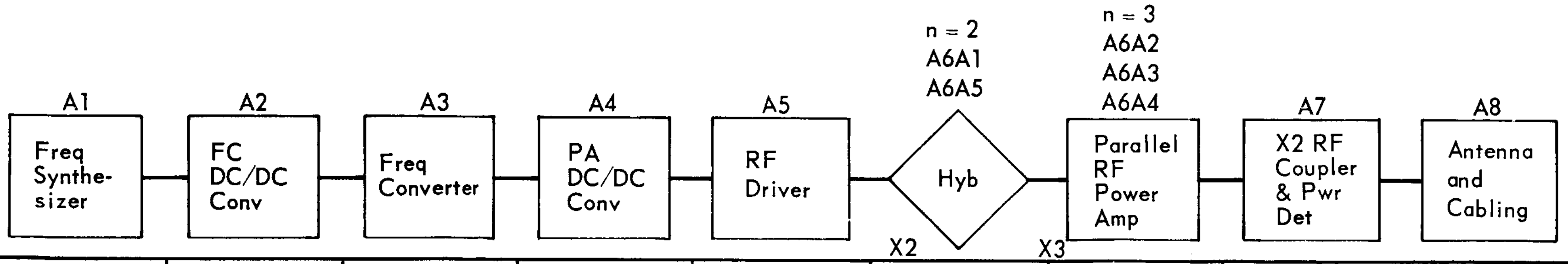
Figure 4.2–9

LOW RATE RADIO RELIABILITY MODEL

FUNCTIONAL FLOW LR RADIO

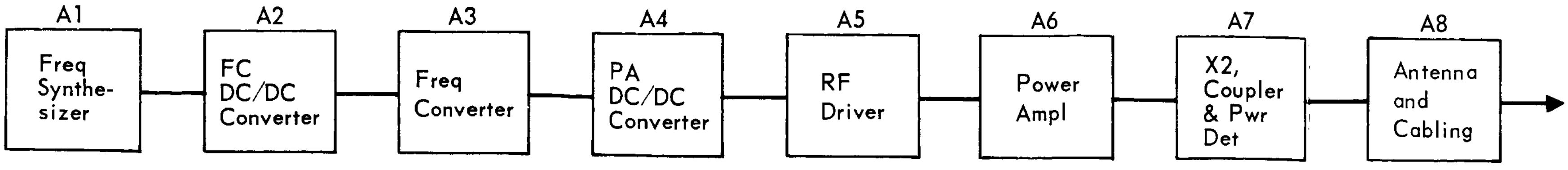


RELIABILITY ASSESSMENT MATRIX



λ	613	224	767	259	337	10 x 2 = 20	144 x 3 = 432	105	48
Σkt	122	122	122	122	122	122	122	122	122
λΣkt	7.46×10^{-4}	2.74×10^{-4}	9.35×10^{-4}	3.16×10^{-4}	4.11×10^{-4}	2.44×10^{-5}	5.26×10^{-4}	1.28×10^{-4}	5.85×10^{-5}
P_s	.999254	.999726	.999065	.999684	.999589	.9999756	.999474	.999872	.9999415

RELIABILITY MODEL



$$P_s = \prod_{i = A1}^{A8} P_i$$

$P_s = 0.9966$

Figure 4.2–10

SLS LOW RATE RADIO FAULT TREE

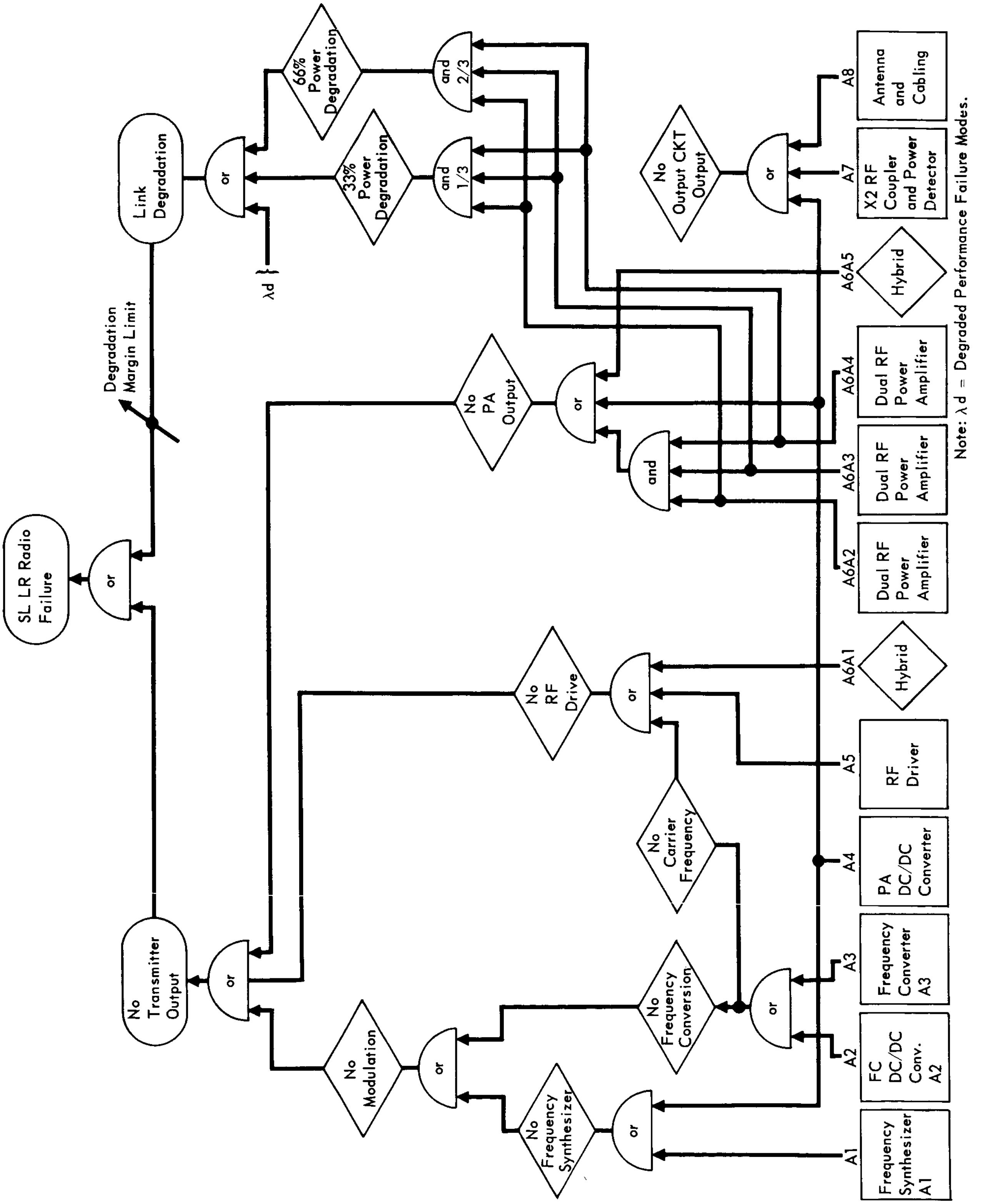


Figure 4.2–11

SL LOW RATE RADIO SUBSYSTEM
COMPLEXITY ESTIMATE

PART TYPE	λ*	FREQUENCY SYNTHESIZER n	FREQUENCY CONVERTER n	FREQUENCY AMPLIFIERS n	POWER SUPPLIES n	TOTAL ϵn	TOTAL $\epsilon n\lambda$
Capacitors							
Ceramic/Glass	1	75	60	32	6	173	173
Solid Tantalum	2	–	–	–	6	6	12
Variable Piston	10	7	11	8	–	26	260
Feed Thru	5	–	16	9	–	25	125
Diode							
General Purpose	1.1	6	11	1	16	34	37
Zener	10	2	1	–	4	7	70
Resistors							
Metal Film	0.3	10	10	5	4	29	9
Carbon Composition	0.1	53	42	13	18	126	13
Transistors							
General Purpose	5	18	16	1	9	44	220
Power	50	–	–	–	3	3	150
RF Power	50	–	–	10	–	10	500
Indicators							
RFC	7.5	6	22	2	–	30	225
Choke	10	5	2	8	6	21	210
Transformers							
Signal	5	7	3	–	–	10	50
Power	25	–	–	–	2	2	50
Miscellaneous							
Crystal	65	1	1	–	–	2	130
Filter, Decoupling	5	–	9	7	–	16	80
Mixer and Diode	50	–	2	–	–	2	100
I.C., Flip Flop	10	15	–	–	–	15	150
Hybrid	10	–	–	2	–	2	20
Directional Coupler	10	–	–	1	–	1	10
Detector, RF Power	50	–	–	1	–	1	50
Antenna and Cabling	48	–	–	1	–	1	48
Total		205	206	101	74	586	2692

*Failure rate in failures per 10^8 hr

Figure 4.2–12

SLS LOW RATE RADIO TEST MATRIX

TEST	Non Operative Test	RF Power Output	Power Amplifier Coll. Current	Power Supply Voltage	DC Current Drain	Case Temperature A	Case Temperature B	MFSK Freq. 1–16 Accuracy	Frequency Stability	Modulation Test	Detected RF Power Output	Spurious Output	Power Stability	AGC Voltage	VSWR Monitor	Frequency
ACCY REQ		0.2 dB	2%	2%	2%	2%	2%	1×10^{-11}	1×10^{-11}	5%	0.5 dB	1 dB	0.2 dB	2%	2%	
Telemetry Points			X	X	X	X	X				X			X	X	
System Test (Pre-Canister)		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
System Test (With Canister)		X	X	X	X	X	X	X	X		X	X		X	X	X
Pre-Launch		X	X	X	X	X	X	X	X		X	X		X	X	X
Inflight Checkout		X	X	X	X	X	X		X		X			X	X	X

Figure 4.2–13

use of Operational Support Equipment (OSE). In flight checkout will be performed through the DSIF. In flight checkout (pre-separation) is initiated by the test programmer and monitored through the spacecraft telemetry system.

4.2.9 Development Status - The required stability and power handling capability, (frequency synthesizer and power amplifier) although demonstrated in the laboratory, require specific attention early in the program.

4.3 TRACKING RECEIVER

4.3.1 Equipment Identification and Usage - The Tracking Receiver accepts the composite RF signal from the High Gain Antenna and its associated RF circuitry. This signal is the comparator network summation signal plus the hour angle (HA) and declination (DEC) error signals. The Tracking Receiver amplifies, detects and separates the error signals, and provides them to the antenna Control Subsystem.

The Tracking Receiver together with the RF feed and associated circuitry comprise a pseudo-conical scan receiving system. The receiver block diagram is shown in Figure 4.3-1.

4.3.2 Design Requirements and Constraints - The Tracking Receiver must be sufficiently sensitive to acquire the DSN signal and phase-lock to it under conditions when the High Gain Antenna is not pointed optimally. The receiver must detect and separate the error signals and provide these signals to the antenna Control Subsystem. The receiver must provide an indication of signal acquisition for checkout purposes and telemetry indication, and be capable of being functionally tested before and after sterilization in the canister.

4.3.3 Physical Characteristics - The Tracking Receiver occupies 188 cu. in., weighs 5.3 lbs, and requires 8 watts.

4.3.4 Operation Description - The receiver is CW narrow-band, double superheterodyne and uses automatic phase tracking.

The incoming RF command signal is converted to 47.8 MHz at the first mixer/preamplifier and supplied to the second mixer. In the second mixer, the signal is converted to 9.56 MHz. The 9.56 MHz IF amplifier drives the phase detector and the AGC detector. The phase detector compares the incoming 9.56 MHz signal with the VCO, and produces a DC voltage output proportional to the phase difference between these two signals. The DC output voltage is coupled to the loop-tracking filter, which supplies the control voltage for the VCO.

The VCO provides an output at the frequency of 19.125 MHz. A multiplier (X3) following the VCO provides outputs at 57.4 MHz to the second mixer and to a multiplier (X36) that supplies the first mixer. The 19.125 MHz frequency from the VCO is supplied also to the frequency divider, which provides the reference signals to the phase detector, the AGC detector, and the video detector. Variations in the amplitude of the incoming signal are detected in the AGC detector which applies a filtered DC voltage to the 47.8 MHz IF amplifier to control the receiver gain.

PSEUDO CONICAL SCAN TRACKING RECEIVER FUNCTIONAL SCHEMATIC

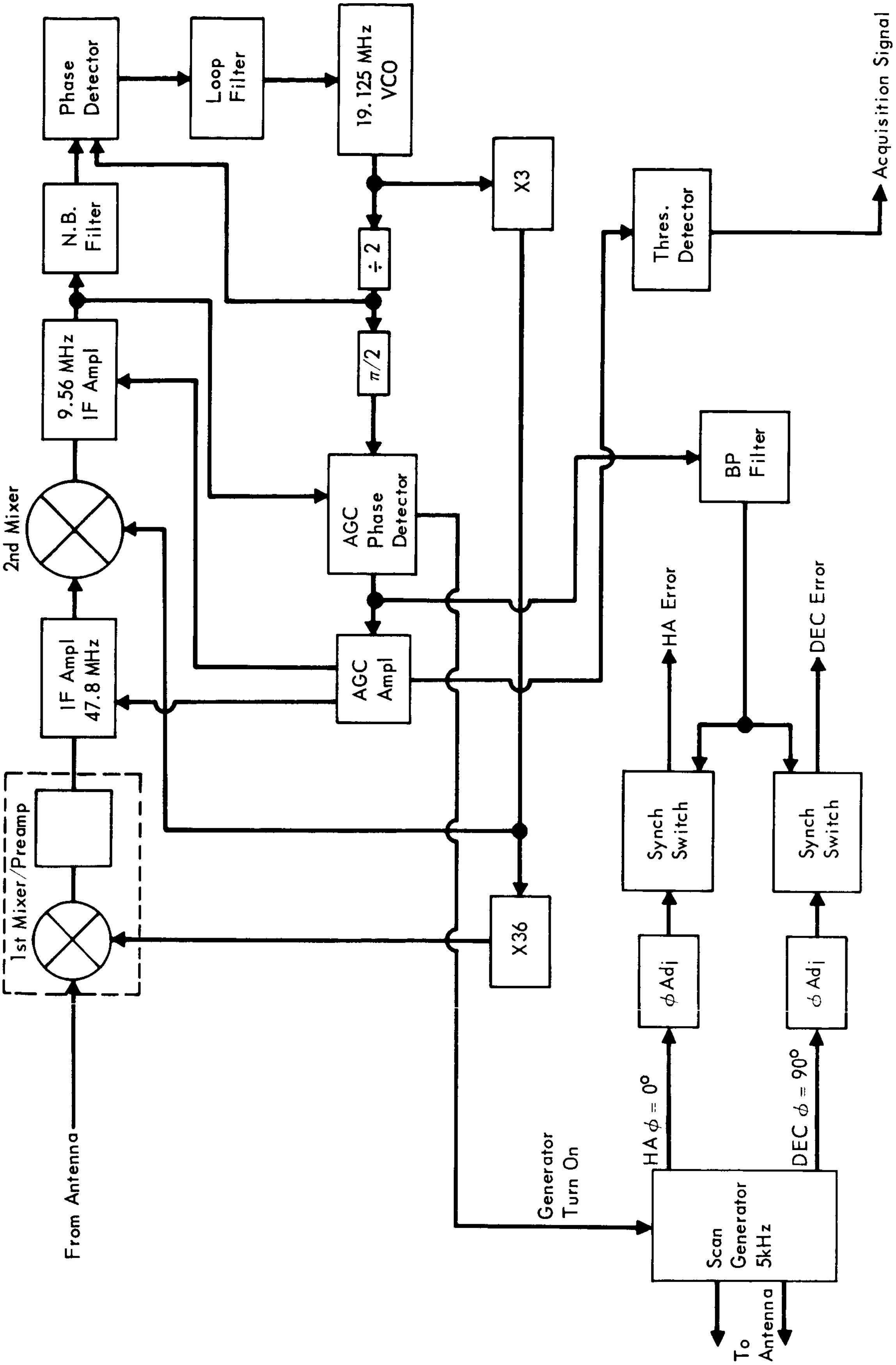


Figure 4.3-1

The output of the AGC Detector is supplied to a bandpass filter tuned to the scan generator frequency. The output of the filter is then applied to the error channel synchronous switches in which the signal is switched (chopped) by the reference signals from the scan generator, generating the two error signals.

4.3.5 Performance Characteristics - The performance characteristics of the Tracking Receiver are summarized in Figure 4.3-2.

4.3.6 Interface Definition - The following connections are required with other subsystems:

Interface	Type
Error Signal to Antenna Control Subsystem	Two DC connections; 100 ohm dynamic impedance, +15 volts maximum.
Acquisition Signal to Antenna Control System	One DC connection; two state output, -15V, +15V.
Receiver Input	S-Band 50 ohm coaxial connector.
AGC, HA Error, DEC Error and Monitors to Telemetry SS	DC connections, 0-5 volts.
SCAN Generator Signals to Modulator	Two AC connections, 5 KC square wave ±5 volts.
Power Supply Input	One DC connection, +28 VDC, 7.2 watts.

An interface diagram appears in Figure 4.3-3.

4.3.7 Reliability and Safety Considerations - The following paragraphs describe the reliability and safety considerations of the SL Tracking Receiver.

4.3.7.1 Mission Success Definition - The Tracking Receiver's mission is to survive prelanding environmental stresses and to provide a carrier lock-on signal to the antenna control logic, and Hour Angle and Declination error signals to the antenna servo electronics. The Tracking Receiver is required to operate as backup to the clock track mode until the termination of SL mission.

4.3.7.2 Reliability Model - The Tracking Receiver has an assessed reliability of 0.9951 probability of successfully performing its mission. The probability of successful lock-on with an AGC lock signal output is 0.9959, and the HA or DEC error signal output has a 0.9953 probability of success. The functional flow model, the reliability assessment matrix and the success flow model are shown in Figure 4.3-4.

TRACKING RECEIVER PERFORMANCE CHARACTERISTICS

PARAMETER	CHARACTERISTIC
Receiver Frequency	2113 5/16 ±5 MHz
Nose Figure	9.0 dB
Threshold Sensitivity	−138 dBm
Dynamic Range	85 dB
IF Predetection Bandwidth	70 kHz
Loop Parameters	
Loop Bandwidth	1 kHz
Phase Detector Output	1 Volt/deg (4 Volts Max)
Phase Detector Constant (K_d)	0.35 Volts/Degree
VCO Constant (K_v)	120 Hz/Volt
VCO Stability	± 1 Part 10^5
AGC Time Constant	23 Sec
Operating Temperature Range	−4° to 165°F
Con-Scan Frequency	5 kHz

Figure 4.3–2

TRACKING RECEIVER INTERFACE DIAGRAM

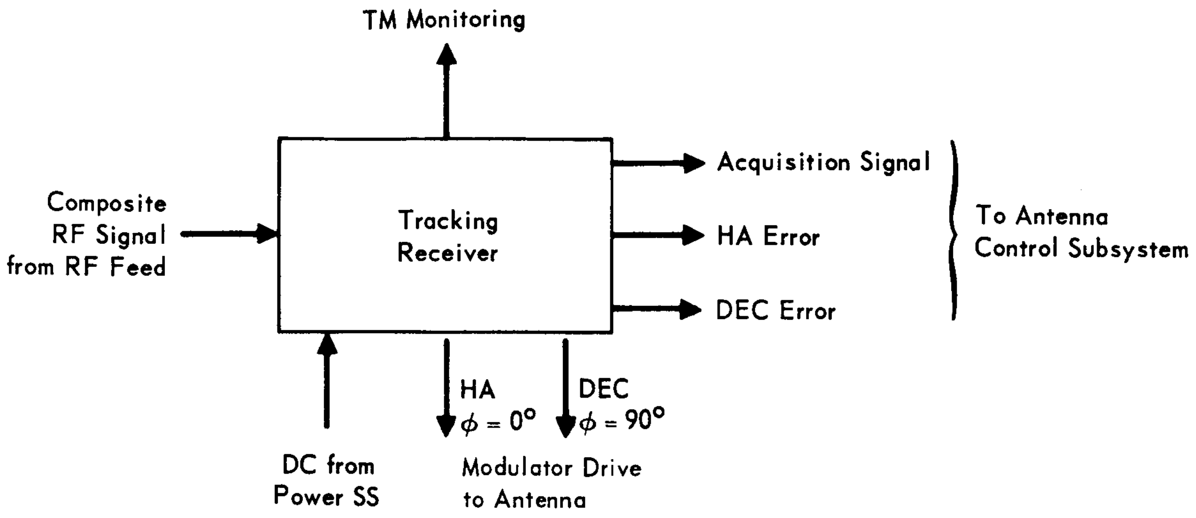
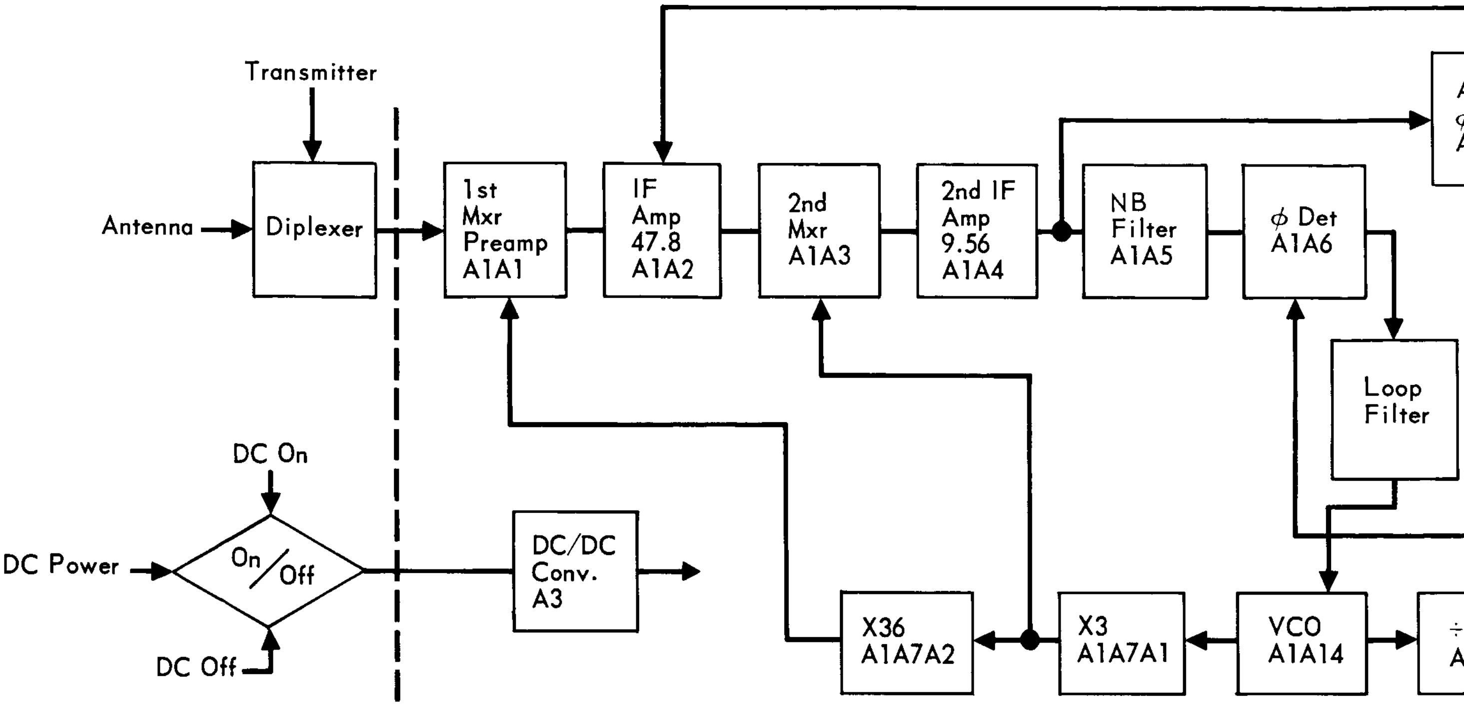


Figure 4.3-3

TRACKING RECEIVER RELIABILITY MODEL

A. FUNCTIONAL FLOW DIAGRAM



B. RELIABILITY ASSESSMENT MATRIX

	A1A1	A1A2	A1A3	A1A4	A1A5	A1A6	A1A14	A1A7	A1A8
λ	121	236	121	292	33	173	328	447	320
Σkt	167	167	167	167	167	167	167	167	167
λΣkt	.000202	.000394	.000202	.000486	.0000551	.000289	.000548	.000746	.000535
Ps	.999798	.999606	.999798	.999514	.9999449	.999711	.999452	.999259	.999465
Totals					P_{A1} = .99621				

C. RELIABILITY FLOW MODEL

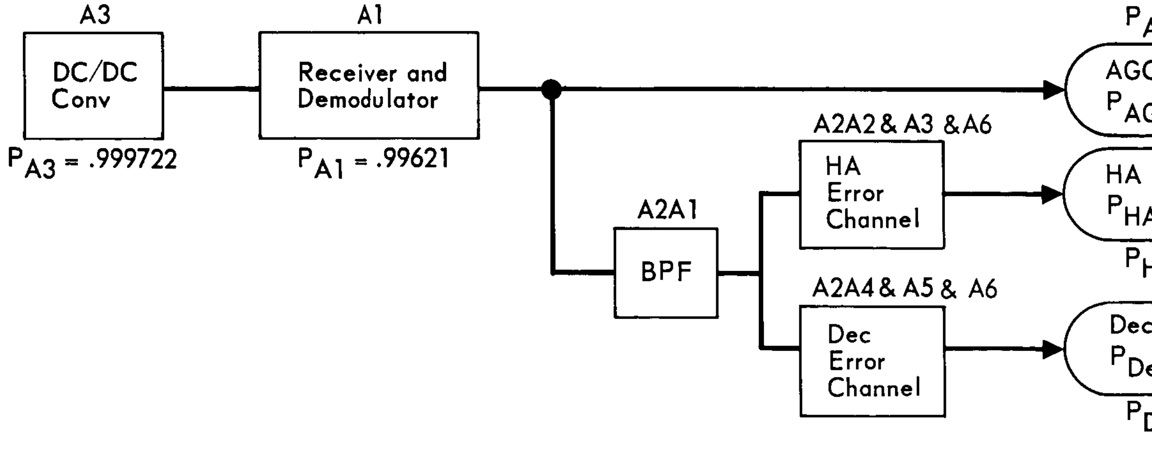
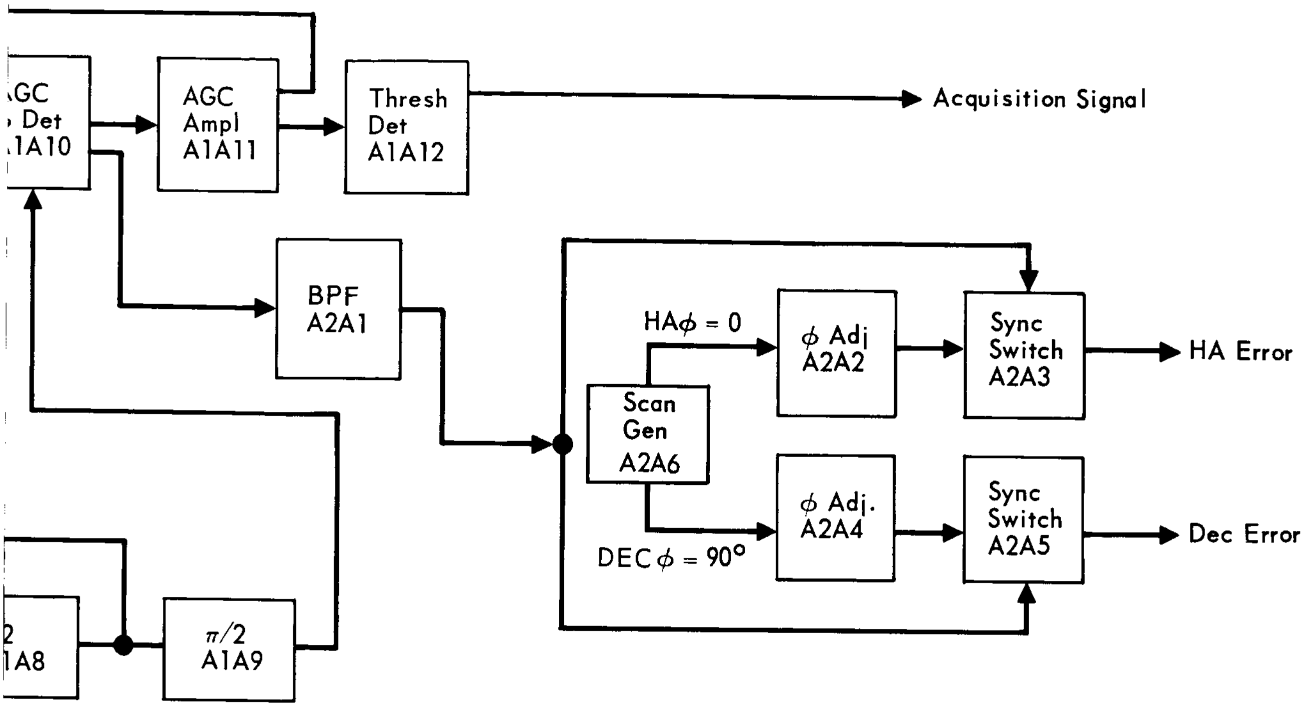
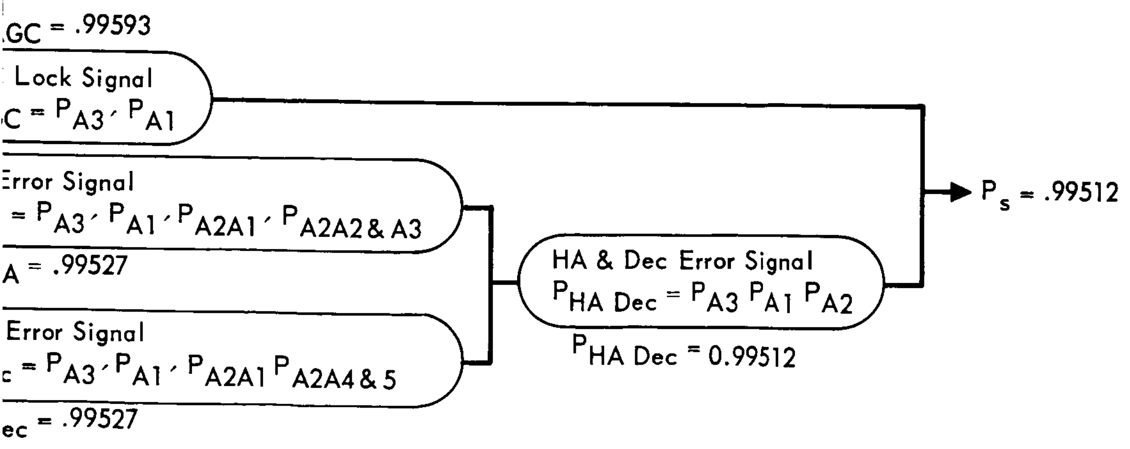


Figure 4.3-4



A1A9	A1A10	A1A11	A1A12	A2A6	A2A1	A2A2 A2A4	A2A3 A2A5	A3
19	33	93	32	24	341	36	70	226
167	167	167	167	167	167	167	167	167
.0000318	.0000551	.000156	.0000535	.0000401	.000570	.0000602	.000117	.000278
.9999682	.9999449	.999844	.9999465	.9999599	.999430	.9999398	.999833	.999722
				P_{A2} = .999253				P_{A3} = 0.999722
				P_{A241} P_{A242} P_{A245} = .999341				



4.3.7.3 Failure Modes and Effects - The fault tree for the Tracking Receiver is shown in Figure 4.3-5. Autotrack is a backup function in the antenna tracking system and its loss does not preclude the reception of High Rate data in the primary clock track mode. The receiver has a mode of failure which is not catastrophic to the overall tracking function. Assuming the primary clock track mode and the tracking receiver DEC error signal has failed, the HA error signal can be used to drive the hour axis.

4.3.7.4 Complexity Estimate - The Tracking Receiver is estimated to have a complexity in the order of 792 piece parts. Figure 4.3-6 is a breakdown of the Tracking Receiver by part type with failure rate contribution.

4.3.7.5 Safety Considerations - No safety considerations are denoted since the voltages are in the 28 Vdc region.

4.3.8 Test - Testing will be conducted as listed in the test matrix of Figure 4.3-7 in accordance with the Integrated Test Plan.

Tests shall be performed prior to canister enclosure, after enclosure prior to final sterilization, after sterilization and during prelaunch operations. All ground testing shall be performed with the use of Operational Support Equipment (OSE). The OSE provides a 2113 MHz test signal to the antenna feed network through the umbilical connector and a hardline. The test signal level at the feed is known from pretest line loss calibration and OSE power monitors. The feed modulates the error channel signals, which are coupled on the same line with the sum channel signal. The composite is supplied to the receivers and the error signal outputs are monitored and compared to input level calibrations. The receiver test matrix is shown in Figure 4.3-7.

4.3.9 Development Requirements - Development requirements for the Tracking Receiver are minimal, since the receiver is a relatively straightforward extension of the Mariner S-Band phase-locked receiver.

TRACKING RECEIVER FAULT TREE

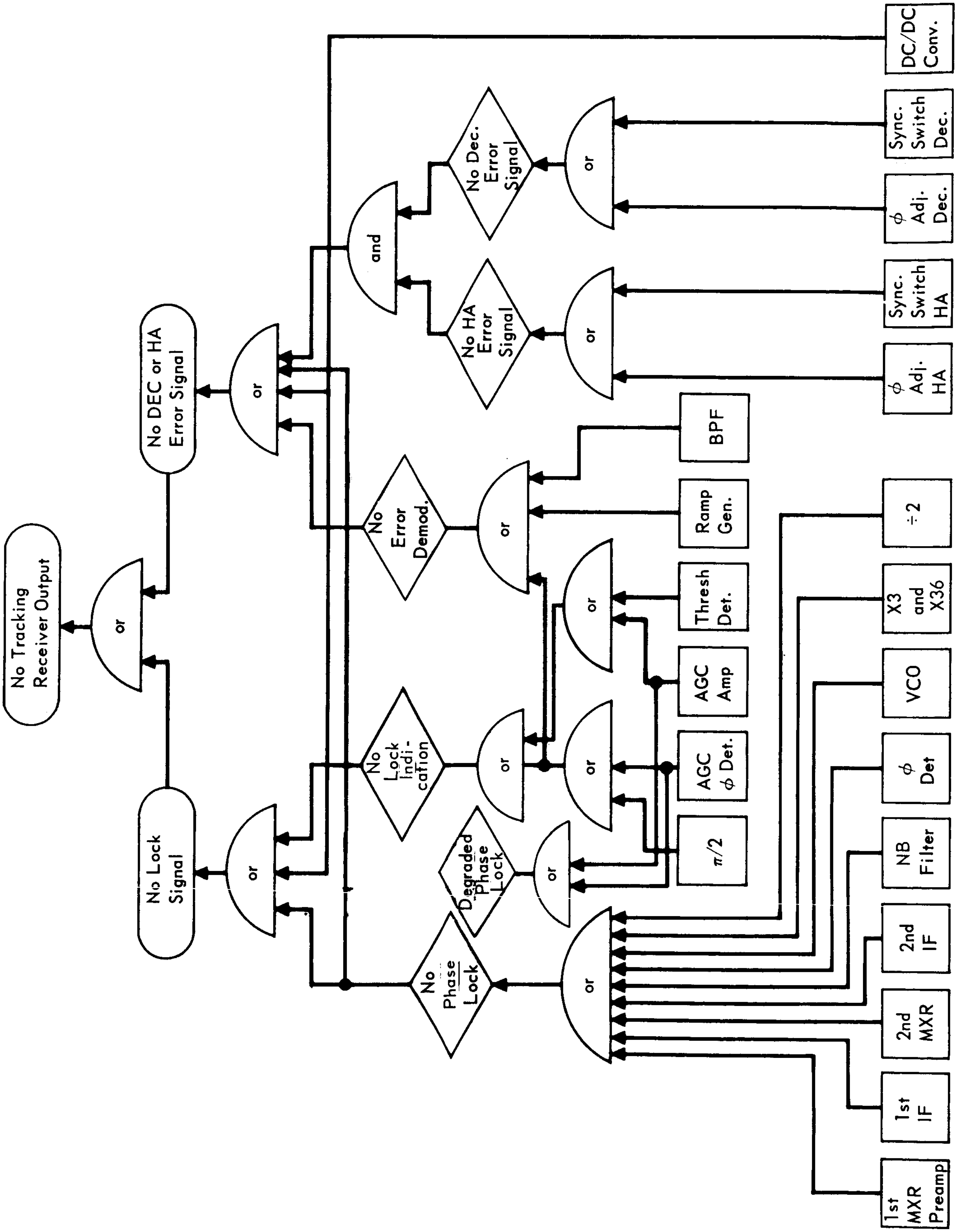


Figure 4.3-5

TRACKING RECEIVER COMPLEXITY ESTIMATE TABLE

PART TYPE	FAILURE RATE F./10^8 HR	QUANTITY	FAILURE CONTRIBUTION
Capacitor, Ceramic/Glass	1	200	200
Capacitor, Variable Piston	10	55	550
Capacitor, Feed Thru	5	22	110
Capacitor, Solid/Tantalum	1	8	8
Capacitor, Standoff	1	7	7
Capacitor, Mylar	0.4	3	1.2
Diode, General Purpose	1.1	19	21
Diode, Zener/Reference	10	11	110
Diode, Mixer	50	4	200
Diode, Varactor	50	1	50
Transistor, General Purpose	5	53	265
Transistor, Power	50	1	50
Resistor, Metal Film	0.3	93	28
Resistor, Carbon Composition	0.1	204	20
Inductor, R.F. Choke	7.5	52	390
Inductor, D.C. Choke	10	5	50
Transformer, Signal	5	42	210
Transformer, Power	50	1	50
Crystal	65	5	325
Crystal Filter	100	1	100
Integrated Circuit	10	5	50
Totals		792	2795

Figure 4.3-6

TRACKING RECEIVER TEST MATRIX

TEST	Non Operative Test	Sensitivity (Threshold)	Local Oscillator Frequency	Mixer Current	Power Supply Voltage	DC Current Drain	Dynamic Range	Bandwidth	Image Rejection	AGC Voltage	Error Channel Outputs (2)
ACCY REQ		1 dB	1 x 10–8	5%	2%	5%	1 dB	5%	1 dB	2%	5%
Telemetry Points										X	X
System Test (Pre-Canister)	X	X	X	X	X	X	X	X	X	X	X
System Test (With Canister)	X			X	X	X	X	X	X	X	X
Pre-Launch	X			X	X	X	X	X	X	X	X

Figure 4.3–7

SECTION 5

ANTENNA SUBSYSTEM

The Antenna Subsystem consists of one high-gain S-band antenna, discussed in Section 5.1 and two low-gain S-band antennas, one for "transmit" and one for "receive", discussed in Section 5.2.

5.1 HIGH GAIN ANTENNA

5.1.1 Equipment Identification and Usage - The High Gain Antenna transmits high data rate information to Earth. To optimize the realized antenna gain, a pseudo conical-scan tracking system is added to point the antenna at Earth. The High Gain Antenna includes the antenna elements, phase comparator, modulators and diplexer portion of the tracking system.

Figure 5.1-1 depicts the functions and major elements of the high gain antenna.

5.1.2 Design Requirements and Constraints - The major design requirements and constraints imposed upon the High Gain Antenna are:

a. Transmit high rate radio RF signal to Earth.
b. Provide a backup antenna pointing system with pseudo conical-scan monopulse tracking.
c. Provide an effective antenna gain of 24.3 dB.
d. Provide capability of being functionally tested before launch
e. Provide for inclusion of elements of the pseudo conical-scan tracking system which must be mounted near the antenna (the phase comparator, the modulator, and the diplexer).

5.1.3 Physical Characteristics - The High Gain Antenna is a 36 inch diameter circular parabolic reflector. The overall distance of the feed from the reflector is approximately 26 inches and the weight of the antenna is about 6.0 pounds. The physical characteristics of the phase comparator, modulator and diplexer are given below:

	Size (in^3)	Weight (lb)
Phase comparator	40	0.3
Modulator	6	0.4
Diplexer	36	1.2

5.1.4 Operation Description - A schematic diagram of the High Gain Antenna appears in Figure 5.1-2.

HIGH GAIN ANTENNA FUNCTIONAL SCHEMATIC

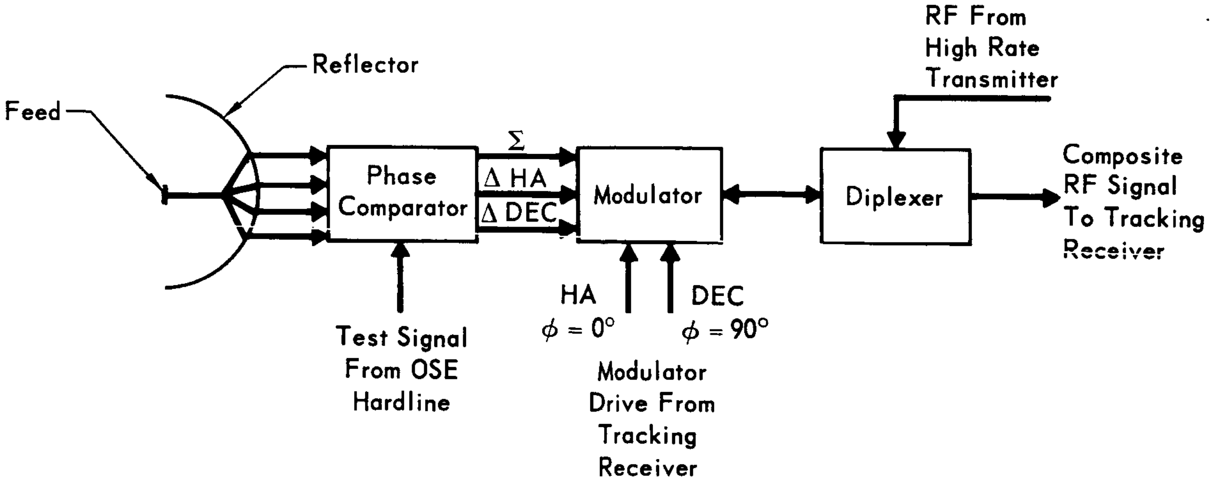


Figure 5.1-1

HIGH GAIN ANTENNA RF SCHEMATIC DIAGRAM

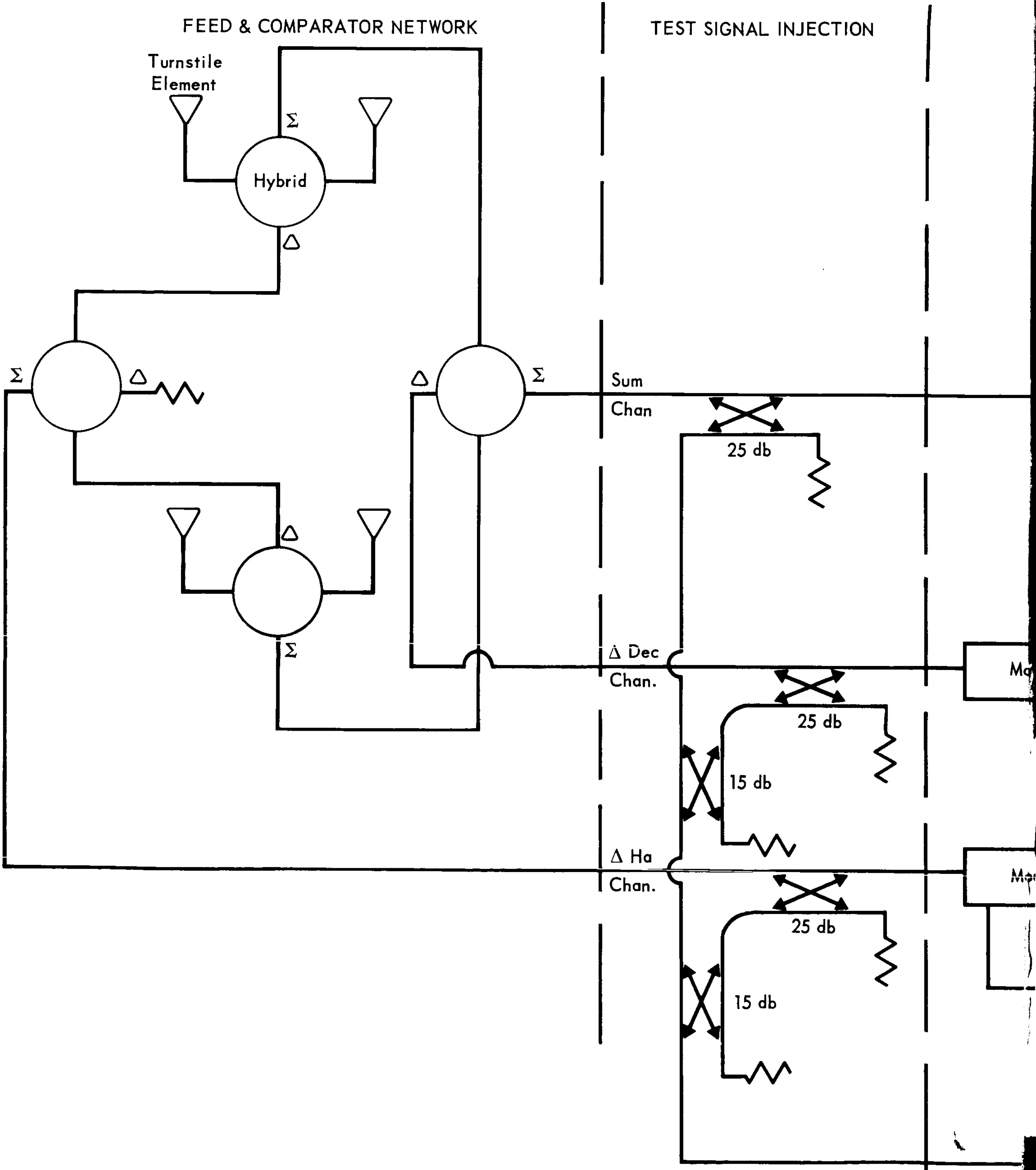
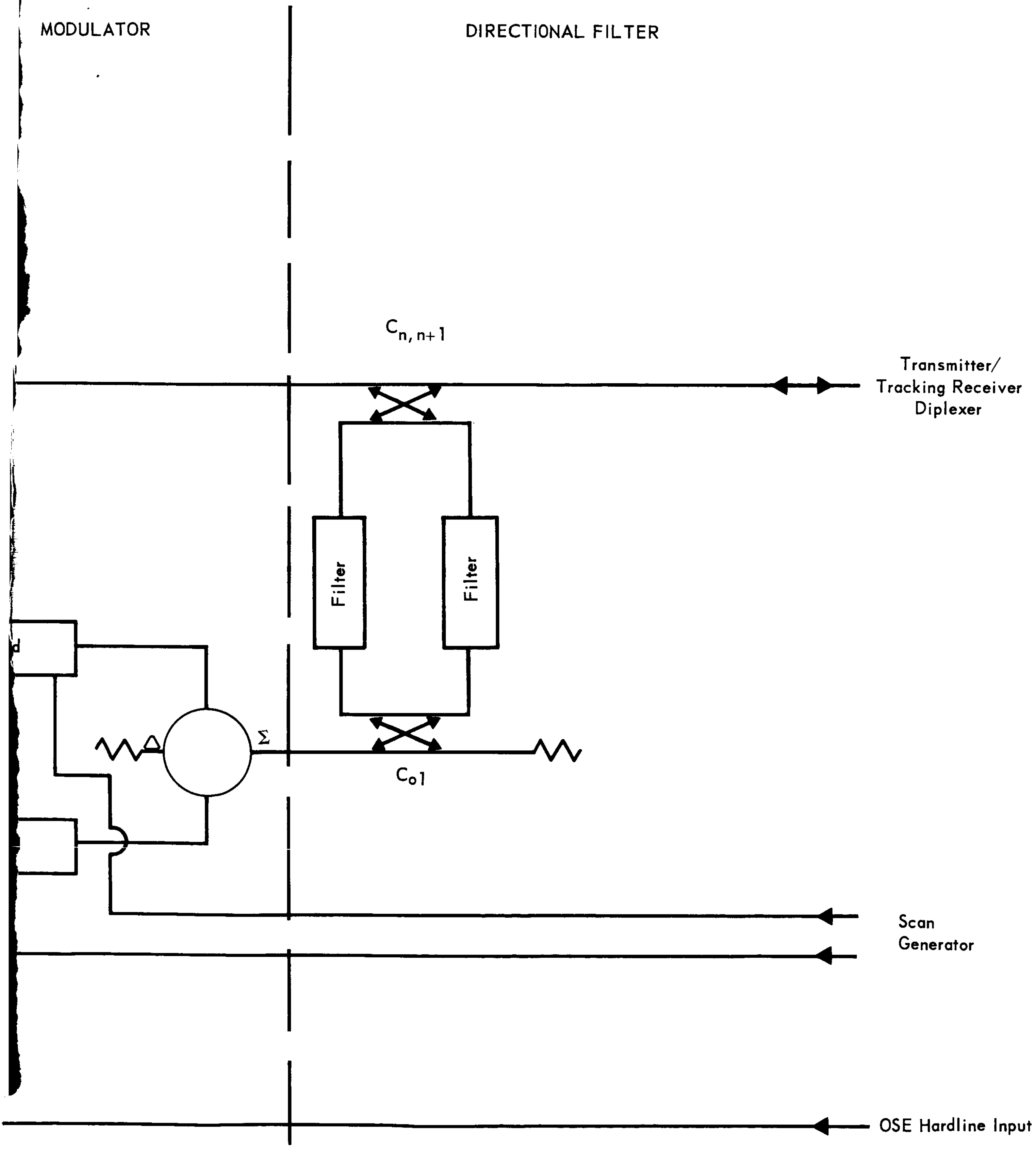


Figure 5.1-2


MODULATOR
DIRECTIONAL FILTER
$C_{n,n+1}$
Transmitter/
Tracking Receiver
Diplexer
Filter
Filter
d
Δ
Σ
C_{o1}
Scan
Generator
OSE Hardline Input

5.1.4.1 Reflector - The antenna reflector is a 36 inch diameter parabolic reflector constructed of plastic honeycomb. The reflecting surface is coated with a thin layer of metallic material. A high temperature resin is used for bonding to meet the sterilization requirements. The honeycomb and dish peripheries are vented.

5.1.4.2 Feed and Comparator Network - The feed consists of four turnstile antenna elements, each similar to Mariner '64 and '69. These elements are mounted inside individual cans to achieve proper illumination of the reflector. The back of the turnstiles is connected to the first of three layers of stripline circuit boards containing the four hybrid comparators. The hybrid comparator operates in the manner of conventional monopulse tracking systems. The comparator output marked "sum channel" represents the main on-axis beam used for transmitting as well as receiving. The Δ DEC and Δ HA channels generate outputs whose amplitudes represent the errors in each axis. The phase of each Δ channel output relative to the sum channel gives the sense, or direction, of the error in that axis.

Test Signal Injection - Two techniques are available for test signal injection; (1) radiation, and (2) hardline connection to the feed network. The second method was selected to eliminate restrictions on RF radiation, and problems with the antenna in stowed configuration. The RF subsystem may be effectively checked out by precisely coupling signals into the sum and error channels, as shown, using directional couplers. This technique provides excellent isolation from the outside environment as the directivity of the couplers provides a signal at the receiver 35 dB above that reaching the antenna. This prevents nearby objects (structure, thermal curtain, etc.) from interferring with the calibration and checkout of the system.

5.1.4.3 Modulator - The modulator consists of PIN diodes shunted across the stripline. When bias is applied to the diodes, they present a low impedance and shunt the energy. By switching the diodes with a square wave signal, they will amplitude modulate the RF signal. Several diodes are placed in parallel to reduce the attenuation and provide additional reliability (losses will be less than 0.6 dB).

The output of the two modulators are summed onto one line with a hybrid.

5.1.4.4 Directional Filter - A directional filter is used to couple the modulated error signal onto the sum line. The error signals are coupled 6 dB down on the sum channel, which represents an equivalent conical-scan crossover of 1.2 dB. The directional filter consists of two directional couplers to couple the energy out of the hybrid onto the sum line. By proper choice of the coupling values C_{o1} and

C_{n}, $_{n + 1}$, -6 dB of the error channel energy is coupled onto the sum channel.

The directional filter uses resonant circuits between the two couplers which are tuned to the receive frequencies. In this manner, the receive energy is coupled through the filter. The transmit energy is rejected by the filter and no energy is coupled off the sum line, hence there is no loss of transmit energy. In addition, this directional filter prevents the transmit energy from reaching the PIN diodes.

5.1.5 Performance Characteristics - The following parameters define the performance of the RF Subsystem.

Frequency

Transmit	2295 MHz
Receive	2113 5/16 MHz

Gain and Pattern - The RF subsystem, together with the reflector dish, will generate a pencil beam of 24.3 dB on-axis gain. For this application, a 36 inch diameter parabolic dish antenna has been chosen.

VSWR - Transmit 1.1:1
- Receive 1.3:1

Axial Ratio - Transmit 1.0 dB
- Receive 2.0 dB

Feed and Line Loss - The total insertion loss between the feed and cables is tabulated below (sum channel only).

Loss	Amount
Feed	0.30 dB
Cable	0.65 dB
Rotary Joint	0.05 dB
Diplexer	0.30 dB
	1.30 dB

Power Handling - 20 watts.

Antenna Scan Rate - The antenna scan rate will be 1 deg/sec (maximum).

5.1.6 Interface Definition - The following connections are required with other subsystems:

Interface	
o Antenna Mounting and Control Equipment	Mechanical Bolt Circle
o RF Signal to Tracking Receiver with Errors AM Modulated	One S-Band 50 ohm RF Connector
o Transmitter Input	One S-Band 50 ohm RF Connector
o Modulator Drive Input	Two Audio Connections, ± 5 Vdc
o OSE Hardline Input	One OSM 50 ohm Connector, -60 dBm Command Signal

5.1.7 Reliability and Safety Considerations - The following paragraphs describe the reliability and safety considerations relating to the High Gain Antenna.

5.1.7.1 Mission Success Definition - The High Gain Antenna (HGA) is required to transmit an S-Band RF carrier, receive an S-Band carrier from Earth and process the received carrier for error signal presentation to the Tracking Receiver. The HGA must survive Launch, Interplanetary Cruise, Entry Descent and Landing environments in a dormant non-operating equipment mode. The antenna must operate successfully in the transmit mode from post-landing turn-on to mission termination with a 25% duty cycle. The receive mode of operation (Monopulse Tracking) is a functional backup redundancy to the primary clock track mode of operation and is also used to augment and improve the clock track antenna pointing accuracy.

5.1.7.2 Reliability Estimate - The estimated reliability for the HGA is .9992. The majority of the HGA elements are passive throughout the mission. The PIN diode modulators are the only active electrical elements and redundancy is provided.

5.1.7.3 Qualitative Analysis - The long duration, non-operating mission environments and sterilization will influence the HGA reliability as compared to the relatively short operating time. Test of the antenna system exclusive of the feed elements and comparator elements will be conducted following sterilization by hardline connection to assure proper operation. The landed low temperature extreme is a concern which requires localized thermal control for elements such as PIN diode modulators.

The more critical part applications are in the rotary joint, flex cable and coax cable system. Specifically designed cables and connectors will be used to eliminate stiffness, brittleness, and contraction of the center conductors in the extreme temperature environment. These environmental effects are minimized by using plated invar and teflon dielectric. The rotary joint has received special emphasis in the design. The relatively slow scan and track rates and small number of tracking sweep cycles permit the use of such materials as teflon for sliding surfaces. The fault tree for the HGA is shown in Figure 5.1-3.

Antenna radiation in a Mars atmosphere and potential RF breakdown problems have been analyzed and tests conducted. The antenna design reflects consideration of the possible spectrum of atmospheres and constituents. Adequate design margin exists to preclude antenna RF breakdown and loss of the High Rate Radio Link.

Potential HGA mechanical damage mechanisms have been considered and minimized. The antenna is in a stowed position until post-landing operations begin. Limited High Rate Radio Link operation is possible in the slowed position if an antenna erection problem should occur. To minimize imparting damage to the antenna and feed elements, features such as ejecting the Entry Science Package TV cameras prior to landing are incorporated. This eliminates the possibility of camera penetration of and damage to SL equipments.

5.1.7.4 Safety Considerations - Due to the low voltages, in the region of 28 Vdc, no special safety considerations are indicated for the High Gain Antenna.

5.1.8 Test - In order to effectively check out the High Gain Antenna equipment, it is necessary to simulate a known pointing error with a known signal level and monitor the error outputs of the Tracking Receiver. In order to accomplish this in the stowed state inside the metal sterilization canister, it is necessary to devise a system that is insensitive to problems of RF radiation and reflection. Only in this manner will the results be consistent and predictable. For this reason, a test RF signal injection network is incorporated into the feed. Precise signals are injected into the sum and error channels of the feed representing a known pointing error. These signals are obtained from OSE hardline input and are injected by means of directional couplers. By monitoring the Tracking Receiver AGC and the error channel outputs, the complete RF subsystem can be checked out excluding the feed elements and comparator network.

The omission of the feed elements and comparator network (all passive devices) from the test loop is insignificant compared to the advantages of precisely calibrating the active part of the system. From the time the complete RF system is installed, the test loop can be used to calibrate the system. Any changes incurred during the sterilization and pre-flight testing can be noted. This type of accuracy can only be obtained in a closed testing system. The test error signals from the

HIGH GAIN ANTENNA FAULT TREE

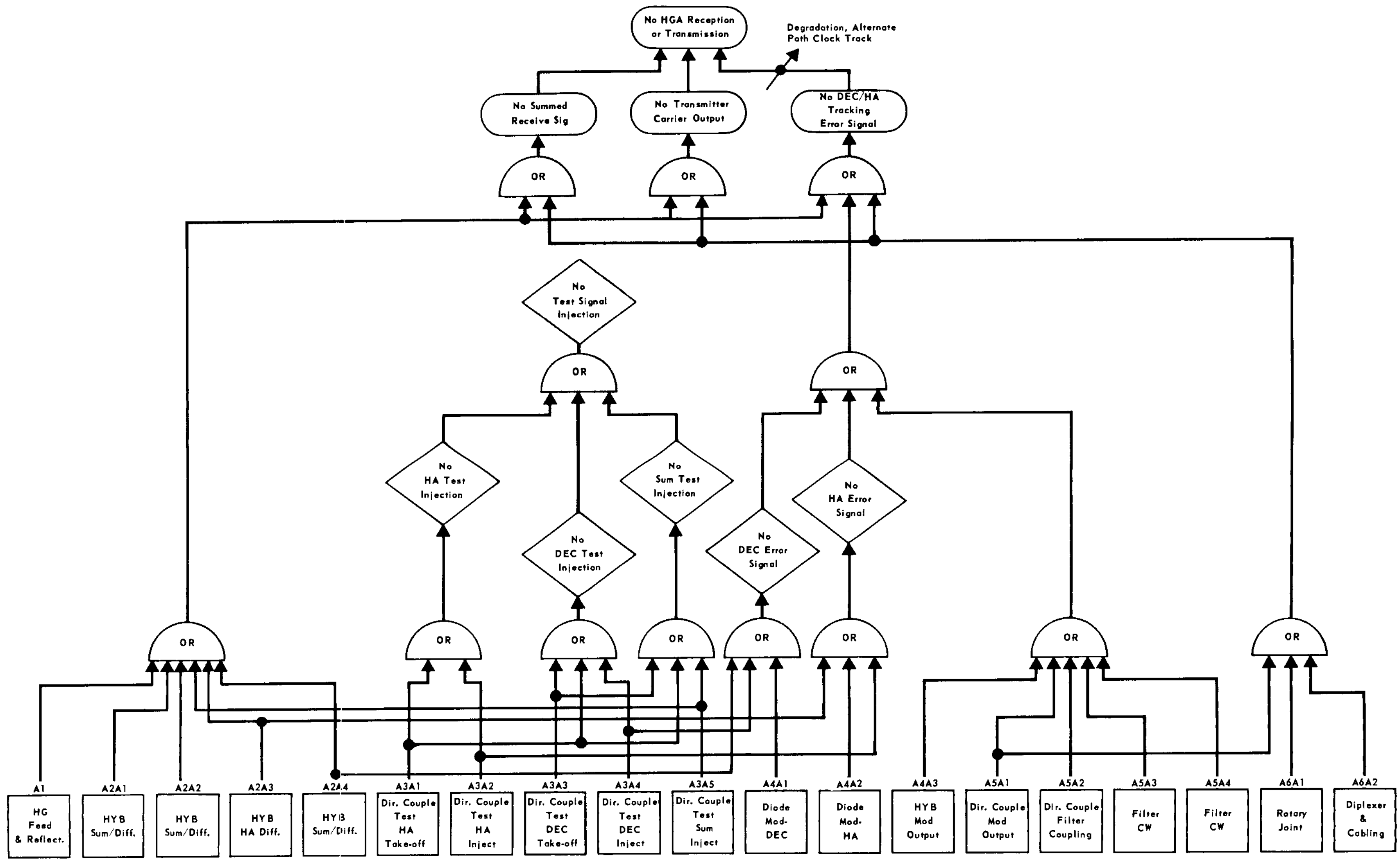


Figure 5.1-3

receiver can be used to further check out the Control Subsystem.

5.1.9 Development Requirements - All items in the feed system can be developed within the present state-of-the-art. The circuit techniques and component designs are well known. The PIN diode switches must be qualified for the Mars environment. Special techniques may be required to limit the temperature excursion. This area warrants additional study to determine the reliability of the switches.

The flexible coax will also require development, which is within the present state-of-the-art, to be capable of operating at -123°C. The possibility of excessive stiffness, brittleness, and thermal contraction will have to be ascertained.

5.2 LOW GAIN ANTENNAS - The Low Gain S-Band Antennas support transmission of data from the SLS Low Rate Radio to the DSN, and reception of commands from the DSN to the SLS Command Receiver. The antennas will be operable from landing until mission termination.

5.2.1 Equipment Identification and Usage - Two identical antennas are used, as shown in Figure 5.2-1.

- Low Gain S-Band Transmitting Antenna - The transmitting antenna radiates five watts of RF power from the SLS Low Rate Radio to the DSN.
- Low Gain S-Band Receiving Antenna - S-band radiation from the DSN to the SLS is captured by the receiving antenna and transferred to the SLS Command Receiver.

5.2.2 Design Requirements and Constraints - The antennas must be RHC polarized for compatibility with the DSN equipment. An unobstructed ±60° field of view around the -Z axis of the Capsule Lander is required to accommodate relative Earth motion and possible attitudes of the CL after landing. The antenna patterns are symmetrical about the -Z axis.

5.2.3 Physical Characteristics - The antennas are RHC polarized, cavity backed Archimedes spirals, located on a common mast as shown in Figure 5.2-2. Each antenna is 5.2 inches in diameter and 1.4 inches deep, with a volume of 30 cubic inches. Weight is one pound per antenna.

5.2.4 Performance Characteristics - A cavity backed spiral antenna pattern is shown in Figure 5.2-3. The beamwidth is approximately 70 degrees in each principal plane. Axial ratio is less than 1.5 dB on axis. Peak gain is approximately 8 dB above circular isotropic. The pattern shown is for a one-quarter scale antenna. The full scale transmitting antenna operates at 2292 MHz. The receiving antenna operates at 2117 MHz.

5.2.5 Reliability - Each antenna presents a single point failure mode in the associated transmission path. However, a functional backup for the low gain transmitting antenna exists in the SLS high gain S-band antenna. All data transmitted from the low gain antenna is also transmitted from the high gain antenna. The low gain S-band receiving antenna is included as part of a backup command subsystem which includes provisions for Earth override of the SLS Sequencer and Timer. The primary failure mechanisms for the antennas are the results of physical damage to the connectors, feed points or elements, which would probably occur during pre-installation or installation handling, and would be evident upon visual inspection or testing before sterilization.

Figure 5.2-1

LOW GAIN ANTENNA BLOCK DIAGRAM

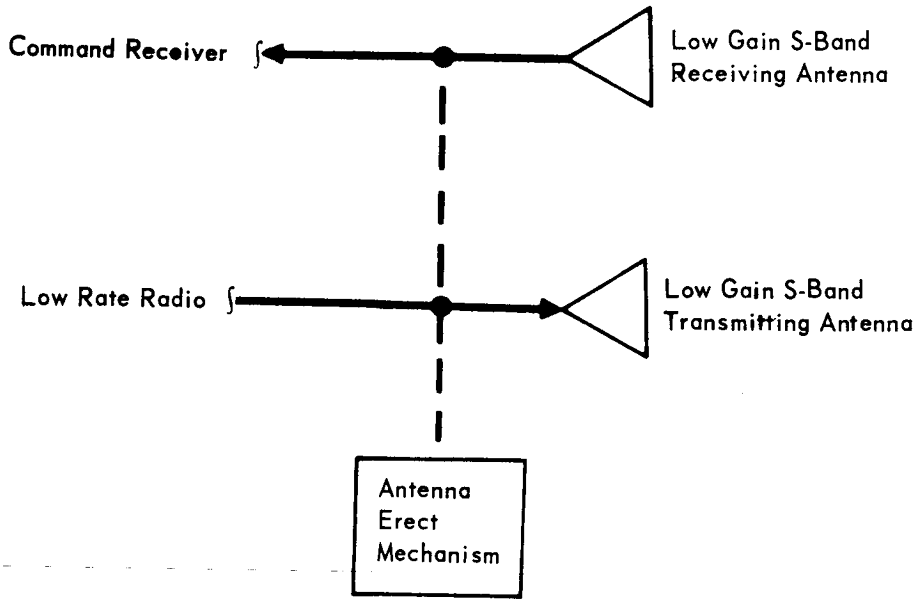


Figure 5.2-1

LOCATION OF LOW GAIN ANTENNAS

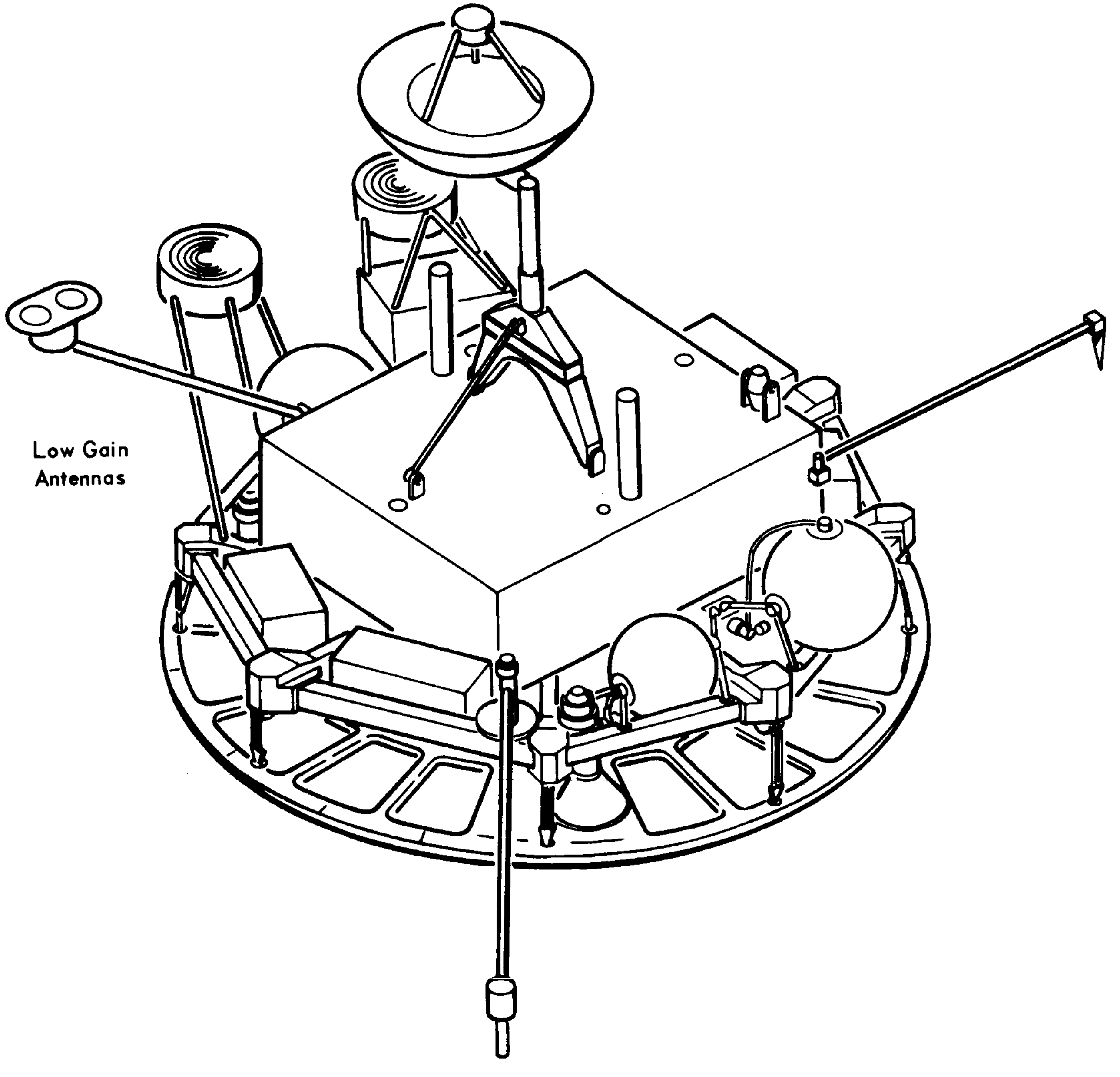


Figure 5.2-2

LOW GAIN ANTENNA PATTERN
(1/4 SCALE)

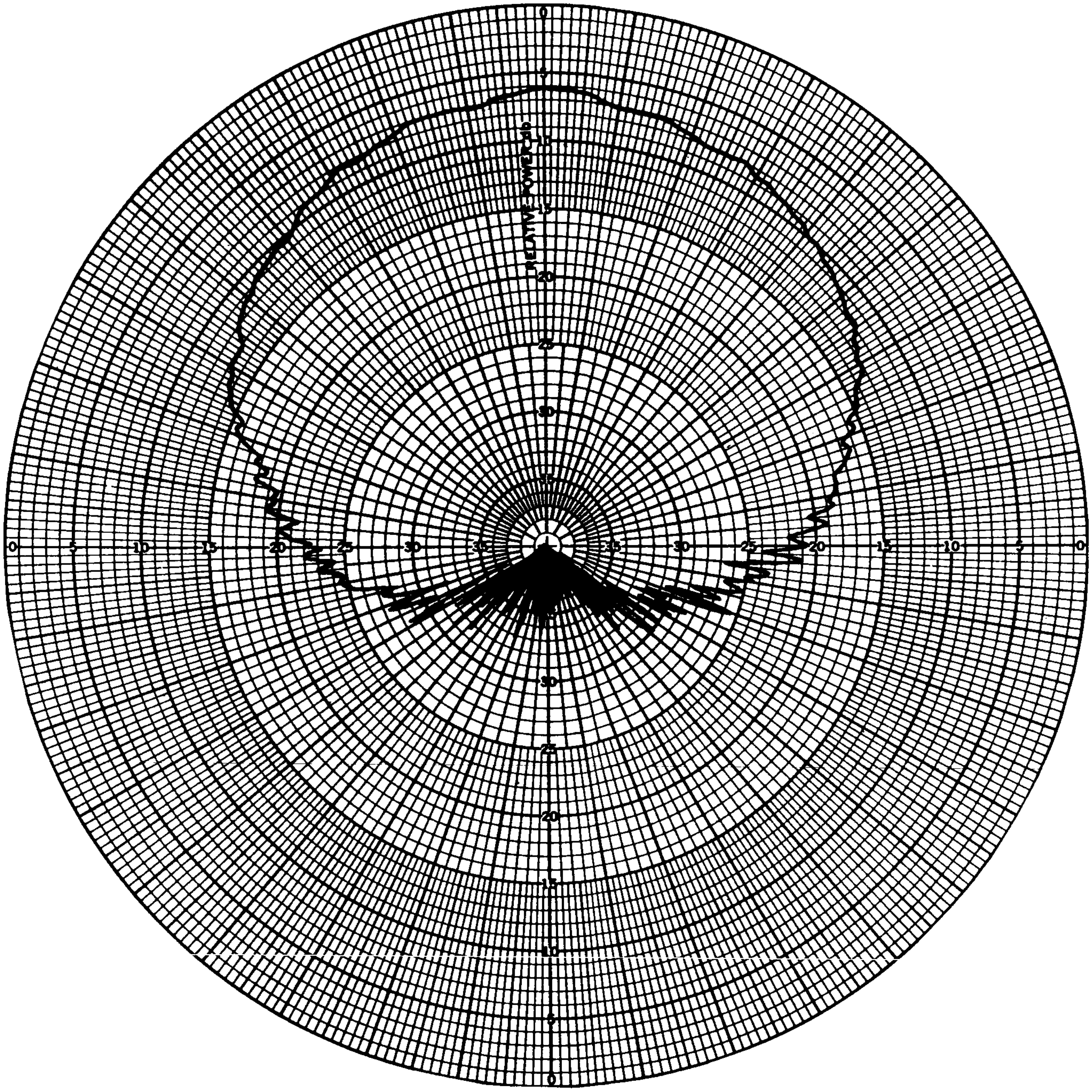


Figure 5.2-3

5.2.6 Test - The Low Gain S-Band Antennas will be tested for pattern coverage and gain after delivery. During subsystem testing the antenna impedance characteristics will be measured after life cycling.

5.2.7 Development Requirements - Antennas with the required characteristics are available.

SECTION 6

COMMAND SUBSYSTEM

6.1 EQUIPMENT IDENTIFICATION AND USAGE - The Command Subsystem for the VOYAGER Surface Laboratory (SL) provides for detection and execution of commands in two modes of operation. During all mission phases prior to Capsule Bus (CB) separation, the Command Subsystem receives commands from the Spacecraft (SC) Command Subsystem. After landing, the Command Subsystem receives commands via the SL Radio Subsystem.

During interplanetary cruise, the Command Subsystem will be employed to activate test sequences and perform related switching functions for the purpose of telemetering performance data on various equipments within the SL.

In Mars orbit prior to separation, the SL Command Subsystem will be used to make any changes to the in-flight testing program that result from Earth analysis of telemetry data. It will also be used to finalize SL programs in readying the SL for landed operations.

After landing, the subsystem will be used as a backup to the Sequencer And Timer and provide Earth with a control link.

6.2 DESIGN REQUIREMENTS AND CONSTRAINTS - To achieve a bit error probability in the command detector of 10^{-5} at receiver threshold, a two channel detector using PN sync modulation is employed.

To achieve a valid command message rejection probability of less than 10^{-4} and an acceptably small probability of accepting an erroneous command, an error-correction capability of one bit for each command message is provided. Also, the in-lock bias is changed so that the probability of out-of-lock indications at threshold is approximately 1/400th of that obtained with the in-lock bias setting employed on Mariner C.

The error-correction feature requires word synchronization of the command message. The method used to accomplish word synchronization consists of sending a 4-bit message preamble (all "ones"). To accomplish word synchronization in this manner, the proper ratio of data subcarrier power to synchronization subcarrier power must be maintained and the data modulation must consist of a steady sequence of zeroes up to the time at which the preamble and subsequent command word are transmitted.

The optimum error-correcting code in terms of equipment weight and power is the Bose-Chaudhuri (63, 57) code. Using this code, the probability of accepting an erroneous command is less than 2×10^{-7}.

6.3 PHYSICAL CHARACTERISTICS - Module construction features include digital networks packages on stacked, printed circuit substrates. The remainder of the circuitry is packaged in welded cordwood modules. Interconnections to the individual modules of the package are via a multiple-layer, printed motherboard. The assembly weighs 2.1 lbs., occupies 35 cubic inches, and draws 2.5 watts for 64 seconds for each command decoded.

6.4 OPERATION DESCRIPTION - A functional diagram of the Command Subsystem operations is given in Figure 6-1. This diagram shows the operational sequences which occur in the processing of a command whether the command is received via the SC Command Subsystem or the SL Radio Subsystem.

The equipment block diagram, Figure 6-2, shows the relationship of the subsystem elements.

The command detector and error-correction networks provide a command message to the command register for decoding when the SL is operating via the SL Radio Subsystem. During cruise and orbit, the command messages are presented directly to the command register via hardline inputs from the SC Command Subsystem.

Power to the decoder, command register and error correction networks is switched on when an in-lock indication occurs. Decoder power is turned off by either a loss of detector lock (either the SL or the SC command detector) or the condition of not having two adjacent commands.

Subsystem self-check is provided by the test generator which utilizes signals from the SL test programmer and the command detector itself.

The command detector shown in Figure 6-3 detects PCM data and bit synchronization signals from the PSK baseband signal which is received from the Radio Subsystem. The transmitter signal utilized in the command detector link is the summation of a synchronization signal PN + $2\ f_s$ and a data signal $\pm \cos (2\pi\, 2\, f_s t)$. The amplitude spectrum of this signal is shown in Figure 6-4. For simplicity, the synchronization signal spectrum is shown as a continuous spectrum rather than a line spectrum with lines separated by 1 Hertz. In addition, the data spectrum, shown as a line, is actually the spectrum of a $2\ f_s$ sine wave bi-phase modulated by a PCM data signal having bit periods of one second duration.

The data detection process, illustrated in Figure 6-5, begins with the selection of the data spectrum from the received spectrum with a $2\ f_s$ bandpass filter. The filtered signal is then multiplied by $2\ f_s \angle 90^\circ$. This results in a full-wave rectified sine wave the d-c component of which is negative for $-\cos 2\pi\, 2f_s t$ (a "1" data bit) and is positive for $+\cos 2\pi\, 2f_s t$ (a "0" data bit). Reconstruction

COMMAND SYBSYSTEM FUNCTIONAL DIAGRAM

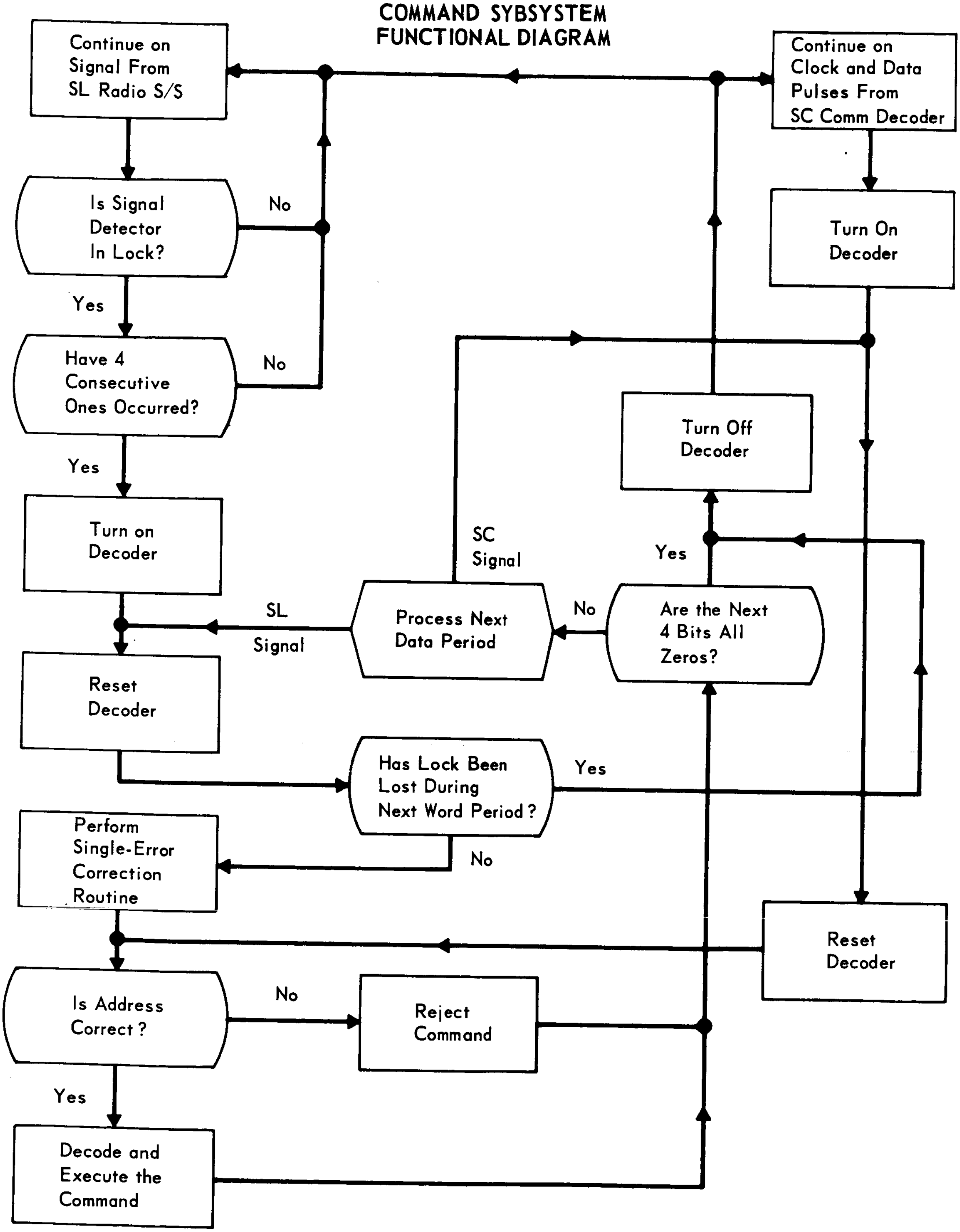


Figure 6-1

COMMAND SUBSYSTEM
SCHEMATIC BLOCK DIAGRAM

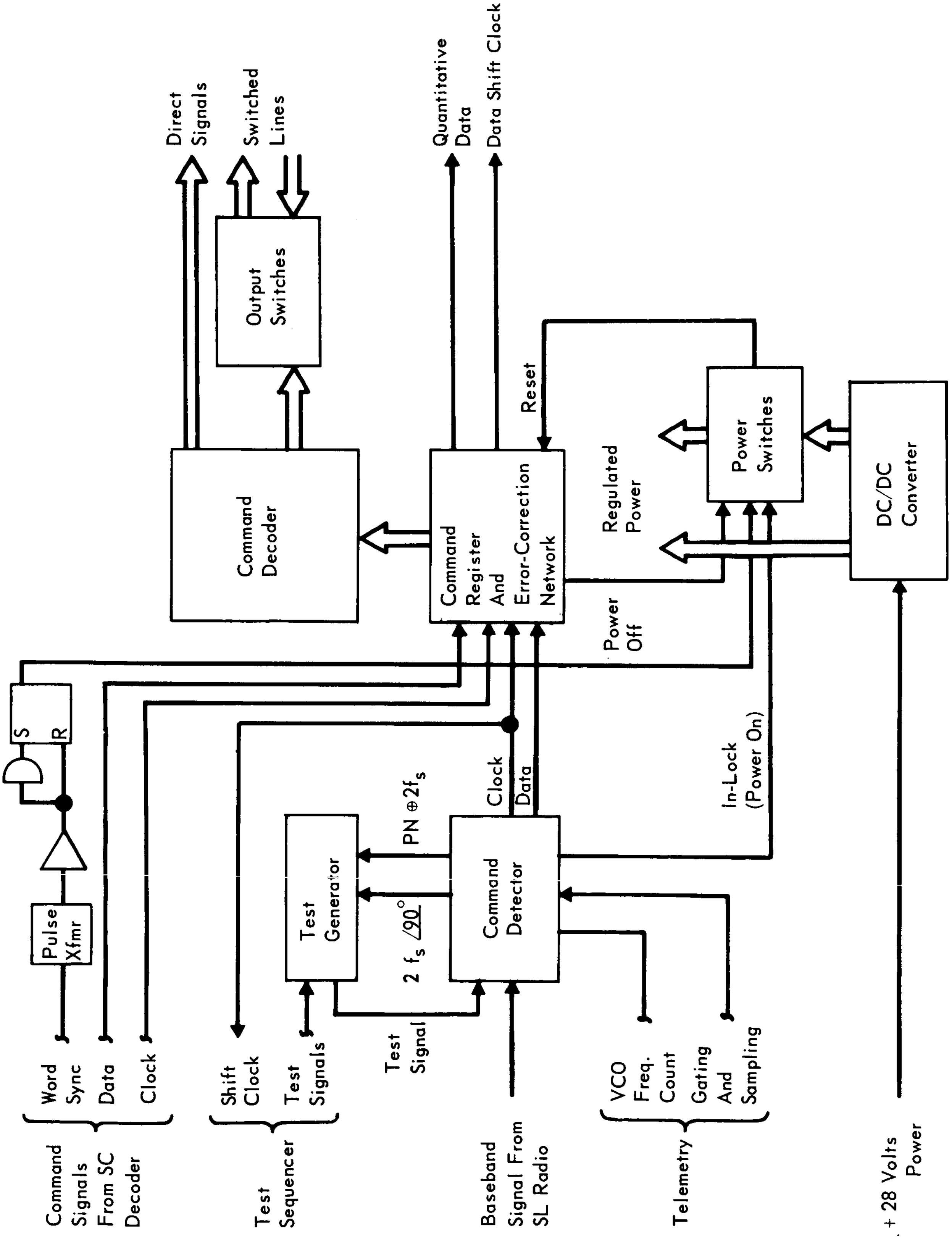


Figure 6-2

COMMAND DETECTOR SCHEMATIC DIAGRAM

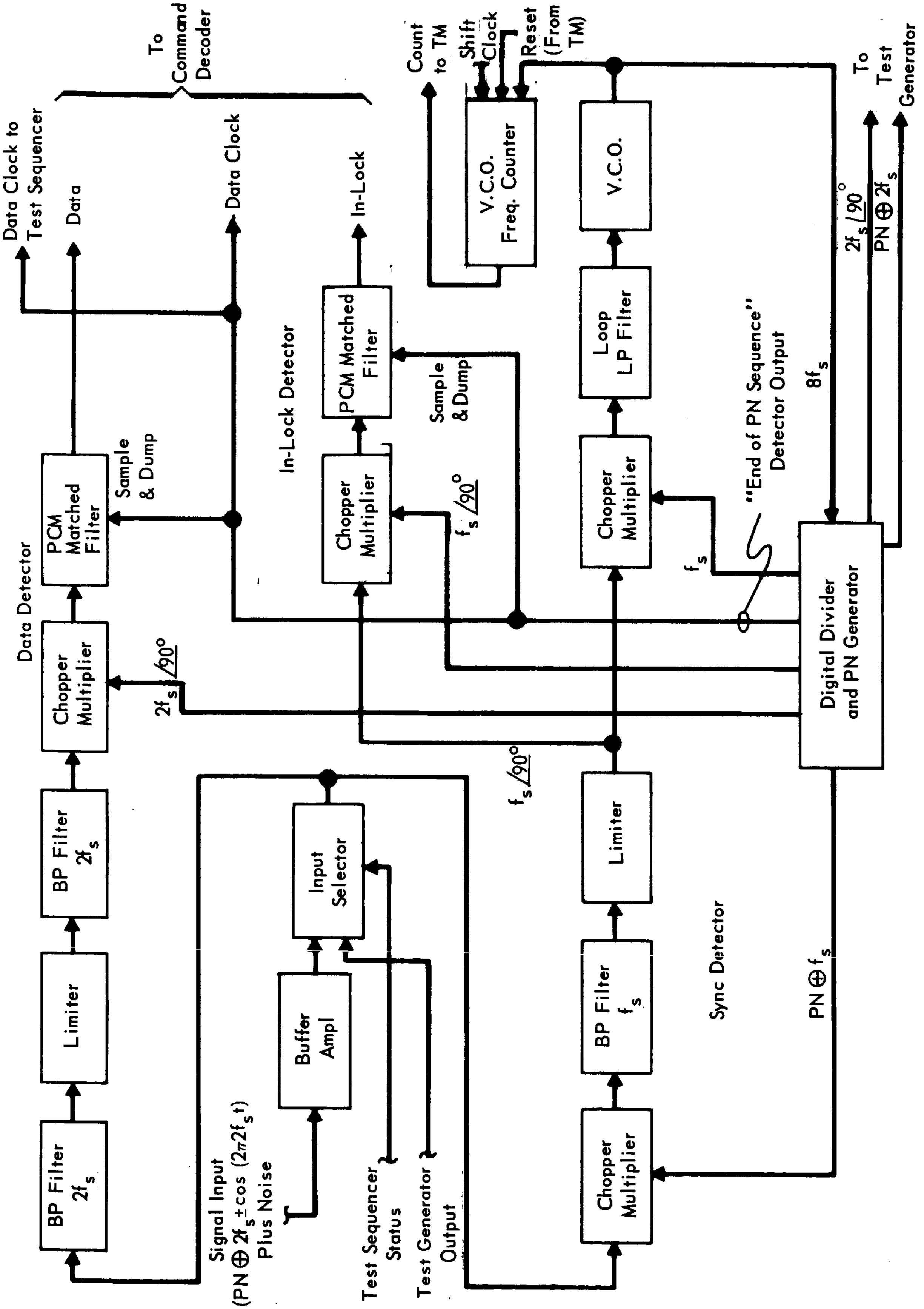


Figure 6-3

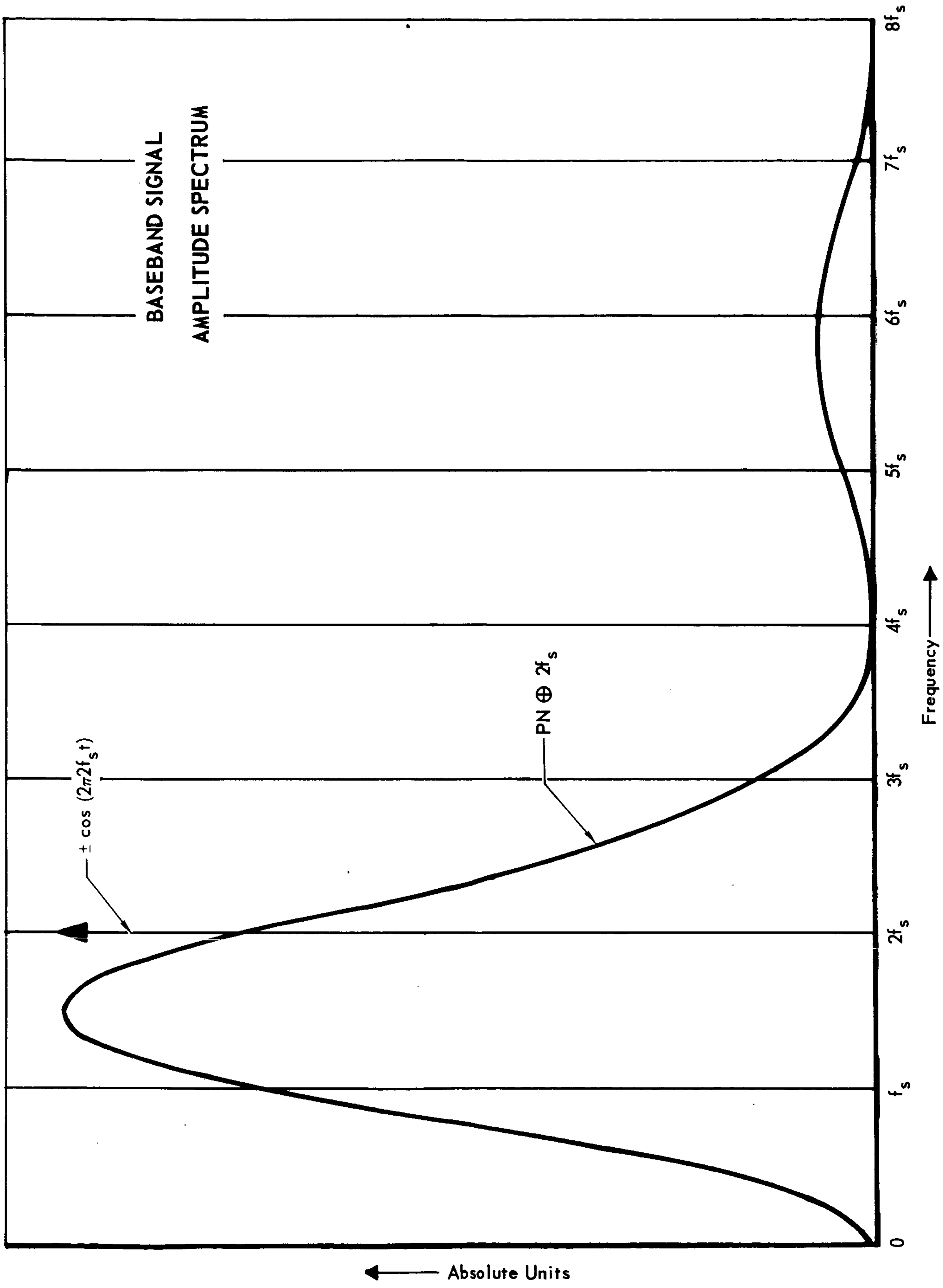
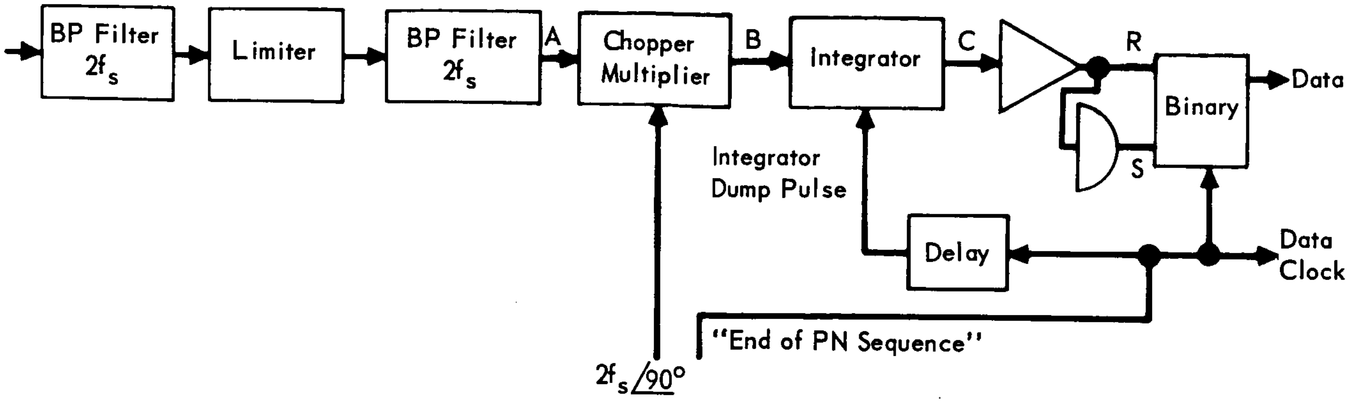
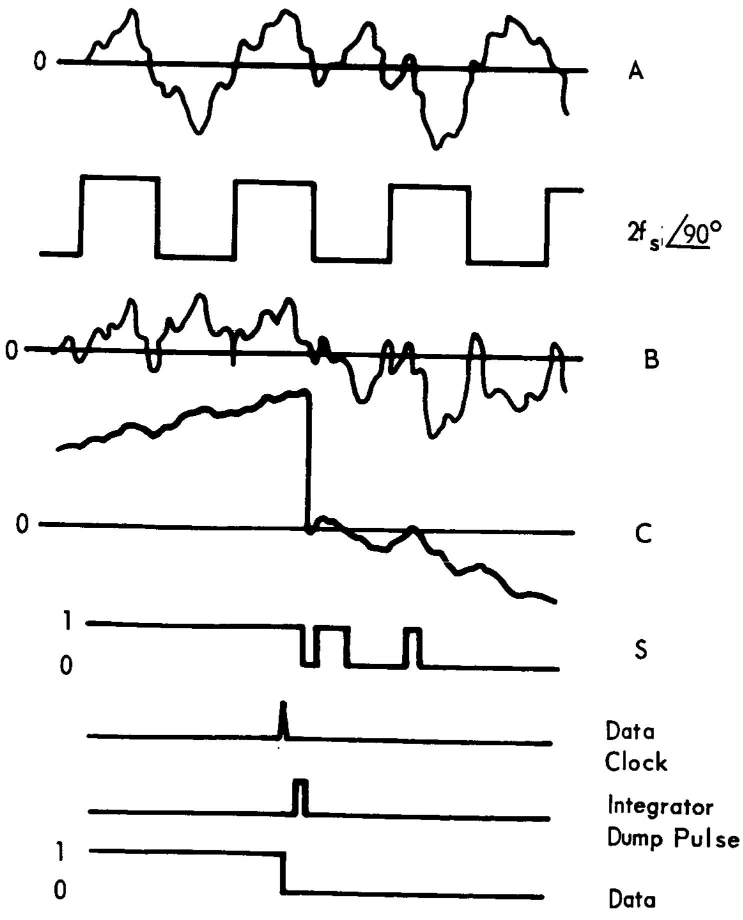

BASEBAND SIGNAL
AMPLITUDE SPECTRUM
± cos (2π2f_s t)
PN ⊕ 2f_s
Absolute Units
Frequency
0
f_s
2f_s
3f_s
4f_s
5f_s
6f_s
7f_s
8f_s

Figure 6–4

DATA DETECTOR



Data Detector Waveforms



DATA DETECTION PROCESS

Figure 6-5

of the NRZ square wave is completed by integrating this signal, sampling the integrated signals at the conclusion of each data bit interval and using the sign of the resultant sample to reconstruct each data bit.

Synchronization for the data recovery process is obtained by means of a phase-locked loop which becomes locked when the received PN sequence is in phase with the internally-generated PN sequence. The two PN sequences are multiplied together in the chopper multiplier. The output is passed through an f_s bandpass filter and limiter. When the PN sequences are in phase the limiter output is $f_s \underline{/90^\circ}$. This signal is multiplied with f_s in the phase locked loop chopper multiplier to develop an error for the local VCO. Lock-on is obtained by initially setting the sync frequency, f_s, at the DSIF to be approximately 1 Hz greater (or less than) the SL sync frequency. With this out of phase condition an error signal developed as just described above will keep the VCO at some frequency different from f_s until the PN sequences are in phase. The PN code autocorrelation function peak occurs within 2 bit intervals to an amplitude of (say) 1. All other peaks in the autocorrelation function have an amplitude of less than $1/f_s$ (Hz). Hence, the two versions of PN provide an autocorrelation peak at the output of the input chopper multiplier which exists for approximately 2 seconds. Since the loop filter time constant is approximately 0.5 seconds, the error signal to the VCO exists for a sufficient long time to achieve lock-on.

The in-lock detector also utilizes the f_s band pass filter and limiter output (i.e. $f_s \underline{/90^\circ}$ when in-lock and random when out-of-lock). This output is multiplied with $f_s \underline{/90^\circ}$ (derived from the local VCO) in a chopper multiplier. The chopper multiplier output is sampled and dumped every bit time and will indicate an out-of-lock condition when the phase difference between the DSIF f_s and the local VCO f_s is too great.

To eliminate the static phase error that will exist between the DSIF f_s and the local VCO f_s as a result of the lock-up procedure, the VCO frequency is telemetered to Earth.

A precision gated counter is employed as the VCO frequency counter. The counter is gated and sampled periodically by the SL Telemetry Subsystem.

The detected data, data clock and in-lock indications are then processed to decode the command. Command word processing begins when the 4-bit preamble is detected. At such time, the entire command decoder is switched on by applying power via the power switches. In addition, as power is switched on, all registers and counters in the decoder are reset. The entire command word (see the command word format, Figure 6-6) is then shifted into the 63-bit register shown in the diagram of Figure 6-7. The timing for this operation and all decoding operations which follow is shown in the timing diagram of Figure 6-8.

Following the input shifting operation via the command detector clock signal, error correction is performed (see also Figure 6-1, Command Subsystem Functional Diagram). The error correction routine corrects all possible single bit errors. This routine consists of performing two end-around shifts of the 63-bit command word. During the first shift, gate A (Figure 6-7) is open and gate B is closed. The end-around shift is via the input shift register gate G_5. Following this, gate B is open and gate A is closed, and the end-around shift is via the input gate G_4. This completes the error correction routine.

Shift timing for both the error-correction operation and the outputting of the 32 bits of quantitative data is provided by the 10 KHz clock generator.

When operating on commands from the SC command decoder, the 63-bit shift register is loaded with the 43 data bits only (bits 1 through 43, Figure 6-6). No error correction is performed, the error correction having been performed by the SC command decoder prior to transfer.

Command decoding operations are performed by decoding bits 1 through 43 of the shift register contents. The command decoding and execution circuits are indicated in the block diagram of Figure 6-9.

Quantitative data (bits 12 through 43) is shifted out from left to right. Pulse transformers are used for quantitative command transfer.

Direct commands are executed by magnetic latching relays.

A block diagram of the test generator is given in Figure 6-10. The circuits are identical to circuits in the command detector of the same name.

When activated by the SL test sequencer, the test generator drives the command detector input with a signal identical to the original PSK signal generated at the DSIF. Data modulation is furnished via a stored command word in the test sequencer.

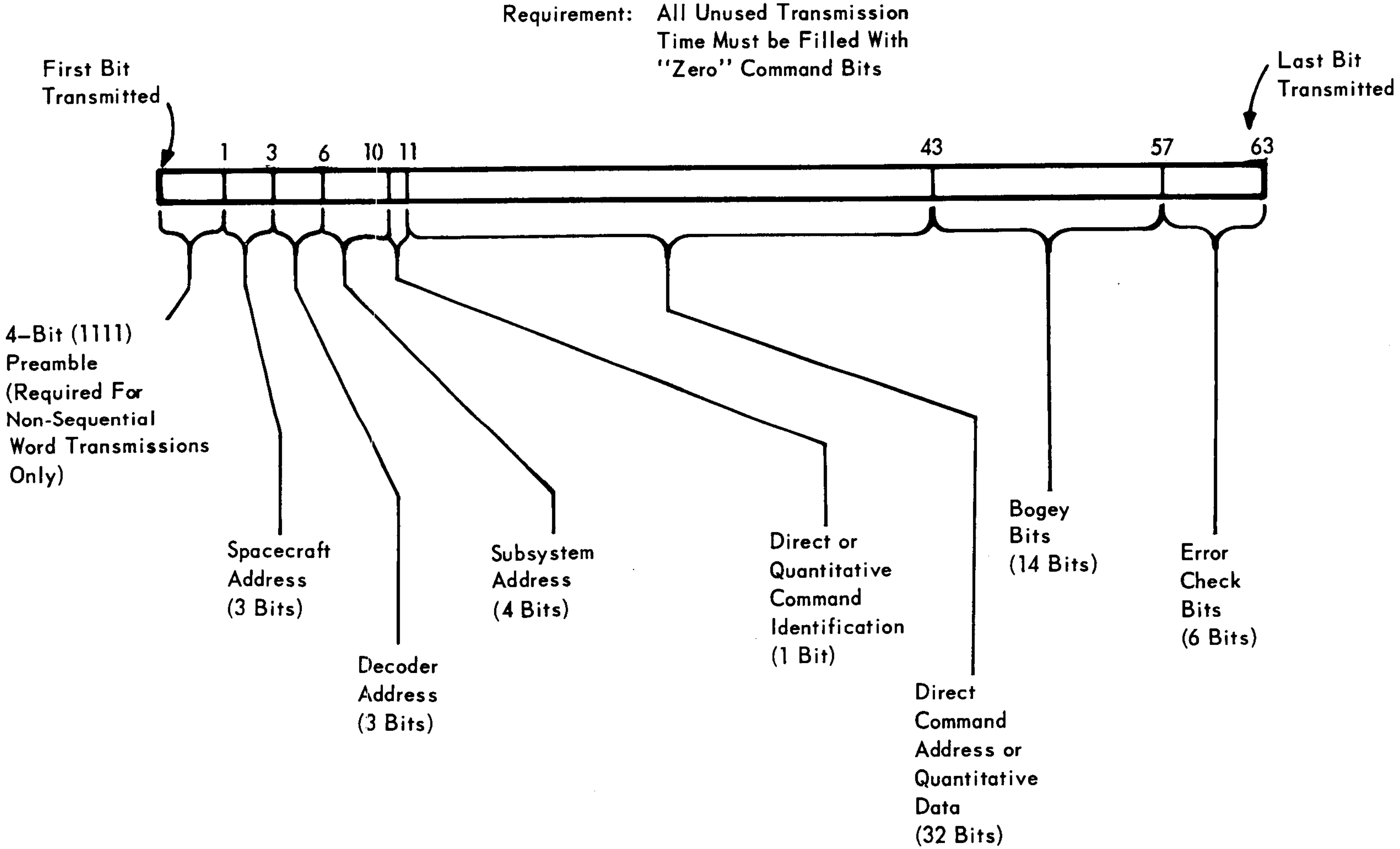
Lock is guaranteed by the fact that the PN code is multiplying itself with zero phase shift.

6.5 PERFORMANCE CHARACTERISTICS - A summary of the SL Command Subsystem performance is given below.

a. Bit error probability at threshold $<10^{-5}$

b. Out-of-lock indication probability at threshold $<9 \times 10^{-7}$.

COMMAND WORD FORMAT



Requirement: All Unused Transmission Time Must be Filled With "Zero" Command Bits

Figure 6-6

COMMAND REGISTER AND ERROR CORRECTION LOGIC NETWORK

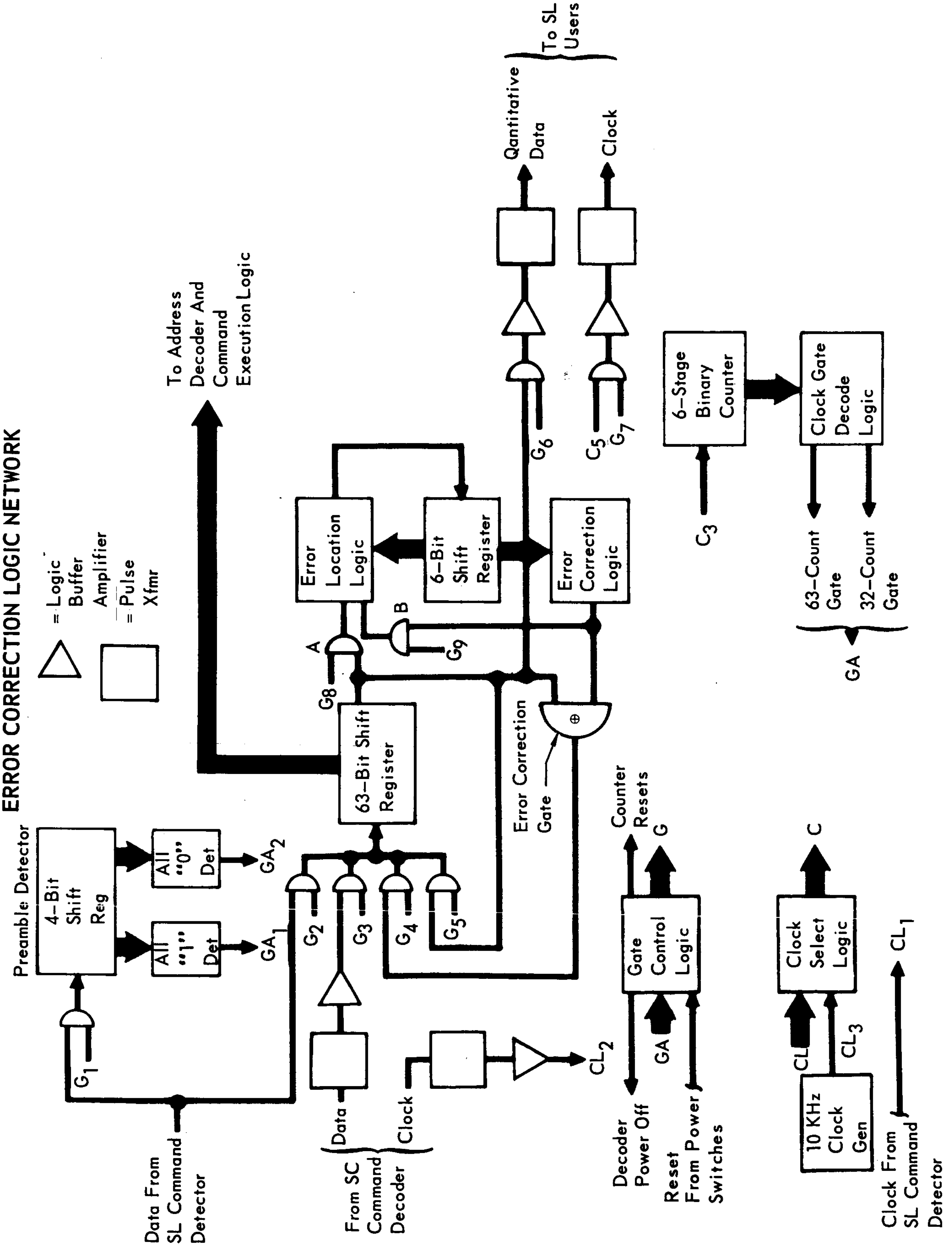


Figure 6-7

COMMAND DECODER TIMING DIAGRAM

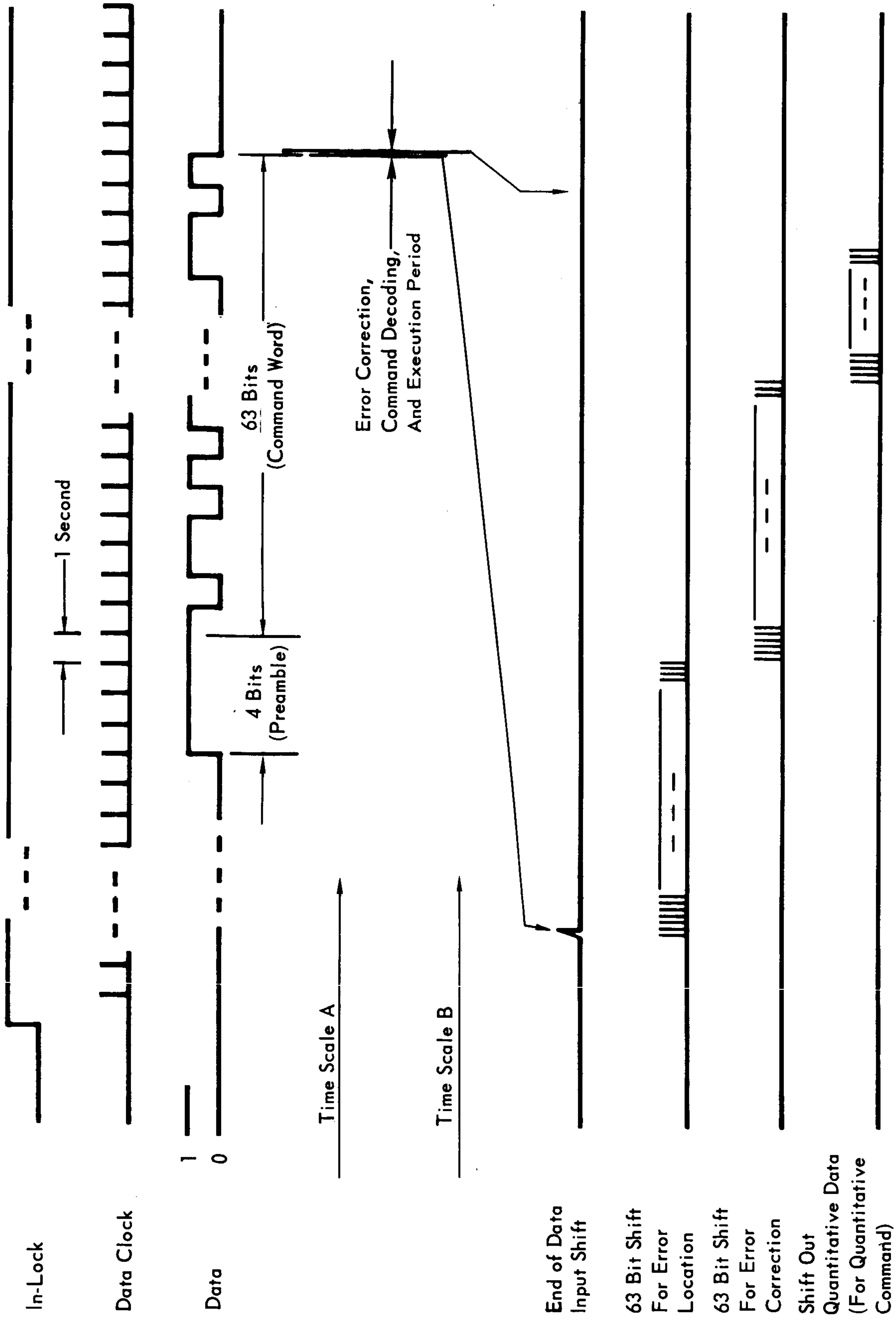


Figure 6-8

COMMAND DECODING AND EXECUTION LOGIC DIAGRAM

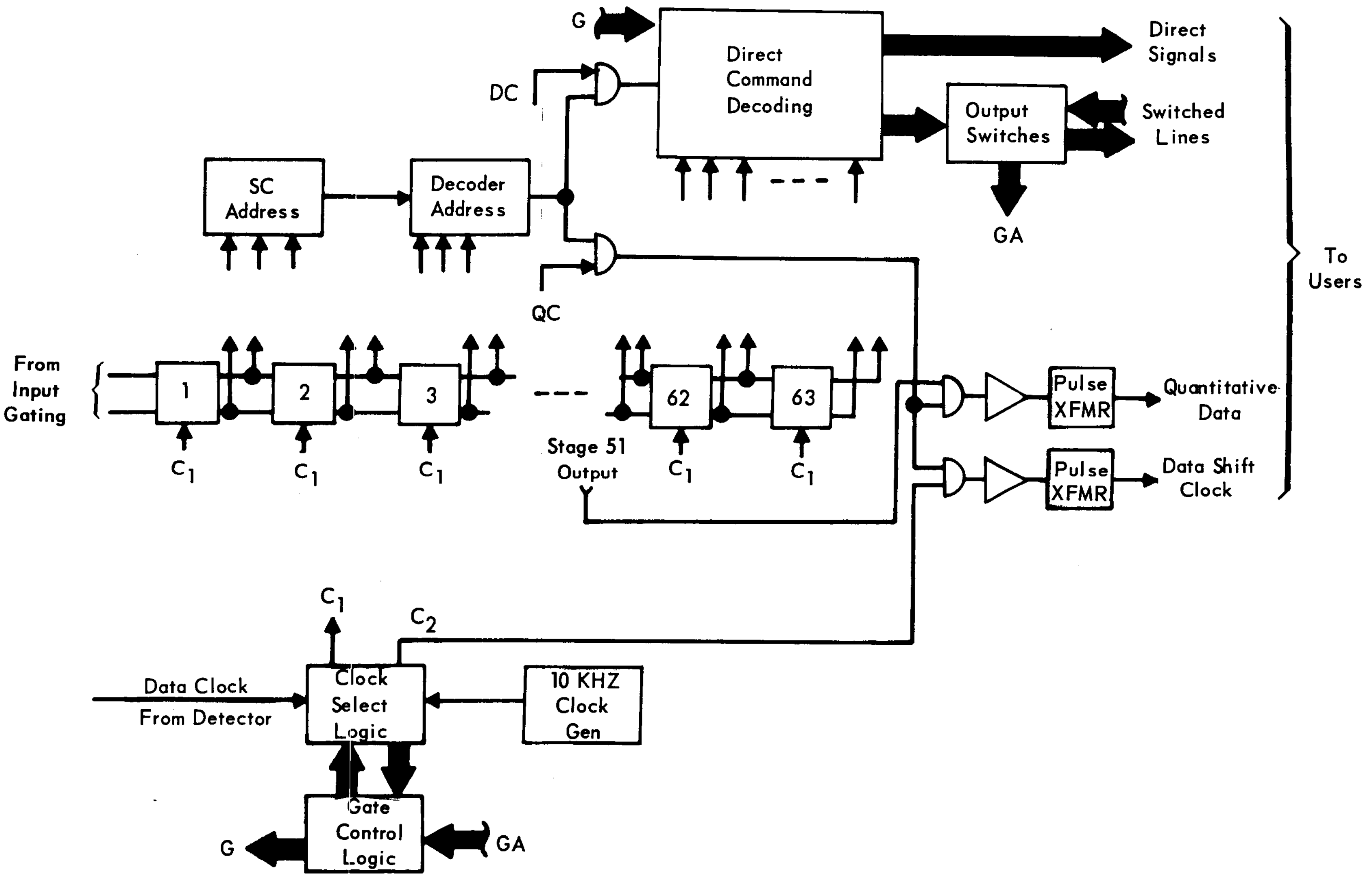


Figure 6–9

COMMAND SUBSYSTEM TEST GENERATOR

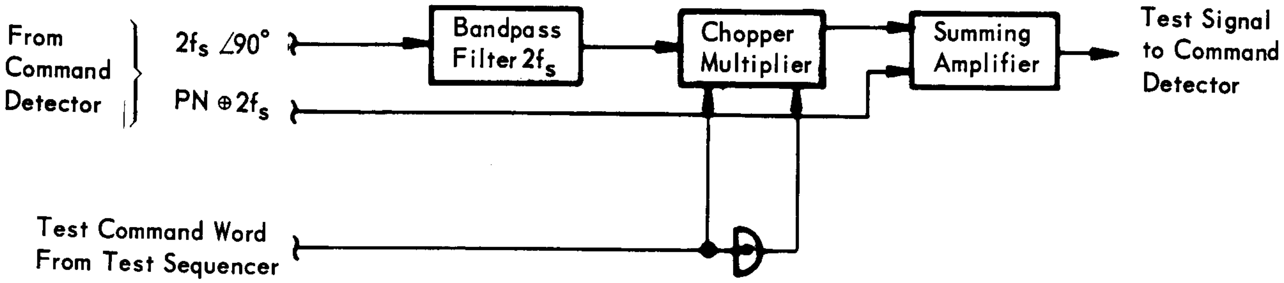


Figure 6-10

c. Probability of rejecting a command $<10^{-4}$

d. Probability of decoding a command with any number of uncorrected errors $<3 \times 10^{-7}$

The latter probability refers to commands which are not rejected but remain in the register for decoding.

6.6 INTERFACE DEFINITION - The SL command list is given in Figure 6-11. All direct commands (DC) are outputted via latching relay contact closures. All quantitative commands (QC) are outputted via a pulse transformer along with synchronization.

Signal interfaces other than command outputs are given below. All pulses are 10 microseconds long.

Inputs	From	Remarks
Word sync	SC command decoder	Pulse
Data	" " "	Polarized pulse
Clock	" " "	Pulse
Test	SL test sequencer	Polarity of pulse indicates start or stop test
Test modulation	" " "	Polarized pulse
Baseband signal	SL radio S/S	Zero to 4 f_s
VCO start/stop	SL TM S/S	Polarized pulses
VCO count dump	" " "	Shift pulses
+28 volts	Power Distribution S/S	Primary power

Outputs	TO	Remarks
VCO count	SL TM S/S	Pulse
Shift clock	Test sequencer	Pulse

In order to minimize weight and maintain immunity from spacecraft system noise, all command data from the SC command decoder to the SL command decoder should be transferred via pulses rather than d-c signals. This choice is based on analysis of cable shielding requirements and ground loop problems associated with direct-coupled as compared with transformer-coupled digital circuits in a noisy system environment.

6.7 RELIABILITY AND SAFETY CONSIDERATIONS - The following paragraphs describe the reliability and safety considerations of the Surface Laboratory Command Subsystem.

RADIO COMMAND LIST

RADIO COMMAND	TYPE DIRECT OR QUANTITATIVE	MAXIMUM VALUE OF QUANTITATIVE WORD AND TOLERANCE	TIME OCCURRENCE (MISSION PHASE, ETC.)
Surface Lab Antenna Pointing Subsystem			
1. Erect Antenna	D	–	Landed, backup only
2. Turn-On Gyros	D	–	Landed, backup only
3. Activate Servo Electronics	D	–	Landed, backup only
4. Servo Electronics to Time Share	D	–	Landed, backup only
5. Reposition Azimuth Axis	Q	28 ± 0.1 V	Landed, backup only
6. Reposition Elevation Axis	Q	28 ± 0.3 V	Landed, backup only
7. Reposition Hour Angle Axis	Q	28 ± 0.1 V	Landed, backup only
8. Reposition Declination Axis	Q	28 ± 0.3 V	Landed, backup only
Surface Lab Radio Subsystem			
1. Turn-On HRSB Transmitter	D	–	T_{26}, T_{29} + 75 min
2. Turn-Off LRSB Transmitter	D	–	T_{26} + 5 min, T_{27}, T_{31}
3. Transfer Power Amplifiers	D	–	Landed, backup to automatic sensor and switch
4. Turn-Off HRSB Transmitter	D	–	T_{27} – 5 min
5. Turn-On LRSB Transmitter	D	–	Landed, when desired by earth
Surface Lab Telemetry Subsystem			
1. Turn-On Cruise Commutator	D	–	T_5 – 1 hr, T_8 – 120 min T_{12} – 55 min
2. Switch Cruise Commutator to Cruise Mode	D	–	T_3 + 144 sec, T_5 – 55 min T_8 – 155 min, T_{12} – 50 min
3. Turn-Off Cruise Commutator	D	–	T_3 + 3 hr, T_5 + 120 min
4. Update Science Program (32 Words)	Q	32 bits	T_{25} + 55 min

5. Turn-On Surface Telemetry	D	–	Backup only
6. Turn-Off Surface Telemetry	D	–	Backup only
7. Switch Surface TM to Night Mode	D	–	T_{27} –5 min
8. Switch Surface TM to Day Mode	D	–	T_{29} + 50 min
9. Switch Surface TM to High Rate Mode	D	–	Backup only
10. Switch Surface TM to Low Rate Mode	D	–	Backup only
11. Switch Surface TM to Checkout Mode	D	–	Backup only
12. Switch Surface TM to Sunrise/Sunset Mode	D	–	Backup only
13. Switch Cruise Commutator to De-orbit Mode	D	–	Backup only
Surface Lab Science Subsystem			
1. Deploy Subsurface Probe	D	–	T_{26}
2. Deploy Mars Surface Sampler	D	–	T_{26} + 1 min
3. Begin Subsurface Probe Experiment	D	–	T_{26} + 2 min
4. Collect & Process Surface Samples	D	–	T_{26} + 3 min
5. Extend Atmos Sensors	D	–	T_{26} + 4 min
6. Start Visual Imaging (Hi-Res)	D	–	T_{26} + 5 min, T_{30} + 90 min
7. Deploy Gulliver IV	D	–	T_{26} + 6 min
8. Start Atmos Experiment (D–N)	D	–	T_{26} + 7 min, T_{28} + 70 min T_{30} + 70 min
9. Start Alpha Spec Bkgd Counter	D	–	T_{26} + 8 min
10. Start Gulliver IV	D	–	T_{26} + 9 min
11. Start Sprectoradiometer	D	–	T_{26} + 10 min, T_{29} + 78 min
12. Stop Surface Sample Process	D	–	T_{26} + 48 min
13. Start Optical Data Experiment	D	–	T_{26} + 50 min
14. Start Ultraviolet Experiment	D	–	T_{26} + 50 min
15. Start Wolf Trap Experiment	D	–	T_{26} + 50 min
16. Start Gulliver III Experiment	D	–	T_{26} + 50 min
17. Stop Optical Rota Experiment	D	–	T_{26} + 65 min
18. Stop Ultraviolet Experiment	D	–	T_{26} + 110 min
19. Stop Alpha Bkgd – Start Sample Anal	D	–	T_{26} + 128 min
20. Stop Hi-Rel, Start Med-Rel Imaging	D	–	T_{26} + 132 min, T_{30} + 217 min
21. Stop Med-Rel, Start Low-Rel Imaging	D	–	T_{26} + 254 min, T_{30} + 321 min
22. Stop Visual Imaging Experiment	D		T + 300 min

Figure 6–11

6-16-2

23. Stop Gulliver IV Experiment	D	–	T_{26} + 309 min, T_{30} + 5 min
24. Start Chromatograph Calibration	D	–	T_{26} + 310 min, T_{30} + 5 min
25. Stop Chromatograph Calibration	D	–	T_{26} + 325 min, T_{30} + 20 min
26. Start Chromatograph Analysis	D	–	T_{26} + 325 min, T_{30} –25 min
27. Stop Chromatograph Analysis	D	–	T_{26} + 340 min, T_{30} –10 min
28. Start Chromat Subsurface Analysis	D	–	T_{26} + 340 min, T_{30} –10 min
29. Stop Chromatograph Subsurface Analysis	D	–	T_{26} + 355 min, T_{30} + 5 min
30. Stop Atmos Experiment (S–S)	D	–	T_{28} + 60 min, T_{30} + 60 min
31. Stop Gulliver III Experiment	D	–	T_{26} + 13 hr
32. Start Chromatograph Experiment	D	–	T_{28} + 5 hr
33. Stop Chromatograph Experiment	D	–	T_{28} + 7 hr
34. Stop Atmos Experiment (D–N)	D	–	T_{30} –70 min
35. Start Atmos Experiment (S–S)	D	–	T_{30} –60 min
36. Start Chromatograph Soil Analysis	D	–	T_{30} + 240 min
37. Stop Chromatograph Soil Analysis	D	–	T_{30} + 360 min
38. Start Chromatograph Soil Calibration	D	–	T_{30} + 360 min
39. Stop Visual Imaging Experiment	D	–	T_{30} + 387 min
40. Stop Chromatograph Soil Calibration	D	–	T_{30} + 420 min
41. Stop Alpha Specification Experiment	D	–	T_{26} + 22.1 hr
42. Stop Wolf Trap Experiment	D	–	T_{26} + 27.5 hr
Surface Lab Power Subsystem			
1. Transfer to Internal Power (Inhibit SC Power)	D	–	Cruise and Mars Orbit, backup only
2. Transfer to External Power (Switch to SC Power)	D	–	Cruise and Mars Orbit, backup only
3. Turn-On SL S&T	D	–	T_{12} –150 min
4. Power-Up Heaters	D	–	Backup Only
5. Power-Down Heaters	D	–	Backup Only
Surface Lab and Sequence and Timer			
1. Update SL S&T (128 Words)	Q	32 bits	T_{12} –147 min
2. Switch SL S&T to Standby	D	–	T_{12} –72 min
Test Programmer			
1. Update Program (64 Words)	Q	32 bits	Backup only

6-16-3

6.7.1 Surface Laboratory Command Subsystem Mission Success Definition - The Surface Laboratory Command Subsystem mission is to provide a command link to the Surface Laboratory and its subsystem users. The functions are to decode and error correct the received command signals, to provide real time control signals, and to provide quantitative information for updating the sequencing, programming, etc. The Command Subsystem is required to operate successfully for a period of 50 hours from landing and during SL checkout.

6.7.2 Surface Laboratory Command Subsystem Reliability Model - The Surface Laboratory Command Subsystem has an assessed reliability of an 0.995 probability of successfully performing the required mission. Figure 6-12 shows the reliability model for the Surface Laboratory Command Subsystem.

6.7.3 Mission Failure Modes and Effects - Figure 6-13 shows the failure fault tree for the Surface Laboratory Command Subsystem. No redundancy is employed, however, two degraded modes of operation exist as shown in Figure 6-13. These are:

a. Loss of Quantitative Commands
b. Loss of Direct Commands

As shown in the fault tree, a failure in the decoder and switches will result in a loss of the direct commands only. The remainder of the electronics necessary for decoding are in series with the entire decoding function.

6.7.4 Estimated Command Subsystem Complexity - The estimated total number of parts of different types contained in the Command Subsystem is given in Figure 6-14. No critical parts applications are envisioned due to the low operating voltages.

6.7.5 Safety Considerations - The Command Subsystem contains no pyrotechnic or other devices requiring special safety precautions.

6.8 TEST - Testing will be conducted as listed in the test matrix of Figure 6-15 in accordance with the Integrated Test Plan.

Tests shall be performed prior to canister enclosure, after enclosure prior to final sterilization, after sterilization and during pre-launch operations. All ground testing shall be performed with the use of Operational Support Equipment (OSE). In-flight-checkout will be performed through the DSIF. In-flight-checkout (pre-separation) is initiated by the appropriate flight capsule test programmer upon command from the DSIF and monitored through the spacecraft telemetry system.

6.9 DEVELOPMENT STATUS - The development of all equipment in the SL Command Subsystem is realizable with component and assembly technology presently in existence.

VOYAGER SURFACE LABORATORY COMMAND SUBSYSTEM RELIABILITY MODEL

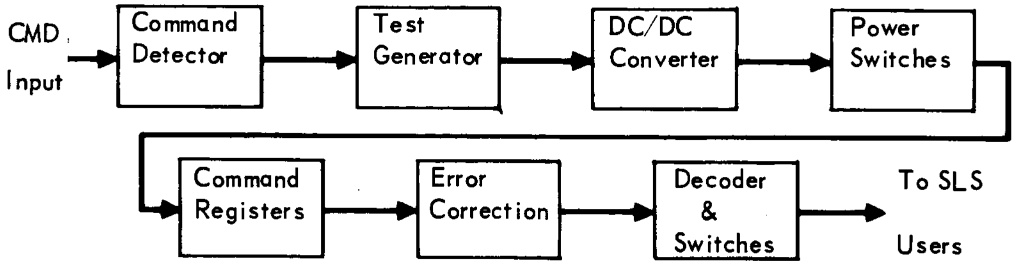


Figure 6–12

VOYAGER SURFACE LABORATORY COMMAND SUBSYSTEM RELIABILITY FAULT TREE

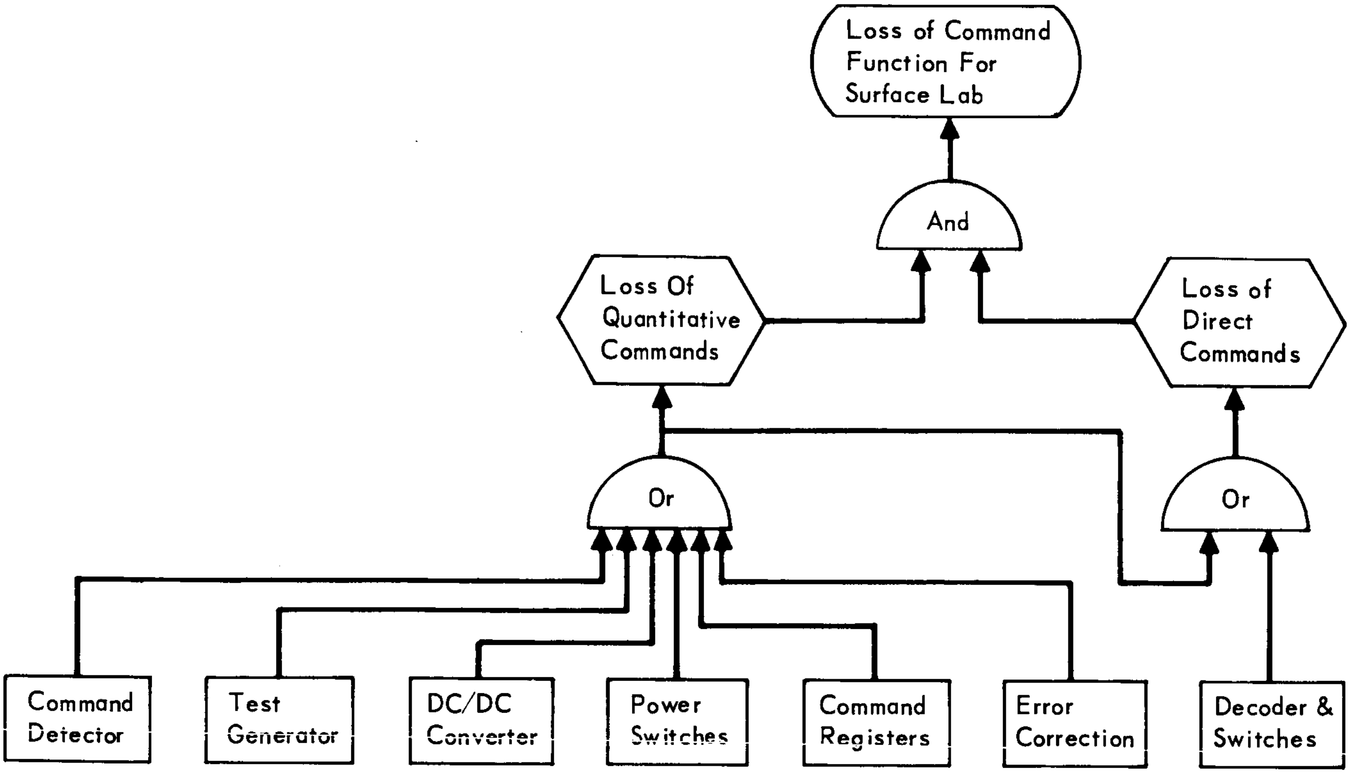


Figure 6–13

VOYAGER SURFACE LABORATORY COMMAND SUBSYSTEM RELIABILITY COMPLEXITY ESTIMATE

PART TYPE	FAILURE RATE, BITS	COMPONENT COMPLEXITY							TOTALS
		COMMAND DETECTOR	TEST GEN.	DC/DC CONV.	POWER SWITCHES	COMMAND REGISTERS	ERROR CORRECTION	DECODER & SWITCHES	
Integrated Ckts									
Digital	10	68/680			5/50	75/750	20/200	15/150	183/1830
Linear	30	22/660	5/150						27/810
Resistors, Metal Film	0.3	106/31.8	32/9.6	10/3	20/6			120/36	288/86.4
Capacitors,									
Ceramic	1.0	56/56	5/5	4/4				10/10	75/75
Solid Tant.	2.0	12/24	2/4	4/8					18/36
Diodes:									
G.P.	1.1	4/4.4		8/8.8	10/11			30/33	52/57.2
Zener	10	1/10		2/20					3/30
Transistors:									
G.P.	5.0		8/40	2/10	10/50			30/150	50/250
Power	50			4/200					4/200
Inductors, L.V.	10			2/20					2/20
Transformers, L.V.	5			1/5					1/5
Totals		269/1466.2	52/208.6	37/278.8	45/117	75/750	20/200	205/379	703/3399.6

Figure 6–14

SL TEST MATRIX COMMAND SUBSYSTEM

Accy Req	TEST	Telemetry	System Test (Pre-Canister)	System Test (With Canister)	Pre-Launch	In-Flight Checkout
	Non Operative Test					
	Command Detector					
3%	Power Supply Voltage	X	X	X	X	X
3%	Power Supply Current	X	X	X	X	X
Carrier	Input Command Signal Level	X	X			
Digital	Command Data Words		X	X	X	X
Digital	Sync. Channel		X			
Digital	Lock Signal	X	X	X	X	X
	Command Decoder					
3%	Power Supply Voltage	X	X	X	X	X
3%	Power Supply Current	X	X	X	X	X
Digital	Input Command Data Word		X			
Digital	Parity	X	X	X	X	X
Digital	Decoded Commands	X	X	X	X	X
Digital	Command Event	X	X	X	X	X
Digital	Bit Sync.		X			

Figure 6-15

SECTION 7

TELEMETRY SUBSYSTEM

The Telemetry Subsystem is composed of two basic parts, the telemetry equipment and the instrumentation equipment. The telemetry equipment, described in Section 7.1 includes the functions of commutation, encoding, formatting, and interfaces with the Science Data Subsystem. The instrumentation equipment includes engineering data transducers, associated signal conditioning, and precision power supply. The instrumentation equipment is described in Section 7.2.

7.1 SURFACE LABORATORY TELEMETRY EQUIPMENT - The telemetry (TM) equipment in the Surface Laboratory (SL) has four functions. The first function is to format SL interplanetary cruise data into a coherent bit stream and transfer this data to the Capsule Bus (CB) for subsequent transmission by the Flight Spacecraft (FSC). The second funtion is to format the SL engineering data, and after proper interleaving with Science Data Subsystem (SDS) data, transfer this bit stream to the SL Data Storage Subsystem (DSS) for subsequent transmission by the Radio Subsystem high rate link. The third function is to format SL critical engineering data for real time transmission via the Radio Subsystem low rate link. The fourth function is to provide sequencing control (only on-off and mode selection control) of the science instruments via the SDS.

7.1.1 Equipment Identification and Usage - The cruise commutation portion of the SL TM has the following major components:

a. analog gates (both single ended high level and double ended low level)
b. differential amplifiers
c. analog to digital converters (including a sample and hold)
d. digital multiplexer (including schmidt triggers for non-logic level bilevel inputs, and holding "circuitry" for pulsed bilevel inputs)
e. dc to dc converter

The landed high data rate commutator portion of the SL TM has the following major components:

a. analog gates (both single ended high level and double ended low level)
b. differential amplifiers
c. analog to digital converters (including a sample and hold)
d. digital multiplexer (including schmidt triggers for non-logic level bilevel inputs, and "holding" circuits for pulsed bilevel inputs)

e. frame and subframe synchronization generators

f. clock

g. sequence programmer

h. dc to dc converter

i. data distributer and selector

j. convolutional encoder (including biphase, Manchester II + 180°, encoder)

k. PSK subcarrier modulator

The landed low data rate commutator portion of the SL TM has the following major components:

a. analog gates (both single ended high level and double ended low level)

b. differential amplifiers

c. analog to digital converters (including sample and hold)

d. digital multiplexer (including schmidt triggers for non-logic level bilevel inputs, and holding "circuitry" for pulsed bilevel inputs)

e. frame and subframe word synchronization generators

f. clock

g. sequence programmer

h. dc to dc converter

The science experiment sequencing function is performed by the programmer and experiment control portion of the SL TM. The major components associated with this control are as follows:

a. a portion of programmer storage

b. experiment control circuits

Figure 7.1-1 is a functional block diagram of the SL TM. Figure 7.1-2 illustrates the usage of the SL TM in terms of mission phases.

The data requirements of the SL TM are defined in Figure 5.4-4 of Part B Volume III, "The Surface Laboratory Instrumentation List". The equipment works principally in conjunction with a) the instrumentation equipment which provides the engineering sensors (their associated instrumentation power supplies) and processes many of the non-standard signals into standard signals, b) the SL Radio Subsystem, c) the CB cruise commutator, d) the SL Sequencer And Timer (S&T) which initiates data acquisition mode changes and data transmission mode changes, e) the SL Electrical Power Subsystem, and f) the SDS which performs analog to digital conversion of experiment data as necessary and provides any subsequencing commands required to run an experiment.

SURFACE LABORATORY TELEMETRY SUBSYSTEM FUNCTIONAL BLOCK DIAGRAM

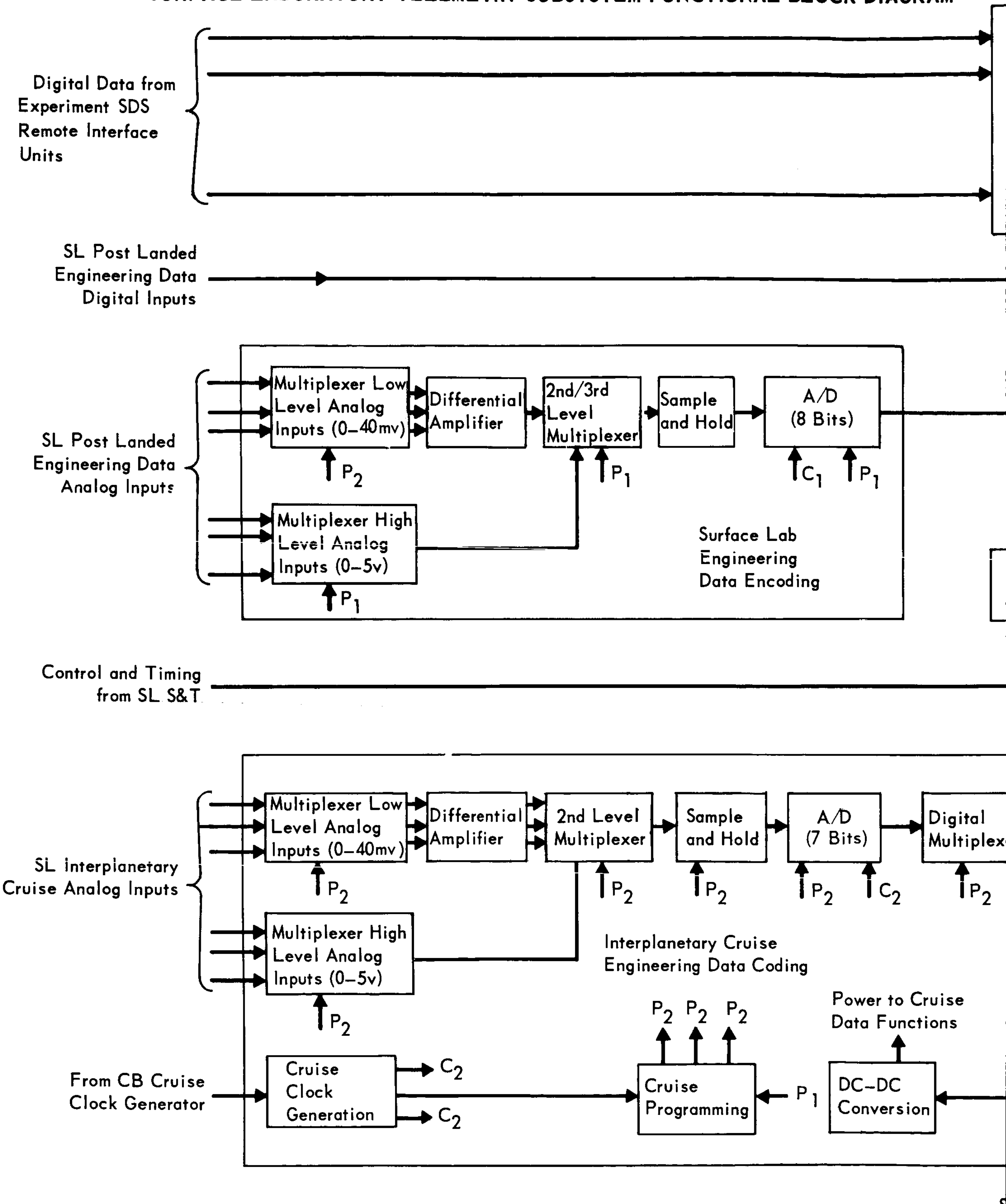
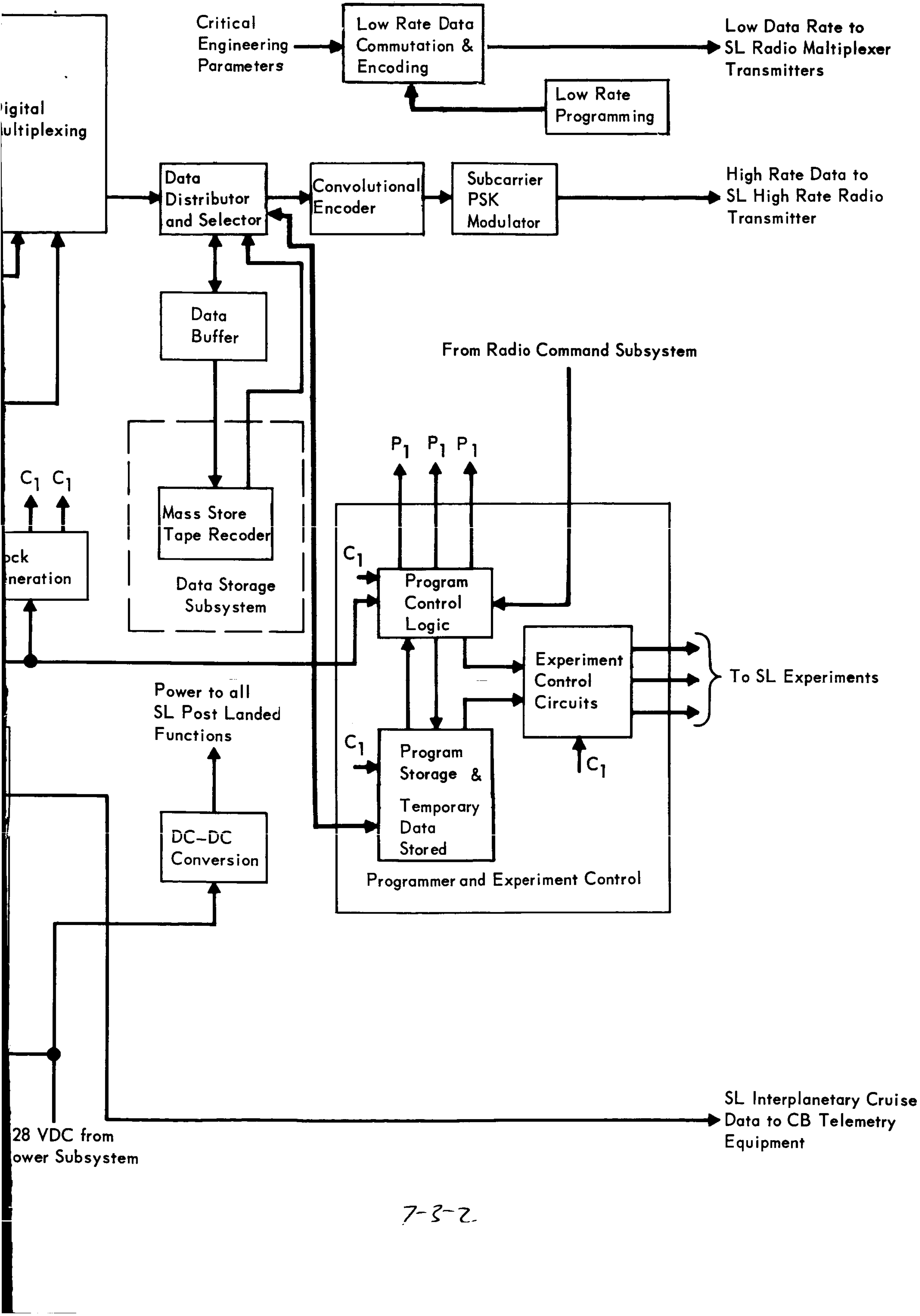


Figure 7.1–1


Critical Engineering Parameters
Low Rate Data Commutation & Encoding
Low Data Rate to SL Radio Maltiplexer Transmitters
Low Rate Programming
igital
ultiplexing
Data Distributor and Selector
Convolutional Encoder
Subcarrier PSK Modulator
High Rate Data to SL High Rate Radio Transmitter
Data Buffer
From Radio Command Subsystem
P_1 P_1 P_1
C_1 C_1
Mass Store Tape Recoder
Data Storage Subsystem
ck
neration
C_1
Program Control Logic
Experiment Control Circuits
To SL Experiments
Power to all SL Post Landed Functions
C_1
Program Storage & Temporary Data Stored
C_1
DC–DC Conversion
Programmer and Experiment Control
SL Interplanetary Cruise Data to CB Telemetry Equipment
28 VDC from
ower Subsystem

SURFACE LABORATORY TELEMETRY EQUIPMENT ACTIVITIES AS RELATED TO MISSION PHASE

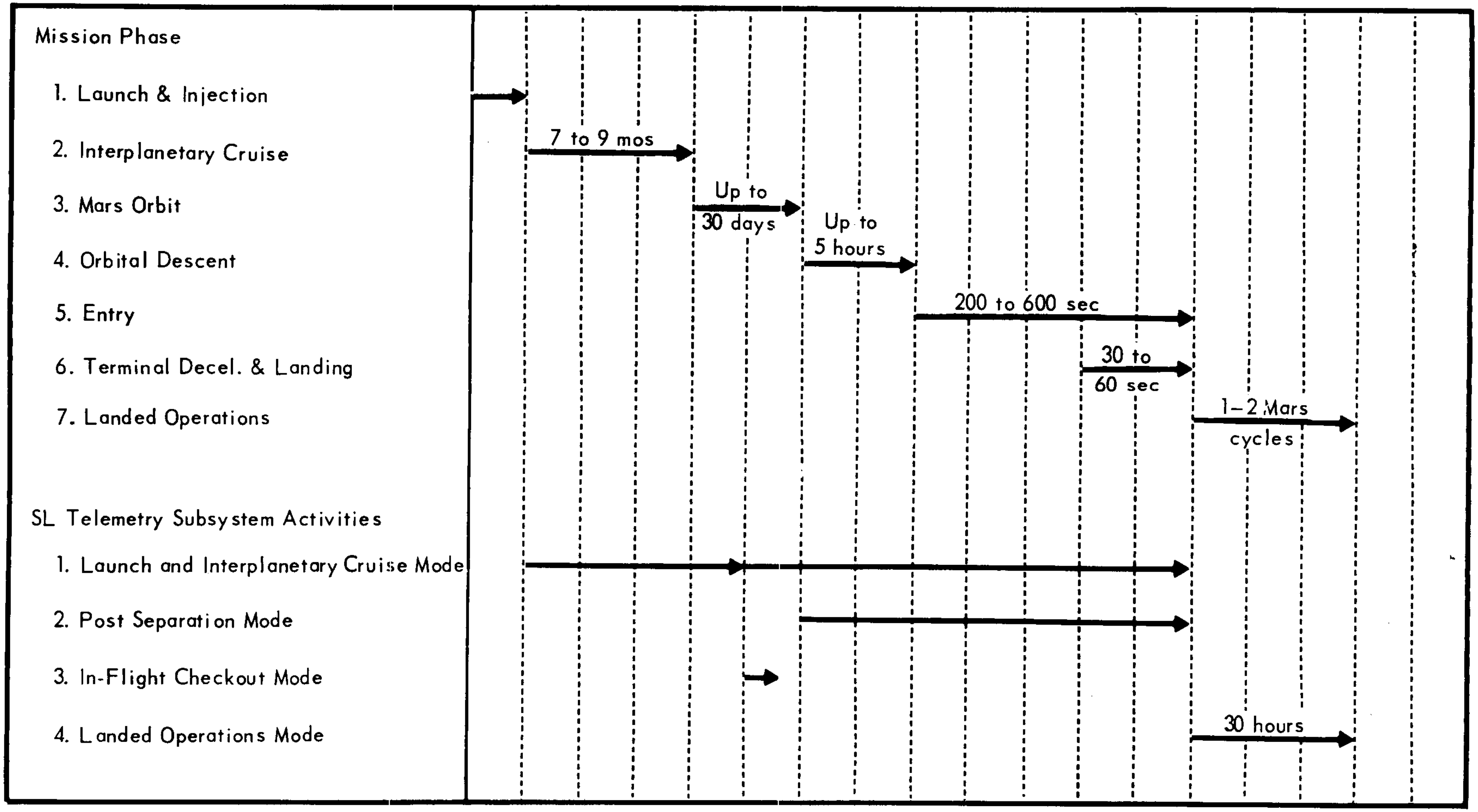


Figure 7.1–2

The SL TM has a total of 175 signal inputs: 58 of which are single ended high level, 54 are double ended low level, 47 are bilevel and 16 are digital. These signals are arranged into 6 data acquisition modes of operation, i.e., only those signals which are active during a given mission phase are telemetered, and 4 data transmission modes, i.e., 4 transmission rates.

7.1.2 Design Requirements and Constraints - Aside from the usual VOYAGER requirements and constraints of:

a. sterilization,
b. low power consumption,
c. hard vacuum space environment,
d. life,
e. reliability, and
f. satisfactory operation after a long dormancy,

the SL TM has specific data oriented requirements and constraints. These are:

a. reprogrammable data formatting and experiment sequencing for mission flexibility
b. significant redundancy in the cruise commutator due to the long operating life
c. dc isolation of all digital interfaces for reducing ground loop vehicle noise
d. usage of alternate functional paths as opposed to block redundancy, and
e. graceful degradation

7.1.3 Physical Characteristics - The SL TM occupies 689 cubic inches, weighs 29.5 pounds and requires 32 watts.

7.1.4 Operational Description - The operational description is divided into two parts. The first part describes the modes of operation of the equipment in terms of the mission phases. The second part describes the function of the principal components.

7.1.4.1 Operational Modes - The SL TM operates in 6 data acquisition modes: launch and interplanetary cruise, in-flight checkout, deorbit and entry, landed daylight, landed night, and landed low rate. In addition the SL TM can operate in any of 4 transmission modes: low rate (.5 BPS), degraded rate (300 BPS), nominal rate (600 BPS), and optimal rate (1200 BPS).

- Launch and Interplanetary Cruise Mode - During this mode the bulk of the SL equipments is dormant; thus only a small amount of status information is required. Only the cruise commutator will be active during this mode. The SL cruise commutator will multiplex the status data and transfer a single bit stream to the data distribution unit in the FSC via the CB. In this mode the cruise commutator is subject to the control (both bit and frame slave) of the spacecraft data distribution unit. The data format for this mode is given in Figure 7.1-3. The format shown is actually the combined format of CB, SL and Entry Science Package (ESP) cruise data. The combined data rate to the FSC is 7 BPS.

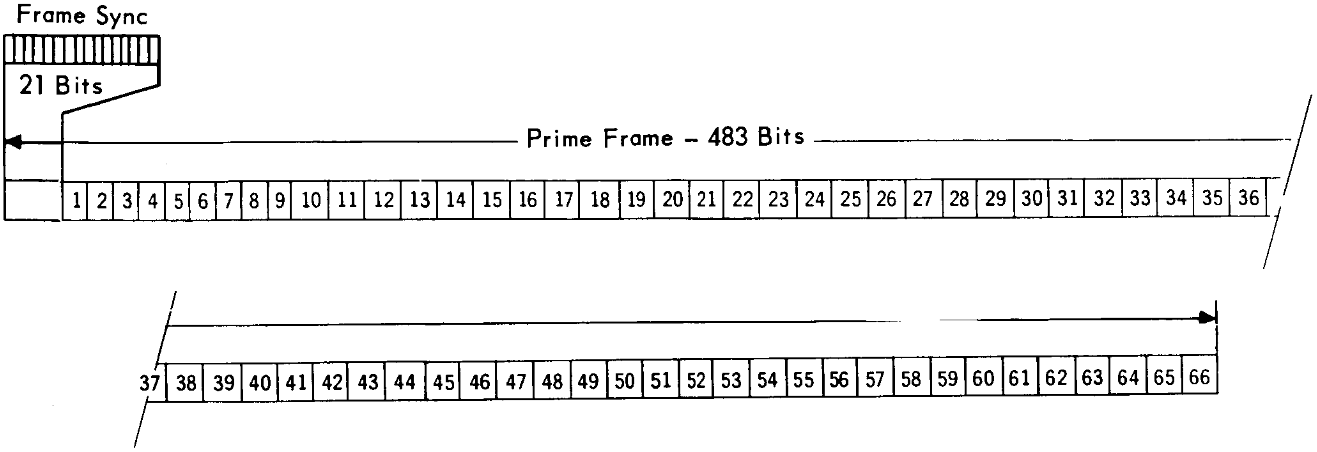
- In-flight Checkout Mode - During this mode all of the SL equipment is tested prior to separation. The SL TM will have three "real" modes here; a memory dump for all of the SL memories, a mode to transmit a calibration facsimile picture, and a mode to support the checkout of other SL subsystems. A fourth or quasi-mode will consist of cycling the SL TM through all of its operational modes. During the normal checkout mode the cruise commutator continues to operate via the CB as described before. The format for this mode is given in Figure 7.1-4. This data is transferred at a 273 BPS rate.

- Deorbit and Entry Mode - Deorbit and Entry mode covers the mission phases from separation of the CB from the FSC to landing on the surface of Mars. As in the Launch and Interplanetary Cruise Mode, most of the SL equipments are dormant so that only status information is required. This is accomplished by making the SL cruise commutator a true remote multiplexer of the CB TM. The combined format of the CB, ESP and SL cruise commutators during this mode is shown in Figure 7.1-5.

- Landed Daylight Data Acquisition Mode - During the Martian day, the SL TM acquires SL engineering data in this mode, interleaves the engineering data with science data acquired by the SDS, and transfers the combined bit stream to the Data Storage Subsystem for subsequent transmission to Earth via the Radio Subsystem high rate link.

The format for acquiring data in this mode is shown in Figure 7.1-6. An interleaving sequence derived from the typical science time line (Figure 5.4-5 of Part B, Volume III) is shown in Figure 7.1-7. In addition to its data acquisition function during this mode, the SL TM provides on-off sequencing and mode selection control of the science experiments via the SDS.

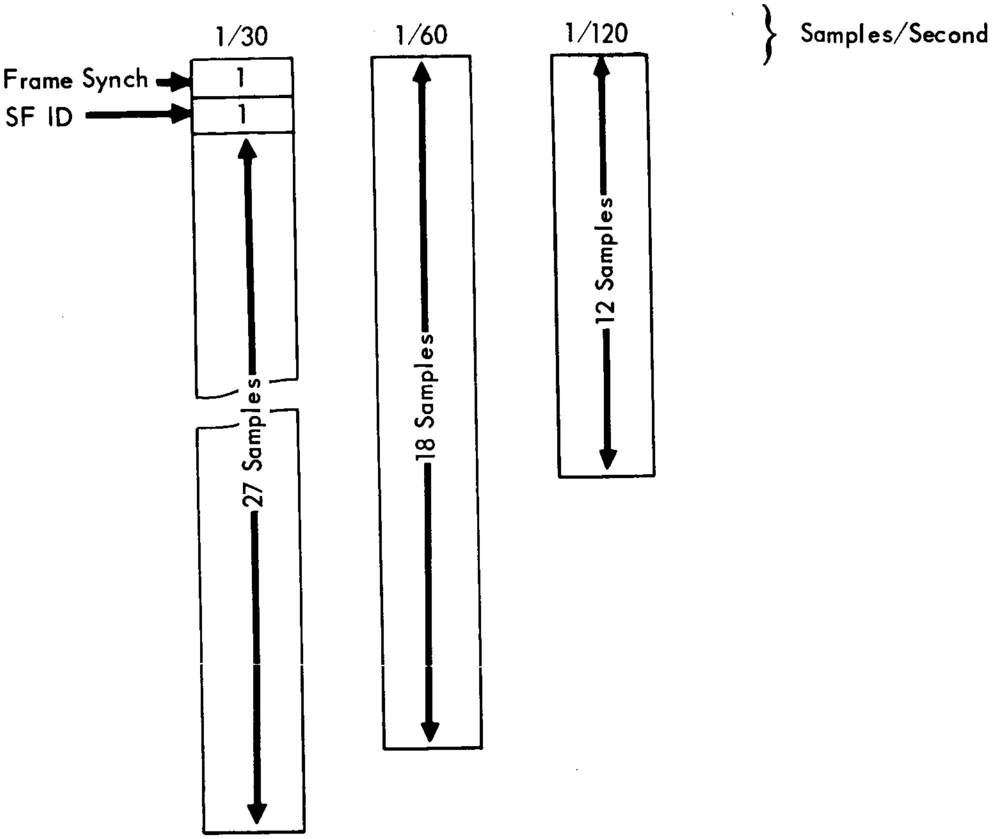
SURFACE LABORATORY LAUNCH AND CRUISE MODE TELEMETRY DATA FORMAT



.4375 BPS
7 Bits/Sample

Figure 7.1-3

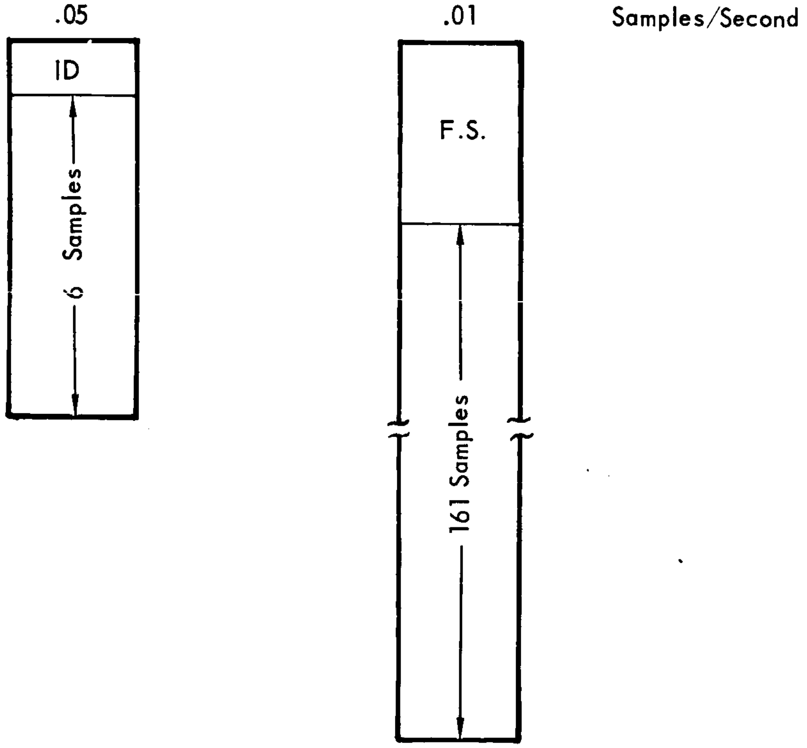
SURFACE LABORATORY EQUIPMENT IN-FLIGHT CHECKOUT MODE, ENGINEERING DATA FORMAT



F.S. – Frame Synchronization 8 Bits
I.D – Subframe Identification 8 Bits
164 Samples/Major Frame
41/30 Samples/Second
41 Samples/Minor Frame
164/15 BPS
8 Bits/Sample

Figure 7.1-4

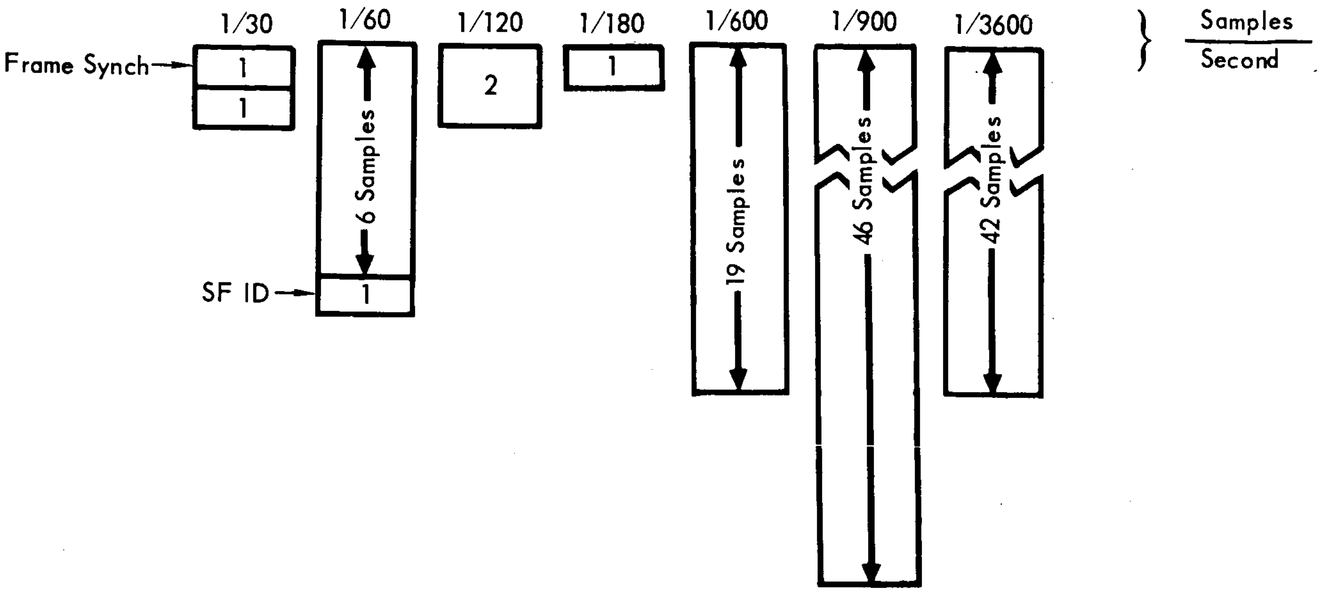
DE-ORBIT/ENTRY ENGINEERING TELEMETRY FORMAT COMBINED SL, ESP, AND CB CRUISE COMMUTATORS



F.S.	– Frame Synchronization 28 Bits
I.D.	– Subframe Identification 7 Bits
200	– Samples/Major Frame
40	– Samples/Minor Frame
7	– Bits/Sample
2	– Samples/Second
14	– BPS

Figure 7.1-5

SL LANDED DAYLIGHT ENGINEERING DATA ACQUISITION TELEMETRY FORMAT



F.S. – Frame Synchronization 8 Bits
I.D. – Subframe Identification 8 Bits
1200 Samples/ Major Frame
10 Samples/Minor Frame
8 Bits/Sample
1/3 Samples/Second
2.667 BPS

Figure 7.1-6

SURFACE LABORATORY TELEMETRY EQUIPMENT – DATA FRAME SEQUENCE FOR STORAGE AND TRANSMISSION

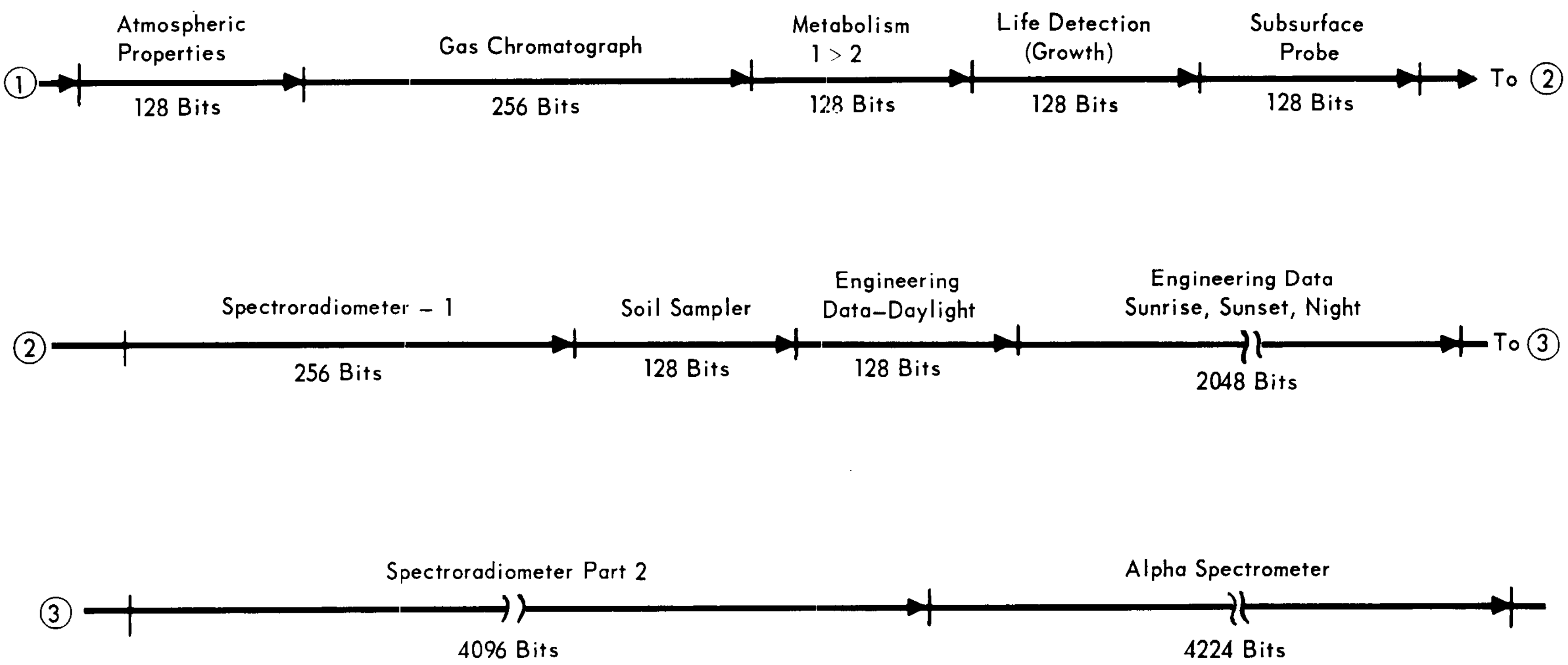


Figure 7.1-7

- Landed Night Data Acquisition Mode - The SL TM operates in this mode during the Martian night. The TM gathers engineering data, interleaves this data with science data from the SDS, and stores both in the core memory. The format for this mode is given in Figure 7.1-8. As in the Landed Daylight Data Acquisition Mode, the SL TM provides on-off sequencing and mode selection control of the science experiments via the SDS.

- Landed Low Rate Data Acquisition Mode - This SL TM mode is active whenever the Earth is in view unless inhibited by Earth command. The low rate link, operating independently of the remainder of the TM, provides critical engineering data as a backup mode to the high rate link and provides a mechanism for evaluating malfunctions of the high rate system that could be corrected by Earth command. The low rate link also has an alternate mode selected by Earth command, by which a small amount of selected science data may be obtained. The format for this mode is given in Figure 7.1-9. The low rate data is transmitted at 0.5 BPS over the Multiple Frequency Shift Keyed (MFSK) link.

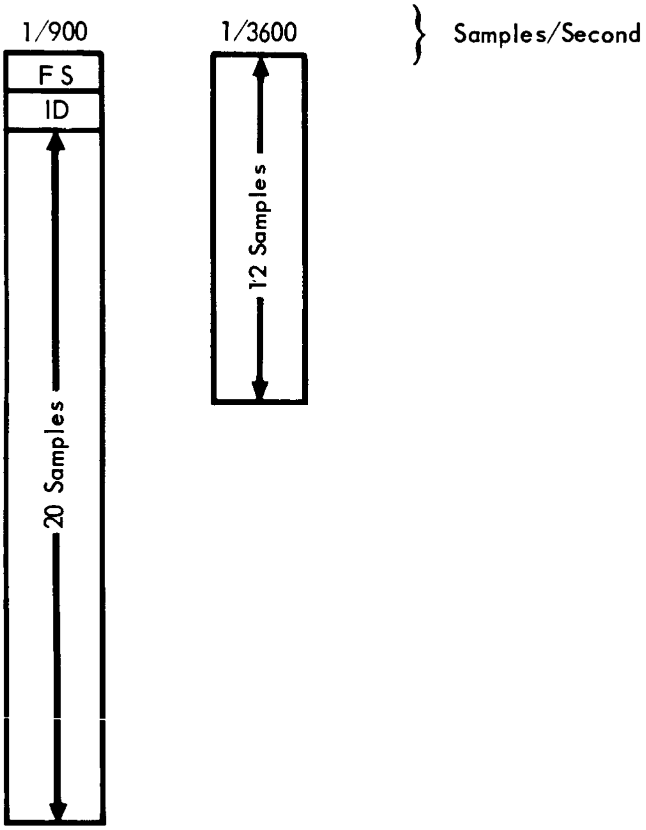
- Landed Nominal Transmission Mode - In this mode SL data is read from the Data Storage Subsystem at 600 BPS and transferred to the convolutional encoder where it is rate 1/3 encoded. The convolutional encoder adds 2 parity bits for each information bit. The resultant bit stream (now at 1800 BPS) is biphase encoded, placed on the PSK subcarrier, and sent to the Radio Subsystem for transmission on the high rate link. This is the primary SL mode for transmitting all accumulated science and engineering data.

- Landed Degraded Transmission Mode - This mode is provided to enhance graceful degradation characteristics of the SL telecommunications. Data is read from the Data Storage Subsystem at 300 BPS, convolutional encoded to 900 BPS (after biphase encoding and PSK modulation) transferred to the Radio Subsystem for transmission on the high rate link. This provides a degraded mode of operation in the event that antenna pointing error is greater than anticipated.

- Landed Optimal Transmission Mode - This transmission mode provides a fast dump capability but requires antenna pointing assistance from Earth. When the Tracking Receiver acquires the Earth originated antenna tracking signal, the TM begins to read data from the Data Storage Subsystem at 1200 BPS. The data is convolutional encoded to 3600 BPS and (after biphase encoding and PSK modulation) is transferred to the Radio Subsystem for RF transmission.

7.1.4.2 Component Description - The commutation portions of the cruise commutator,

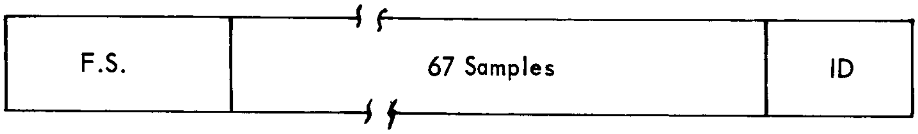
LANDED NIGHT ENGINEERING DATA ACQUISITION TELEMETRY FORMAT



F.S. – Frame Synchronization 8 Bits
I.D. – Subframe Identification 8 Bits
100 Samples/Major Frame
25 Samples/Minor Frame
8 Bits/Sample
1/36 Samples/Second
2/9 BPS

Figure 7.1-8

SL LOW RATE DATA ACQUISITION TELEMETRY FORMAT



F.S. – Frame Synchronization – 14 Bits
I.D. – Identification – 7 Bits
.07 Samples/Second
.49 BPS

Figure 7.1-9

low rate commutator, and main commutator are functionally identical and similar to conventional telemeters, i.e., the analog gating, differential amplifier, sample and hold, analog to digital conversion, digital multiplexing and synchronizing operations. The "programming" portions of two of the commutators are distinctly different from the third. The cruise commutator, and low rate commutator are hardwired devices, employing conventional matrix programming. The main commutator is a stored program device, employing interlaced tube programming. The data storage interlacing operation is unique to the main TM. The following component description is divided into two parts; commutation and programming.

o <u>Commutation</u> - The input signals are gated through MOSFET switches appropriately "treed"; that is, the gates are arranged into subgroups such that the failure of a single input switch will not propagate the failure any further than the subgroup. The specific treeing design is a function of the maximum allowable back-current into the data sources, programming efficiency and, most importantly, reliability. The single ended high level signals are gated directly to the sample and hold portion of the analog to digital converter. The double ended low level signals first pass through a differential amplifier which converts them to single ended high level signals, and then to the sample and hold. The sample and hold charge time is chosen to minimize aperture error. The analog to digital converter output is gated through the digital multiplexer together with the frame and subframe synchronization words and the bilevel data. All the bilevel data is buffered - the "logic level" digital data being directly buffered, while the "non-logic" level bilevels are passed through schmidt triggers for voltage conversion. Some of bilevels are pulsed, thus requiring "holding" circuitry. Depending upon the specific accuracy requirements, the bilevels may or may not be time tagged. The output of the digital multiplexer is the coherent PCM bitstream. Ten percent spare channels are included for system growth.

o <u>Programmer</u> - The cruise commutator and low rate commutator are hardwired matrix multiplexers identical to conventional telemeter programmers. The clock drives a countdown logic network which in turn initiates gate closures.

The main SL TM programmer, a stored program device, performs two separate and distinct functions: data formatting, and experiment on-off and mode selection control. Formatting is accomplished with interlaced tube multiplexing. Interlaced tube formats are described in Section 5.4, Part B, Volume III. The clock drives a "hardwired" tube structure - any given position in the tube being a switch identified in core. The interlaced tube memory has a unique address for each data channel. The "hardwired" tube structure is used to sequence the memory. The addresses of all the data channels are stored sequentially in memory. When a frame is to be sampled, the control unit accesses the memory, decodes the word, samples the channel, and adds one to the memory position for the next memory word. This process repeats until a rate group is completed. When a rate group is completed, and it is not time to repeat the group, the next lowest rate group is initiated until it is time to reinitiate the sampling of the next highest group.

The combination of a hardwired logic tube structure and stored program switch position assures a) that a single core failure will not disrupt the entire format, and b) a new switch position may be easily reprogrammed into core by a simple core address technique.

In addition to performing data format control, the TM programmer controls turn-on, turn-off, and mode selection of science instruments via the SDS. To minimize reprogramming, several experiment time lines will be stored in the TM programmer prior to launch. Each can be updated before separation or after landing. Just prior to FSC-CB separation, one of the time lines will be selected based on the expected landing time and position. Control words stored in memory contain turn-on, turn-off, and applicable mode information for each experiment. Shortly after landing the TM programmer begins comparing control words with vehicle time. When comparison is achieved, a coded word is transferred to the SDS initiating an experiment. The key to the operation is the very high data transfer rate available (i.e., 32, 768 BPS), so that the programmer is able to asynchronously transfer data and issue commands without transfer conflicts occurring. A block diagram of the programmer is given in Figure 7.1-10. The magnetic core memory utilizes 20 mil ferrite cores in a 3D organization with a total capacity of 65,536 cores. The memory serves not only to store formatting instructions and experiment sequencing instructions but also as temporary data storage. The low data acquisition rate during the Martian night precludes placing the data directly on tape. The data is instead placed in core storage and may be read onto tape during the next picture taking cycle or transmitted directly from core.

SLS TELEMETRY EQUIPMENT PROGRAMMER

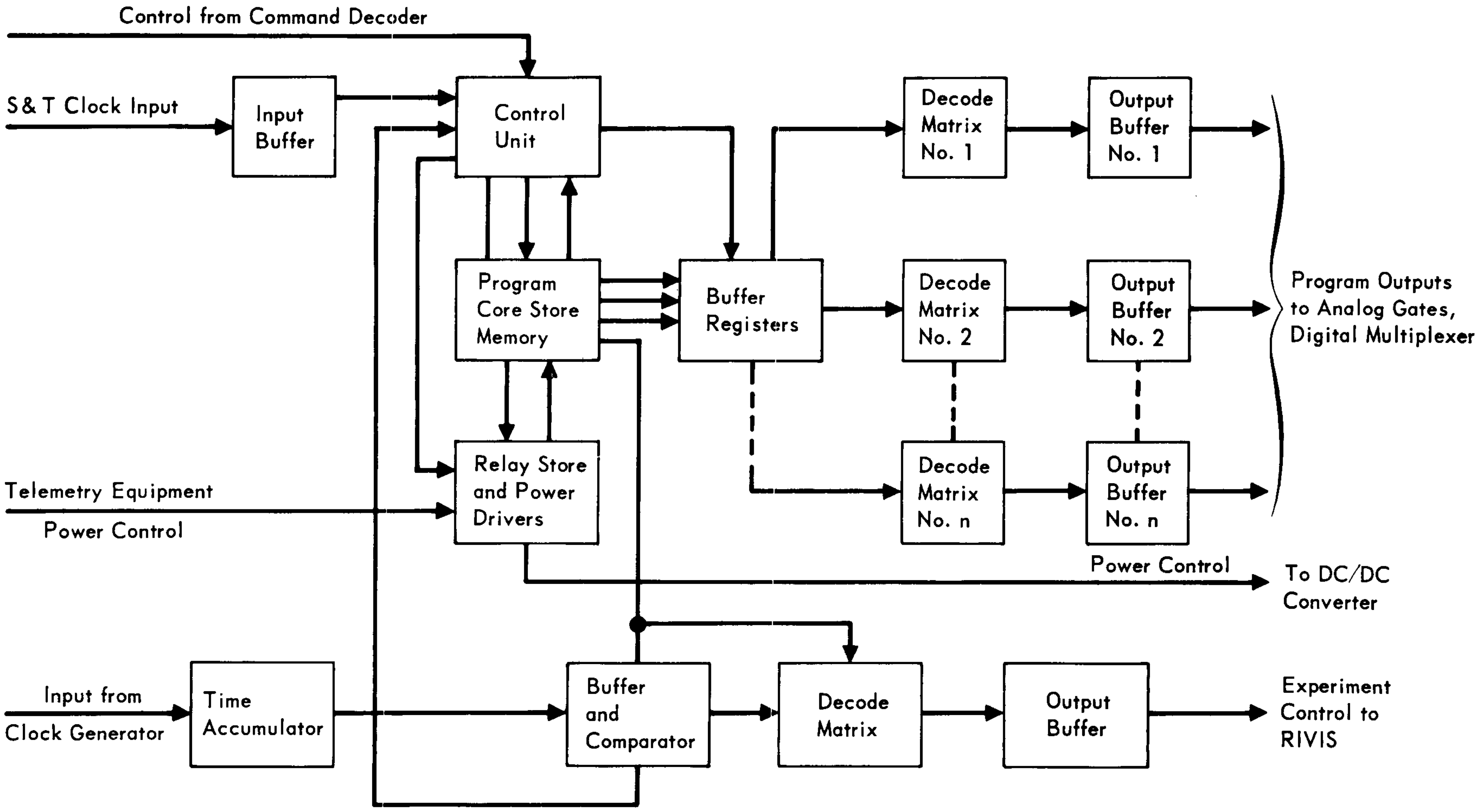


Figure 7.1-10

7.1.5 Performance Characteristics -

a. Input Signals

- Single Ended High Level, 0-5V, 0-5Kohm
- Double Ended Low Level, 0-40MV, 0-500 ohm, maximum of 10V common mode
- Logic Level Digital Inputs - 0 or 5V, 0-5Kohm
- Non-logic Level Bilevel - 0 or 28V, 0-10Kohm

b. Conversion Accuracy

- Single Ended High Level, ± 1 count in 254 counts
- Double Ended Low Level, ± 2 counts in 254 counts
- Logic Level Digital, 1 error in 10^5
- Non-logic Level Bilevel, 1 error in 10^3 with less than 1V as a "space" and greater than 4V as a "mark".

c. Output Signals

- All digital, 0 or 5V, 5Kohm
- Straight binary encoded NRZ, zero and full scale suppression out of ADC
- PSK modulated subcarrier with convolutional encoding to the Radio Subsystem high rate link with biphase level encoding
- NRZ encoded serial PCM to CB cruise commutator
- NRZ encoded serial PCM to Radio Subsystem low rate link
- NRZ encoded serial PCM to Data Storage Subsystem

d. Programming

- Interlaced or burst tube programming for all stored programs
- Matrix or interlaced tube programming for all hardwired programs
- Reprogram switch positions by radio command in stored programs
- Random access memory
- Reprogram experiment sequencing by radio command

e. General

- Analog switching action is independent of source impedance.
- DC isolation in all digital interfaces
- Signal, power and chassis ground isolation
- Vehicle time in each frame

7.1.6 Interfaces - The interfaces are given in Figure 7.1-11.

7.1.7 Reliability and Safety Considerations - The SLS Telemetry Equipment Reliability Model, Fault Tree and Complexity Estimate are shown in Figures 7.1-12, 7.1-13, and 7.1-14 respectively. The estimated reliability for the SLS Telemetry Equipment

SL TELEMETRY INTERFACES

	SL S&T	Data Storage	Instrumentation	CB Cruise Commutator	SL Radio	SL Command	SL Power Bus	SDS
Main SL TM								
Analog Gates			X					
Digital Multiplexer	X					X		X
Clock	X							X
Programmer	X							X
DC to DC Converter							X	
Data Distributor & Selector		X						
PSK Subcarrier Modulator					X			
Cruise Commutator								
Analog Gates			X					
Digital Multiplexer	X			X				X
DC to DC Converter							X	
Low Data Rate Commutator								
Analog Gates			X					
Digital Multiplexer	X					X		X
Clock	X							X
Programmer					X	X	X	
DC to DC Converter							X	

Figure 7.1-11

VOYAGER SURFACE LABORATORY TELEMETRY EQUIPMENT RELIABILITY MODEL

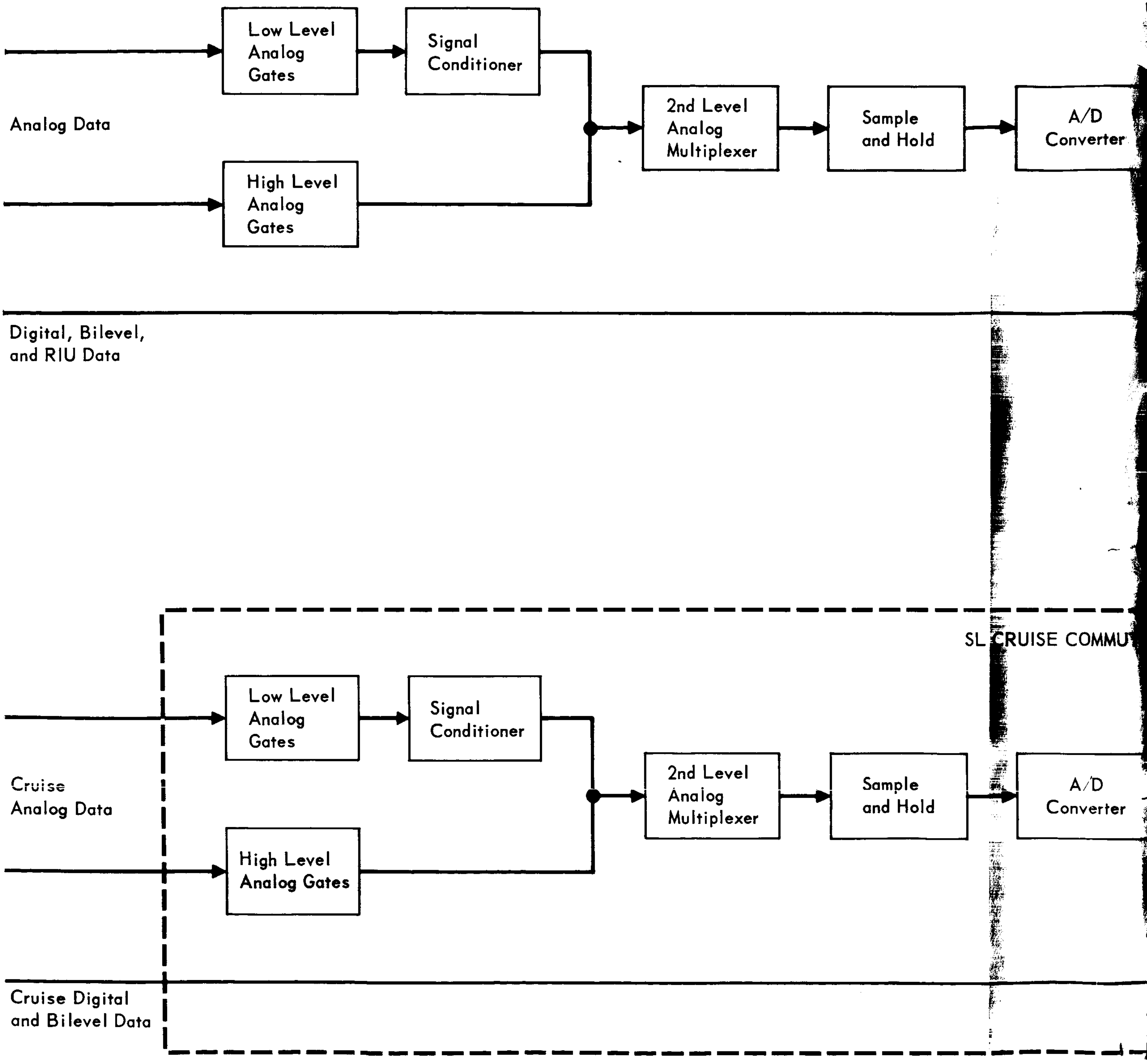
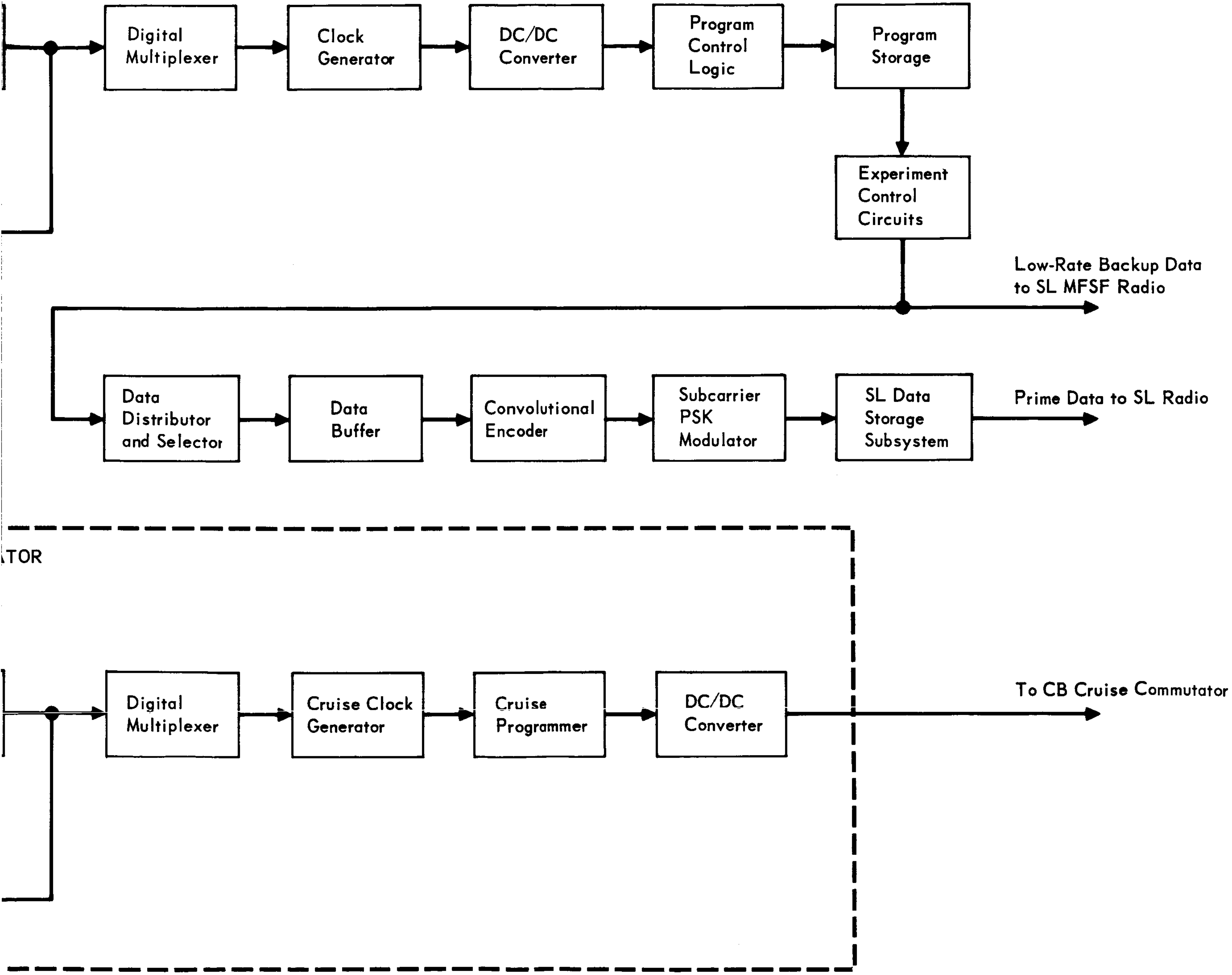


Figure 7.1–12

7–20–1


Digital Multiplexer
Clock Generator
DC/DC Converter
Program Control Logic
Program Storage
Experiment Control Circuits
Low-Rate Backup Data to SL MFSF Radio
Data Distributor and Selector
Data Buffer
Convolutional Encoder
Subcarrier PSK Modulator
SL Data Storage Subsystem
Prime Data to SL Radio
TOR
Digital Multiplexer
Cruise Clock Generator
Cruise Programmer
DC/DC Converter
To CB Cruise Commutator

7-10-2

VOYAGER SURFACE LABORATORY TELEMETRY EQUIPMENT RELIABILITY FAULT TREE

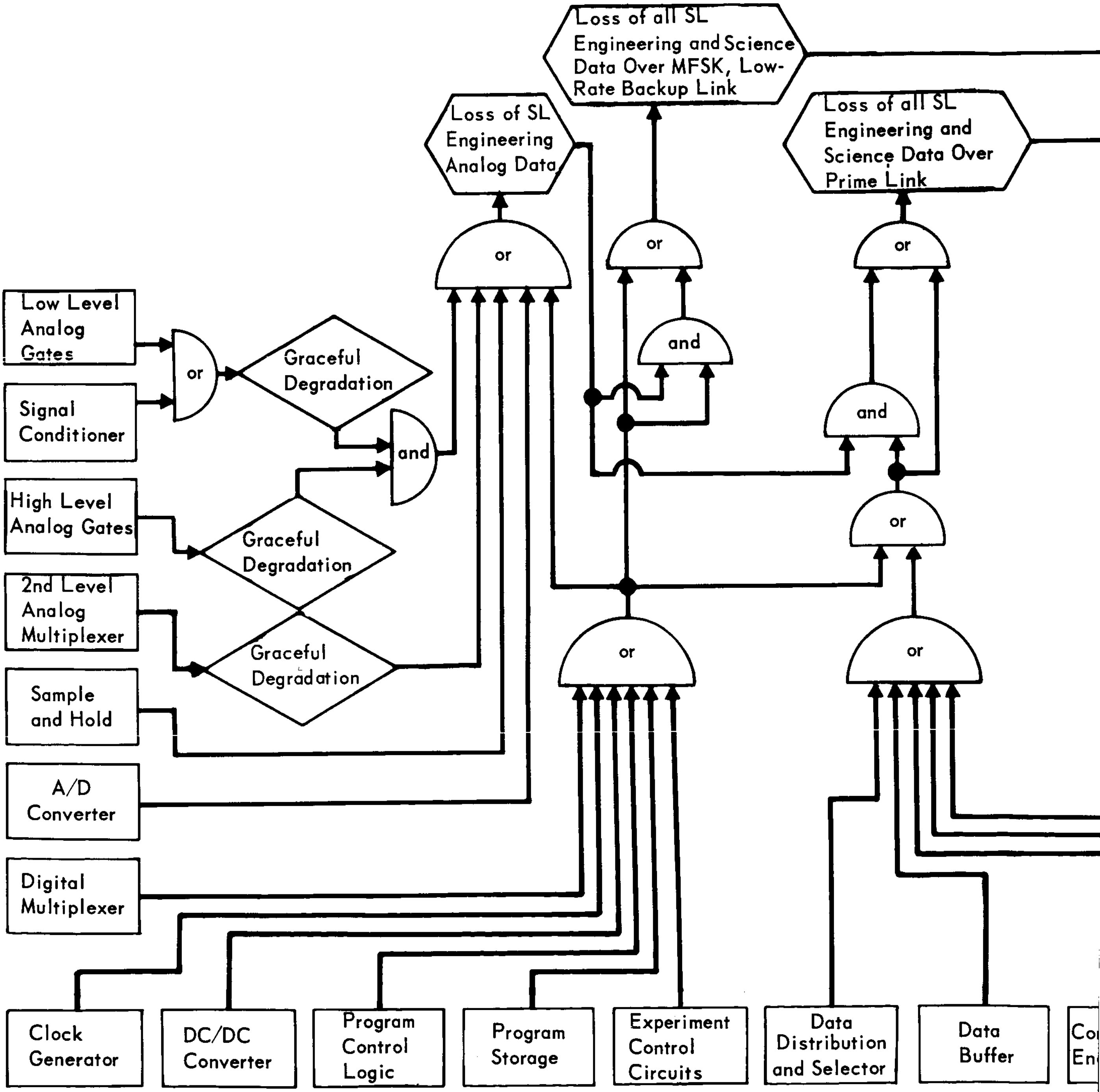
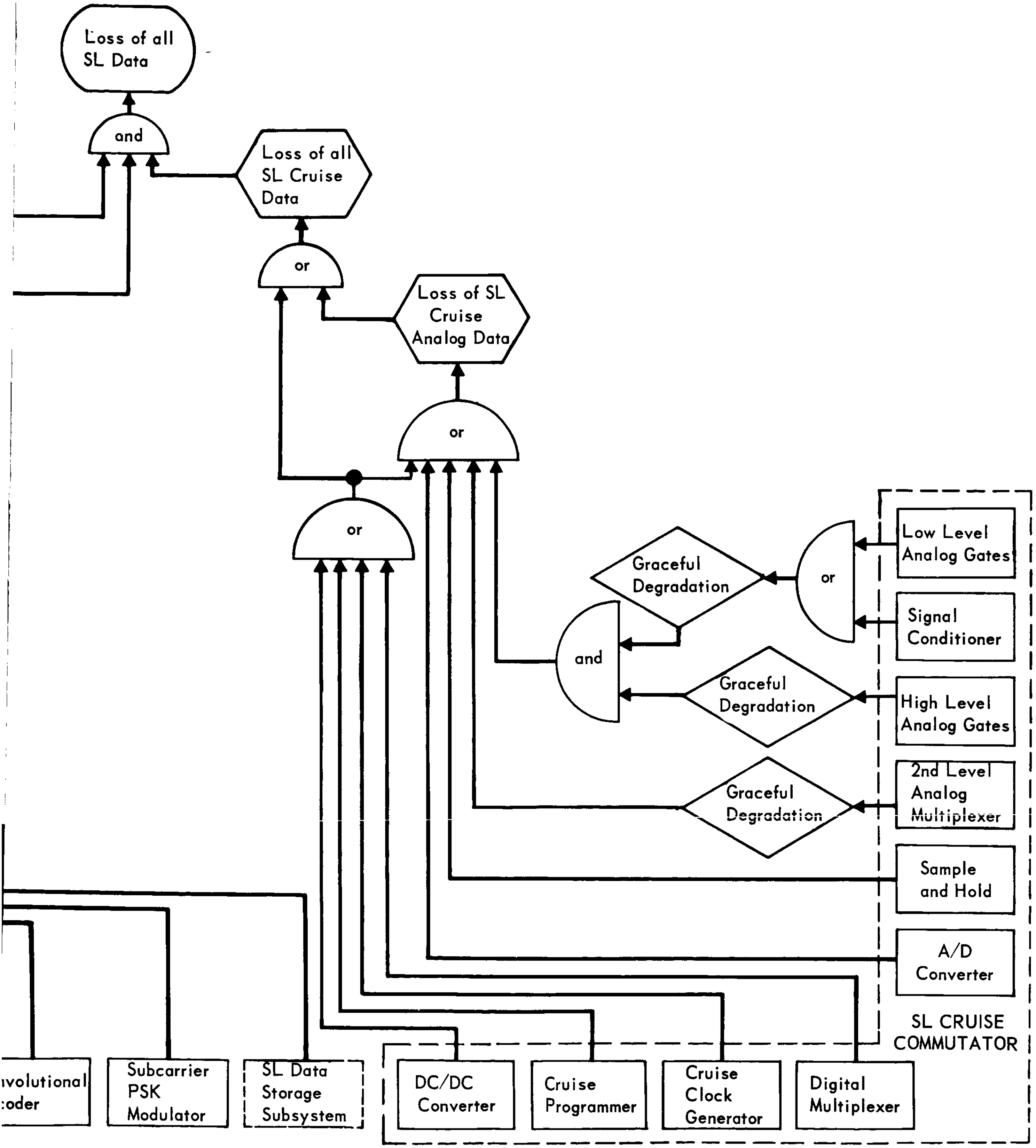


Figure 7.1–13


Loss of all SL Data
and
Loss of all SL Cruise Data
or
Loss of SL Cruise Analog Data
or
or
Graceful Degradation
or
and
Graceful Degradation
Graceful Degradation
Low Level Analog Gates
Signal Conditioner
High Level Analog Gates
2nd Level Analog Multiplexer
Sample and Hold
A/D Converter
SL CRUISE COMMUTATOR
ıvolutional
:oder
Subcarrier PSK Modulator
SL Data Storage Subsystem
DC/DC Converter
Cruise Programmer
Cruise Clock Generator
Digital Multiplexer

VOYAGER SURFACE LABORATORY TELEMETRY EQUIPMENT RELIABILITY COMPLEXITY ESTIMATE

PART TYPE	FAILURE RATE, BITS (10^{-8} failures per hour)	SLS–TM QUANTITY	TOTAL FAILURE RATE, BITS (10^{-8} failures/hour)	SLS CRUISE COMMUTATOR	
				QUANTITY	FAILURE RATE, BITS
Integrated Circuits					
Digital	10	943	9430	380	3800
Linear	30	105	3150	150	4500
Transistors:					
General Purpose	5.0	534	2670	2	10
Power	50	4	200	4	200
Diodes:					
General Purpose	1.1	1680	1768.8	8	8.8
Zener	10	2	20	2	20
Resistors:					
Metal Film	0.3	936	280.8	10	3
Carbon Composition	0.1	596	59.6		
Ladder Network	9.6	1	9.6	1	9.6
Capacitors:					
Ceramic	1.0	180	180	4	4
Solid Tantalum	2.0	116	232	4	8
Mylar	0.5	1	0.5	1	0.5
Memory Cores	0.002	262,144	524.3		
Memory Connections[1]	0.1	(14,000)	1400		
Inductors, Low Voltage	10	4	40	2	20
Transformers, Low Voltage	5.0	2	10	1	5
Totals		267,176	19,975.6	569	8588.9

NOTES: 1. The number of memory connections affect the failure rate only.

Figure 7.1-14

is .971. The cruise commutator and encoder has an estimated reliability of .996 excluding programming functions. Due to the continuous operation of the cruise commutator and encoder throughout interplanetary cruise, active redundant analog data switches and a standby redundant analog to digital converter have been incorporated into the design. The standby redundant ADC is switchable by MOS command. Programming function redundancy considerations require further analysis. Alternatives include operation on a duty cycle basis, additional circuit redundancies, or decentralization of programmer timing functions to permit limited operation and data retrieval in spite of individual failures. No special safety provisions are required because there are no high voltage applications in the telemetry equipment.

7.1.8 Test - The bulk of the telemetry-using subsystems are tested through the telemetry subsystems during the test build-up from factory tests through lift-off. During the Mars orbit in-flight checkout mode, all of the using subsystems are tested through the Telemetry Subsystem. Prior to any of the using subsystem tests, the telemetry is tested. The telemetry tests are conducted in three steps, a "cycle" through all modes, a memory readout mode, and a checkout mode. (See Figure 7.1-15)

The telemetry tests are principally directed toward the major functional blocks by following a specific data "chain". Each "chain" is identified by a block of signal types, e.g., a low level calibration signal(s) is injected to a low level gate and the output of the TM (at the Radio Subsystem input) is monitored. This tests the chain of low level signals, namely, the gates and gate driver programming, the differential amplifier, the digital multiplexer, and the interleaver. Note that each individual gate is not tested (in-flight) but all of the major functional blocks are tested in flight when monitoring the using subsystems.

7.1.9 Development Status - Aside from the normal VOYAGER development requirements, specifically reliability and sterilization, the CB TM will generally not require any state-of-the-art advances. The exception is the core stack drivers at low temperature. This problem in past space programs has been alleviated by close temperature control; however, the battery weight necessary for the VOYAGER mission makes this solution prohibitively heavy.

SURFACE LABORATORY SYSTEM
TELEMETRY EQUIPMENT TEST MATRIX

TEST	ACCY REQ	Telemetry Points	System Test (Pre-Canister)	System Test (With Canister)	Pre-Launch	In-Flight Checkout
Non Operative Test						
Clock Generator						
Gating Signal Sequence and Timer Input	Digital		X			
Output Clock Signals	Digital		X			
Cruise Commutator						
Commutating Gate Signal Sequence	Digital		X			
Input Calibration Signals	1%	X	X	X	X	X
A to D Calibration Signals	1%	X	X	X	X	X
Engr. Data ADC/Multiplexer						
Input Calibration Signals	1%	X	X	X	X	X
A to D Calibration Signals	1%	X	X	X	X	X
Digital Test Pattern						
Digital Test Pattern	Digital	X	X	X	X	X
Operating Sequence	Digital	X	X	X	X	X
Programmer and Experiment Controller						
Input Commands	Digital	X	X	X	X	X
Output Signal Sequence	Digital		X	X	X	X

Figure 7.1-15

7.2 INSTRUMENTATION - This section presents the functional description of the instrumentation equipment required for acquisition of the SL engineering performance and diagnostic data. The instrumentation equipment is identified as that portion of the telemetry subsystem where the data signals are sensed and conditioned to outputs compatible with the PCM encoders. The equipment configuration described herein is typical and evolved from a study of the SL engineering measurement requirements as summarized in the Instrumentation List of Part B, Volume III.

7.2.1 Equipment Identification and Usage - The instrumentation equipment includes transducers, signal conditioners, and the associated instrumentation power supply.

7.2.1.1 Transducers - Transducers are located throughout the SL to provide performance and diagnostic data from the SL and its subsystems. The specific transducer types required are temperature, pressure and position.

A preliminary list of SL transducers with functional and performance information appears in Figure 7.2-1. The list includes transducer part numbers used in other aerospace applications which are representative of those that will be used in the SL. Total quantities of each type transducer required are:

- Temperature Sensors -37
- Pressure Transducers - 8
- Position Transducers - 4

7.2.1.2 Signal Conditioners - The signal conditioners accept and process analog, bi-level, and digital data signals from the various subsystems and supply inputs compatible with the PCM encoders. All non-standard analog signals are scaled to the 0 to 5 volt PCM system range. Signal conditioning of data signals is accomplished either in the subsystem equipment, the telemetry equipment, or in a self-contained Signal Process Unit (SPU). Figure 7.2-2 contains an overall list of signal conditioning requirements including type and location. The time shared low level differential amplifier and the majority of the binary signal conditioning take place in the telemetry equipment and therefore are discussed along with that equipment. Where signal conditioning can be more easily accomplished at the source, it will be included in the subsystem design. However, the same design philosophy of circuit isolation, impedance transformation, and scaling applies to this category.

7.2.1.3 Instrumentation Power Supply - This equipment is comprised of a dc/dc converter which converts raw dc power from the battery to regulated 5 Vdc power. This power provides excitation to the temperature sensors and the potentiometric transducers and provides calibration linearity voltages to the commutators.

7.2.2 Design Requirements and Constraints - The SL instrumentation equipment for

SLS TRANSDUCER LIST

DATA IDENT. NO.	MEASUREMENT	SUBSYSTEM	RANGE	SIMILAR TO MANUF/PART N
Temperature				
RS 5–6	TWT Temperature (2)	Radio	25° to 150°F	RDF/55P886010
RS 13	Low Rate S-Band Xtal Temperature	Radio	25° to 150°F	RDF/55P886010
RS 14–15	High Rate S-Band Xtal Temperature (2)	Radio	25° to 150°F	RDF/55P886010
DS 1	Oscillator Temperature	Telemetry	25° to 150°F	RDF/55P886010
ST 1	S & T Master Oscillator Temperature	Sequencer	-10° to 150°F	RDF/ 55P88601
TS 1-8	Radiator Temperature (8)	Thermal Control	-200° to 150°F	RDF/55P886010
TS 9-16	Cold Plate Temperature (8)	Thermal Control	-50° to 200°F	RDF/55P886010
ES 5–8	Battery Temperature (4)	Power	0 to 120°F	RDF/55P886010
VS 10–15	Facsimile Camera Temperature (6)	Science	-200° to 150°F	RDF/55P886010
AS 3–4	Alpha Spectrometer Temp (2)	Science	-200° to 150°F	RDF/55P886010
PS 11	Pressure Transducer Temperature	Science	-200° to 150°F	RDF/55P886010
PS 12–14	Anemometer Temperature	Science	-200° to 150°F	RDF/55P886010
Pressure				
TS 17-24	Heat Pipe Fluid Pressure (8)	Thermal Control	0 - 15 psia	SERVONIC/ 55P886008-2
Motion				
RS 1-4	High Gain Antenna Gimbal Position (4)	Antenna	(Integral Part of Antenna	

Δ Element and bridge separate

Figure 7.2–1

REPRESENTATIVE TRANSDUCERS

– NO.	USED ON	TYPE	INPUT POWER	OUTPUT SIGNAL	SIZE	WEIGHT LB.
-7	122Y	Thermoresistive	5Vdc, .4mA	0 - 40mVdc	1 x .8 x .4 Δ	.18
-7	122Y	Thermoresistive	5Vdc, .4mA	0 - 40mVdc	1 x .8 x .4 Δ	.18
-7	122Y	Thermoresistive	5Vdc, .4mA	0 - 40mVdc	1 x .8 x .4 Δ	.18
-7	122Y	Thermoresistive	5Vdc, .4mA	0 - 40mVdc	1 x .8 x .4 Δ	.18
0-7	122Y	Thermoresistive	5Vdc, .4mA	0-40mVdc	1 x .8 x .4 Δ	.18
-5	122Y	Thermoresistive	5Vdc, .4mA	0 - 40mVdc	1.1 x .5 x .4	.123
;5	122Y	Thermoresistive	5Vdc, .4mA	0 - 40mVdc	1.1 x .5 x .4	.123
-7	122Y	Thermoresistive	5Vdc, .4mA	0 - 40mVdc	1 x .8 x .4 Δ	.18
-7	122Y	Thermoresistive	5Vdc, .4mA	0 - 40mVdc	1 x .8 x .4 Δ	.18
-7	122Y	Thermoresistive	5Vdc, .4mA	0 - 40mVdc	1 x .8 x .4 Δ	.18
-7	122Y	Thermoresistive	5Vdc, .4mA	0 - 40mVdc	1 x .8 x .4 Δ	.18
-7	122Y	Thermoresistive	5Vdc, .4mA	0 - 40mVdc	1 x .8 x .4 Δ	.18
	Gemini	Potentiometric	5Vdc, .25mA	0-5Vdc	1.0 dia x 2.4	.313
System)		Potentiometric	5Vdc, .25mA	0–5Vdc	–	–

SLS INSTRUMENTATION – SIGNAL CONDITIONING LIST

DATA IDENT. NO.	MEASUREMENT	SUBSYSTEM	RANGE	SIGNAL CONDITIONING		
				LOCATION	TYPE	OUTPUT
RS 1	Receiver AGC Course	Radio		Radio Sub.		0 to 5Vdc
RS 3	Receiver Static Phase Error	↓		↓		↓
RS 7	TWT Cathode Current	↓		↓		↓
RS 8-9	TWT Helix Current (2)	↓		↓		↓
RS 10	Low Gain Drive Power	↓		↓		↓
RS 11	Low Rate S-Band Xmtr Power	↓		↓		↓
RS 12	High Rate S-Band Xmtr Power	↓		↓		↓
RS 16	Low Rate S-Band Oscillator Drive	↓		↓		↓
RS 17-18	High Rate S-Band Oscillator Drive (2)	↓		↓		↓
RS 19	Receiver Input SNR	↓		↓		↓
RS 21	Modulator Verification	↓		↓		↓
RS 22	Receiver Input Power	↓		↓		↓
RS 2	Receiver AGC Fine	↓		↓		0 to 40mVdc
RS 4	Receiver L.O. Drive	↓		↓		↓
RS 23	High Rate Transmitter Frequency	↓	23 bits	PCM	Binary	Digital
RS 20	Low Rate Transmitter Frequency	↓	23 bits	PCM	Binary	Digital
DS 4	DC Input Voltage	Telemetry	18 to 38Vdc	SPU	dc Signal Conv	0 to 5Vdc
DS 5-7	A/D Linearity Voltage (3)	↓	0 to 5Vdc	–	–	↓
DS 12	Cruise Commutator DC Input Volt.	↓	18 to 38Vdc	SPU	dc Signal Conv	↓
DS 17-19	Cruise Comm A/D Linearity Volt. (3)	↓	0 to 5Vdc	–	–	↓
DS 20-22	C/O A/D Linearity Volt. (3)	↓	0 to 5Vdc	–	–	↓
DS 8-10	Low Level Amp. Linearity Volt. (3)	↓	0 to 40mVdc	–	–	0 to 40mVdc
DS 11	Transducer Voltage Source	↓	↓	–	–	↓
DS 13-15	Cruise Comm LL Amp. Linearity Volt. (3)	↓	↓	–	–	↓
DS 23-25	C/O LL Amp. Linearity Volt. (3)	↓	↓	–	–	↓
DS 2	Telemetry Mode	↓	4 bits	PCM	Binary	Digital
DS 3	Vehicle Mode	↓	10 bits	↓	↓	↓
DS 16	Cruise Comm Telemetry Mode	↓	4 bits	↓	↓	↓

Figure 7.2-2

ES 1-4	Battery Voltage (4)	Power	18 to 38Vdc	SPU	dc Signal Conv	0 to 5Vdc
ES 13-16	Battery Charge Current (4)	↓	0 to 2A	SPU	Mag Amp	0 to 5Vdc
ES 9-12	Battery Current (4)	↓	0 to 5A	–	–	0 to 40mVdc
AS 6	Alphaspectrometer Voltage	Science		Science Sub		0 to 5Vdc
AS 7-12	Alphaspectrometer Detector Data Rate(6)	↓		Science Sub		0 to 5 Vdc
AS 5	Alphaspectrometer Voltage	↓		Science Sub		0 to 40 mVdc
AS 13-18	Alphaspectrometer Detectors ON-OFF (6)	↓		PCM	Binary	Bilevel
PY (20)	Pyrotechnic Current Pulse (20)	Pyrotech	Pulse	SPU	Pulse Detector	Bilevel
PY (9)	Pyrotechnic Arm Relay (9)	Pyrotech	Bilevel	PCM	Binary	Bilevel
ST 6-8	Power Supply Voltage (3)	Sequencer	–	SPU	dc Signal Conv	0 to 5Vdc
ST 2	Frequency Monitor Reference	Sequencer	Bilevel	PCM	Binary	Bilevel
ST 3	Command Receipt Parity Check	Sequencer	Bilevel	PCM	Binary	Bilevel
TP 4-7	Power Supply Voltage (4)	Test Prog.	–	SPU	dc Signal Conv	0 to 5Vdc
TP 1	Update Received	Test Prog.	Bilevel	PCM	Binary	Bilevel
TP 2	Routine in Progress	Test Prog	6 bits	PCM	Binary	Digital
TP 3	Internal Clock	Test Prog.	6 bits	PCM	Binary	Digital
AT 8	Tracking Recvr AGC	Antenna	0–5Vdc	–	–	0–5Vdc
AT 15	Receive Antenna Reverse Pwr	Antenna	0–5Vdc	–	–	0–5Vdc
AT 16	Transmit Antenna Reverse Pwr	Antenna	0–5Vdc	–	–	0–5Vdc
AT 1-3	Antenna Monitor (3)	Antenna	0 or 28Vdc	PCM	Binary	Bilevel
AT 9-14	Antenna Monitor (6)	Antenna	0 or 28 Vdc	PCM	Binary	Bilevel
AT 17	Antenna Monitor	Antenna	0 or 28 Vdc	PCM	Binary	Bilevel

the most part will be modifications or evolutions of existing designs influenced by VOYAGER peculiar constraints. Those principal constraints influencing the modifications are sterilization, low power consumption, satisfactory operation in a hard vacuum environment for approximately 6,000 hours, and satisfactory operation after a dormancy period of approximately 6,000 hours. Specific requirements for the three areas of instrumentation equipment are delineated below.

7.2.2.1 Transducers - The specific measurement requirements are:

Temperature - Extensive structural, equipment, and component temperature measurements are required to provide important temperature-time histories during all mission phases and SL operation for:

- Verification of proper thermal control performance
- Verification that temperature critical electronic components and batteries are maintained within the controlled temperature spans
- Indication of critical electronic component operating temperatures
- Diagnosis of failures and failure mode determination

Pressure - Measurements of the thermal control heat pipe system pressures are required during all mission phases and SL operation.

Position - Measurement of the SL antenna gimbal positions is required during interplanetary cruise, in-flight checkout, and during SL daytime operation.

7.2.2.2 Signal Process Unit - The following signal conditioning is required in the signal process unit for:

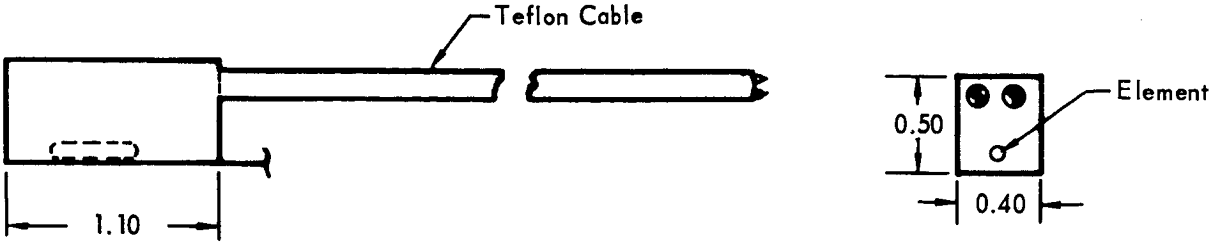
- Monitoring of power system bus voltages and telemetry, sequencer and test programmer regulated voltages
- Current monitoring of the power system battery charge current intermittently during space flight
- Detection of the pyrotechnic firing current pulse to each squib circuit

7.2.2.3 Instrumentation Power Supply - The main requirement of the instrumentation power supply is to convert 28 Vdc battery power to precision regulated voltages with high efficiency and long term stability and reliability for excitation of the temperature sensors and potentiometric transducers during all mission phases and during SL operation.

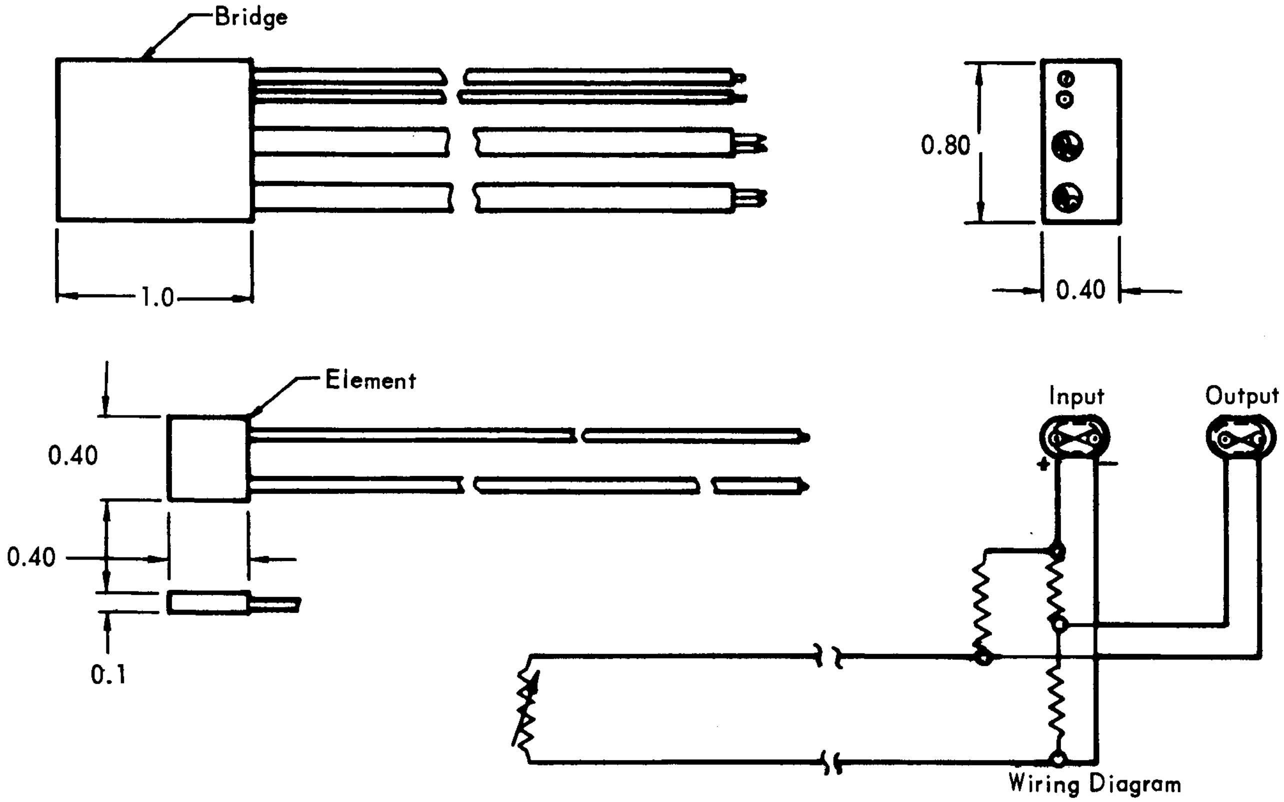
7.2.3 Physical Characteristics - The size and weight of typical transducers are given in Figure 7.2-1; outline drawings of those transducers with reference part numbers are illustrated in Figure 7.2-3.

7.2.3.1 Transducers - The temperature sensors will be connected in a conventional wheatstone bridge arrangement of two types, i.e., integral bridge and element or

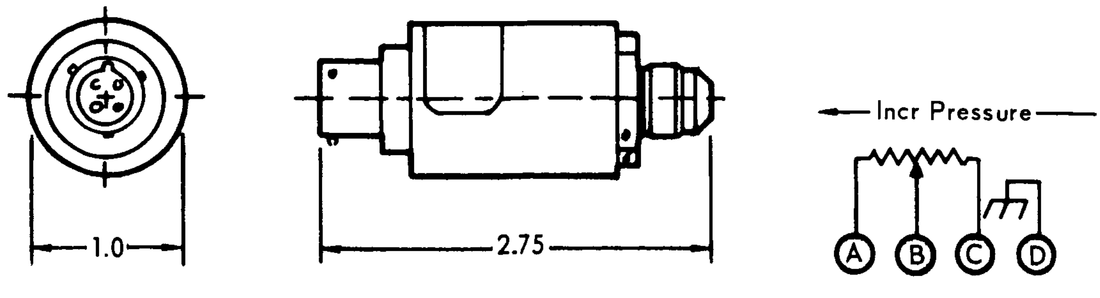
SLS REPRESENTATIVE TRANSDUCERS



55P886010-5 Temperature Sensor/Integral Bridge & Element



55P886010-7 Temperature Sensor/Remote Element & Bridge



55P886008-39 Pressure Transducer

Figure 7.2-3

separate element and bridge. The integral bridge sensors have a platinum resistance element and bridge completion network molded into one integral unit. The sensing elements are fully annealed pure platinum wire mounted in a strain free manner. Where it is not possible to mount an integral bridge sensor, separate element and remote bridge will be used. Depending on the location, surface temperature sensors are attached by cementing or spot welding of flanges. Silver doped epoxy cement will be used for good heat transfer.

Pressure transducers will be of the potentiometric type. The mechanical portion of the pressure transducer is a bellows which varies the wiper position of a potentiometer with input pressure variation.

The position transducers will be of the potentiometric type. These transducers will be an integral part of the antenna erection mechanism and their configuration will be tailored to the antenna design.

7.2.3.2 Signal Process Unit - The SL SPU will be a self-contained unit consisting of plug-in solid state, signal converter modules and associated power converter modules, interconnecting wiring, interface connectors, necessary hardware, and a suitable enclosure. The SPU will be designed for flexibility to accommodate changes in quantity, type and range of measurements. The initial configuration will have the following types of modules with one or more signal converters per module:

- o Voltage Monitor
- o Current Monitor
- o Pyrotechnic Current Pulse Detector
- o Power Supply

Each module of the same type will have standardized dimensions and connector pin assignments for interchangeability. The configuration of the SPU is governed by the quantity of modules required for SL measurements. A preliminary estimate of the SPU size is 14 modules in a 8" x 6" x 4" configuration, weighing approximately 6 pounds. This initial configuration provides for 10% excess signal conditioning capability. Total power consumption is estimated to be 8 watts.

7.2.3.3 Instrumentation Power Supply - The Instrumentation Power Supply is a self-contained unit consisting of a solid state dc/dc converter, regulator and filter circuitry, interface connector, necessary hardware and a suitable enclosure. The unit will be approximately 3.5" x 2.5" x 1.0" with a maximum weight of .5 pound and a maximum power consumption of .5 watts.

7.2.4 Operation Description - The functional operation of the instrumentation equipment is illustrated in the block diagram in Figure 7.2-4. The Instrumentation Equipment provides the following functions throughout the mission:

- o Subsystem status cruise monitoring data
- o Subsystem in-flight checkout data
- o Failure diagnostic data

Information concerning the mission phases and sequences during which the individual transducers and signal conditioners are required to be in operation appears in the SL Instrumentation List of Part B Volume III. Functional operations are discussed further in the following sub-paragraphs.

7.2.4.1 Transducers - The temperature sensors and potentiometric pressure transducers are in operation throughout all mission phases to Mars surface impact and during SL operation. The Instrumentation Power Supply provides excitation power.

7.2.4.2 Signal Process Unit - The Signal Process Unit voltage and current monitors and pyrotechnic current pulse detectors are controlled by the SL telemetry equipment at the times required.

7.2.5 Performance Characteristics

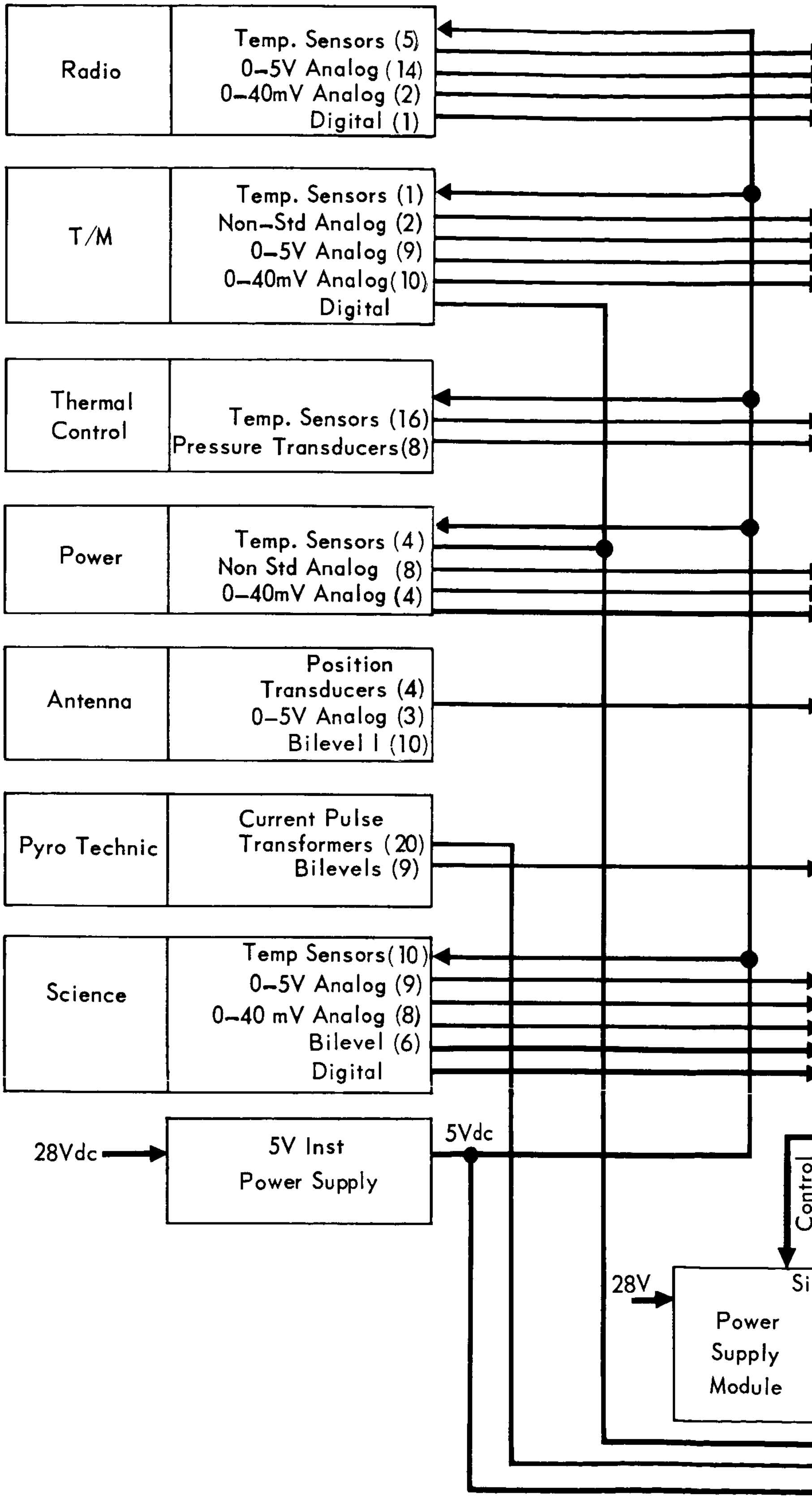
7.2.5.1 Transducers - The transducer performance summaries are tabulated below:

	Temperature Sensor	Pressure Transducer	Position Transducer
Excitation	5.0 ± .005 Vdc	5.0 ± .005 Vdc	5.0 ± .005 Vdc
Power Consumption	2mW	1.25 mW	1.25 mW
Output Signal	0 to 40 mVdc	0 to 5 Vdc	0 to 5 Vdc
Theoretical Transfer Function	Linear	Linear	Linear
Output Impedance	500 ohms max	5K ohms max	5K ohms max
Static Error Band	1% FS	2% FS	2% FS

7.2.5.2 Signal Process Unit - The Signal Process Unit (SPU) performance summary is

Input Power	28 ± 5 Vdc
Total Power Consumption	8 watts
dc Signal Converters	
o Input Signal Impedance	500K ohms min
o Output Signal	0 to 5 Vdc
o Output Impedance	2K ohms max
o Error	±1% FS
o Ripple and Noise	20 mV max
o Frequency Response	±1% DC to 100 Hz

SLS INSTRUMENTATION EQUIPMENT BLOCK D



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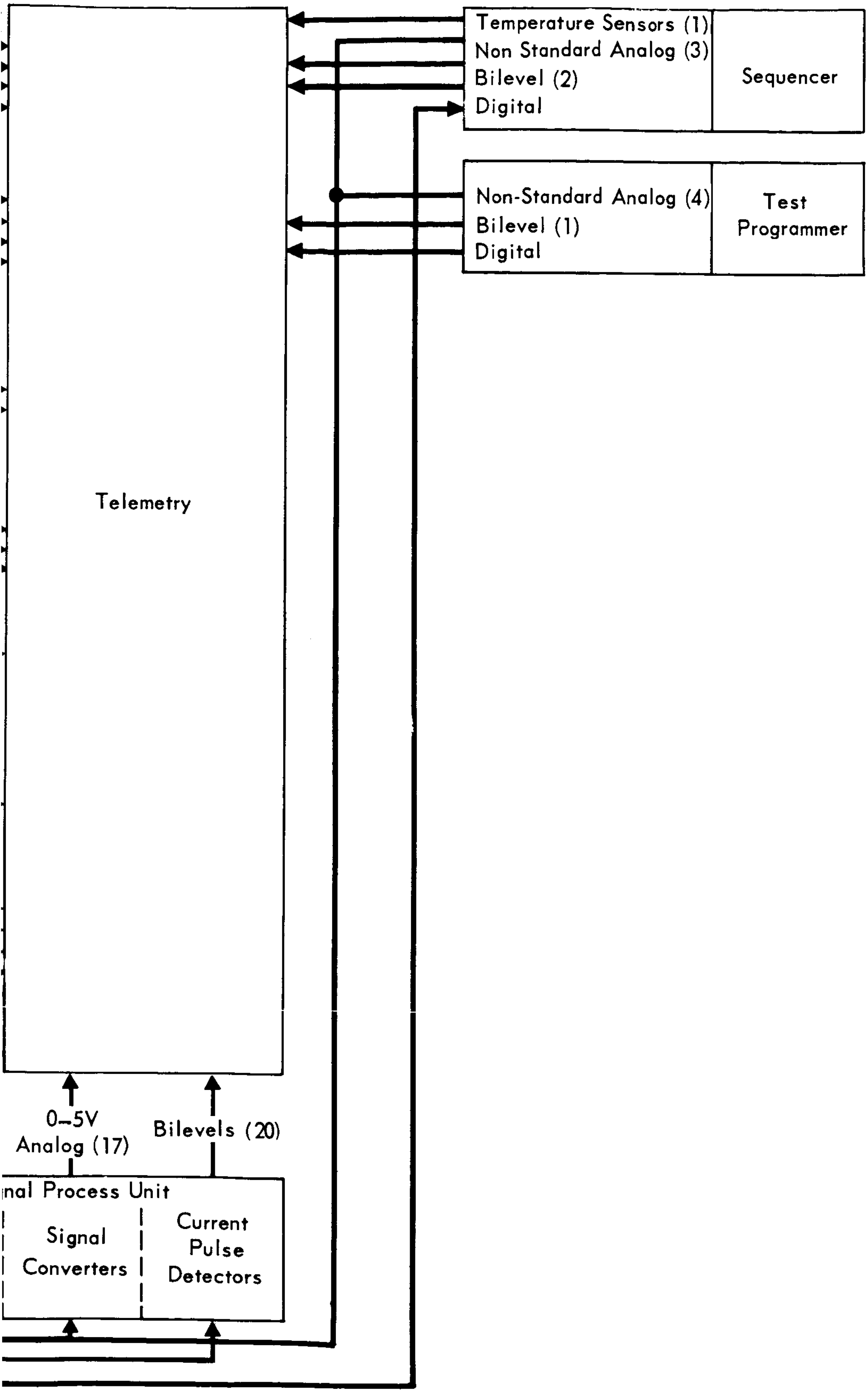


Figure 7.2–4

7. 2 - 8 - 2

Pyrotechnic Current Pulse Monitor

o Discrete Output	0 or 5 Vdc
o Output Impedance	2K ohms max
o Response Time	5 micro sec

7.2.5.3 Instrumentation Power Supply - The dc/dc converter performance summary is tabulated below.

o Input Power	28 ±5 Vdc
o Power Consumption	.5 watts
o Output Voltage	5.0 Vdc
o Output Current	0 to 5.0 ma
o Regulation	0.20%
o Ripple	10mV peak to peak

7.2.6 Interface Definition - Refer to Figure 7.2-4 for interface identification.

7.2.7 Reliability Considerations - A primary objective in the selection of the Instrumentation Equipment design concept was that no instrumentation failure would cause a significantly degrading or possible catastrophic direct effect on any functional SL subsystem. To adequately perform all functions, the Instrumentation Equipment must survive launch environment and operate reliably throughout interplanetary cruise to Mars surface impact and during SL operation. The design features sturdy mounting of all sensors and minimum operating electrical stress to assure reliable long duration operation. In addition, heat sink provisions are required to assure low operating thermal stress. A high signal conditioner to source impedance will be provided at all times. That is, isolation will still be provided in the event of a signal conditioner failure or shutdown.

The major reliability factors considered in selecting the transducer types were: proven reliability, inherent simplicity, and where possible high level output without amplification.

While instrumentation failures must be minimized, the system should be capable of tolerating some individual instrument degradation. For failure tolerance, two techniques have been considered; back-up redundant sensors and direct data correlation between existing data sensors. Thermal testing is effective in correlation of temperature distribution throughout the SL and therefore will provide indirect data retrieval from a failed temperature sensor during a mission. The estimated reliability for the SL Instrumentation Equipment is .987 for mission success.

7.2.8 Test - All modules in the SPU utilizing active elements will provide circuitry for removing input signals and applying at least two known precision input voltages for pre-flight and in-flight calibration and operational confidence checks.

The transducers which utilize only passive circuit elements will not be automatically calibrated during pre-flight and in-flight checks. These units are made of resistors of the highest quality available. The basic transducers would be more reliable than the automatic checking equipment required for remote calibration.

7.2.9 Development Requirements - Instrumentation items are presently available which are potentially capable of meeting the VOYAGER sterilization and mission requirements. Such materials as potting, varnish, insulation, etc., and soldering and assembly techniques used in manufacturing present day transducers and signal conditioners will require changes to meet the stringent VOYAGER requirements. These items will require investigation and development tests.

SECTION 8

SURFACE LABORATORY DATA STORAGE SUBSYSTEM (DSS)

8.1 EQUIPMENT IDENTIFICATION AND USAGE - The Surface Laboratory Data Storage Subsystem (DSS) consists of a magnetic tape recorder/reproducer and associated input/output electronics and support equipment providing a maximum storage capacity of 1.1×10^7 bits. Video data from the Science Data Subsystem (SDS) is recorded during the day from the telemetry buffer storage. Delayed playback is at a rate selected for compatibility with the conditions of the high rate communication link. During the night science and engineering data is recorded for subsequent playback and transmission.

8.2 DESIGN REQUIREMENTS AND CONSTRAINTS - The major design requirement on the DSS is sterilization. Although significant progress has been made in the sterilization of components, three critical items which are major contributors to the magnetic tape system performance and reliability remain problem areas. The precision transport mechanism, particularly the drive belts and lubricants, have a reduced performance after heat sterilization. Laminated magnetic record/reproduce heads develop high stress under thermal cycling causing misalignment and reduced performance. The major item however is the magnetic tape. Under extreme temperature cycling the tape undergoes shrinkage (causing buckling) and loss of adhesion (between the oxide and the backing material). Several approaches are being pursued to resolve these problems. Drive belts and tapes fabricated from Kapton (H-film) by duPont and produced by Kinelogic Corporation and Lash Laboratories respectively, and non-laminated head construction such as those by Phillips Electronics Ltd. are techniques applicable to wider temperature tolerances, the latter with an upper limit of approximately 165°F.

The requirement for storage of 1.1×10^7 bits of digital data at rate of 12 kbps is best satisfied by a multitrack recorder with parallel recording. This reduces the effective bit packing density. This technique and the use of an Iso-Elastic drive or equivalent transport are compatible with the design objective for minimum size,weight and power together with maximum reliability and performance. This reduces the tape capacity, the operating speed, and the drive system complexity.

Playback rate of the stored data must be compatible with the Surface Laboratory Telemetry Subsystem. This requirement is met with a phase-locked loop speed control of the playback drive system and synchronization of the output buffer register providing serial NRZ data to telemetry.

8.3 PHYSICAL CHARACTERISTICS - The DSS occupies a volume of 264 cubic inches, weighs 10 lbs and consumes 10 watts when operating. The system consists of eight tracks and 230 feet of tape. The tape transport is a continuous motion, reel-to-reel, belt-driven configuration with flangeless reels.

8.4 OPERATION DESCRIPTION - The DSS mode of operation is selected by either SL control or Radio Command. The DSS is switched into the high or low rate record modes by command from the telemetry programmer. Recording periods are provided for television and for dumping of the scientific and engineering data accumulated during the non-transmission period. This latter data is temporarily held in the telemetry core buffer. As shown in Figure 8-1 playback mode control is derived from the telemetry, or by the backup radio command. The record mode speed changes are accomplished by frequency countdown and voltage attenuation of the record motor power supply. Precise playback speed control and data synchronization with the telemetry is achieved by a phase-locked loop motor drive control. Phase comparison between the reproduced clock, from the recorder, and the reference clock from the telemetry varies the VCO output providing playback speed control. The skew register accommodates reasonable mechanical misalignment between channels and transport perturbations such as vibration, wow, and flutter. The skew register is followed by shift registers synchronized to the telemetry clock thereby eliminating time displacement errors associated with digital recording.

The Iso-elastic drive transport configuration includes a seamless pressure belt which encircles the periphery of the tape pack and is driven by a differential capstan configuration. Tape packs are kept under positive pressure.

The SL baseline mission sequence (morning landing) results in the following time profile for the DSS:

a. Record 4.3 x 10^6 bits of low-resolution (9000 bps) TV during morning.

b. Playback stored data at 600 bps during day.

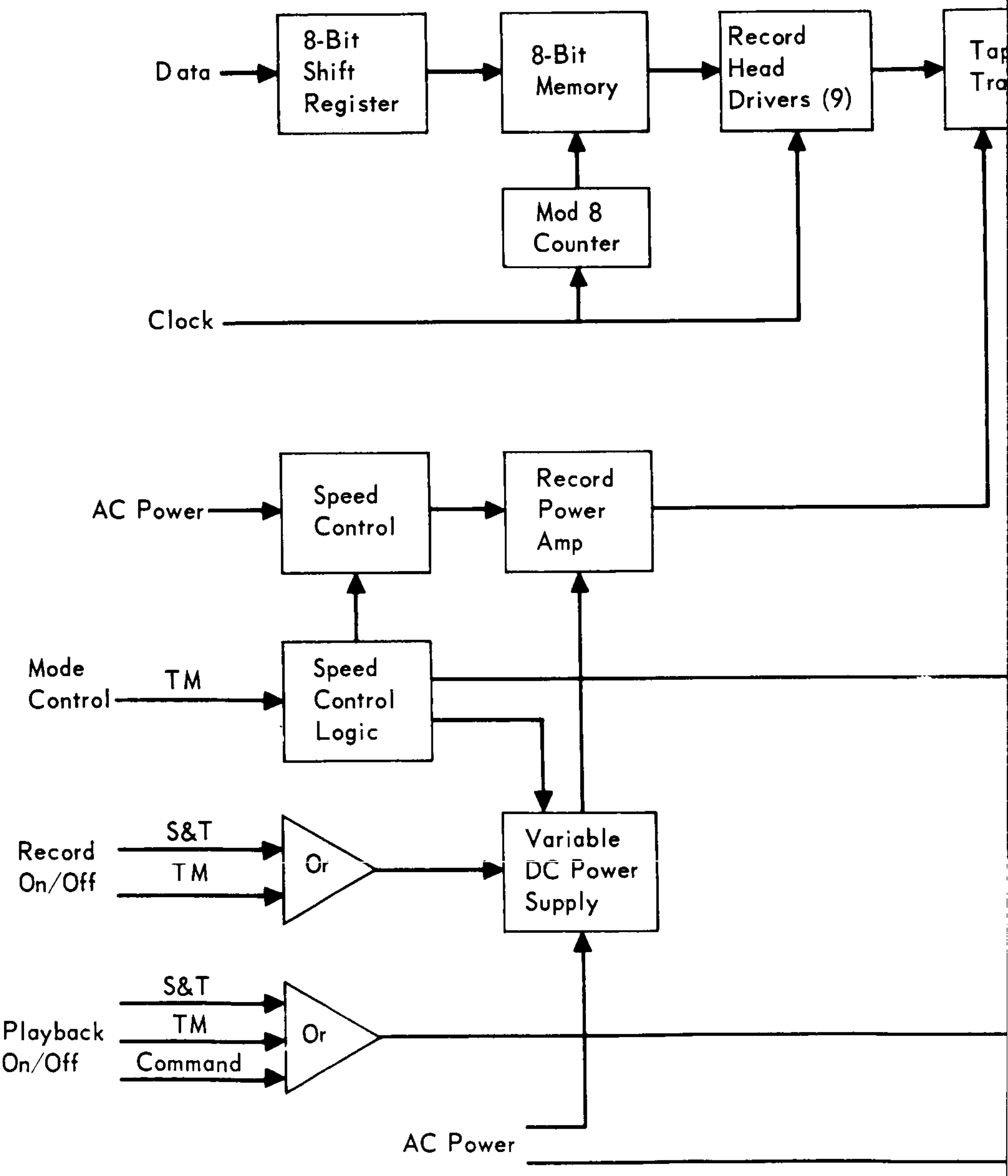
c. Record 4.8 x 10^6 bits of high-resolution (12,000 bps) TV during evening.

d. Record approximately 10^6 bits of science and engineering data overnight in four periods of about 250,000 bits each.

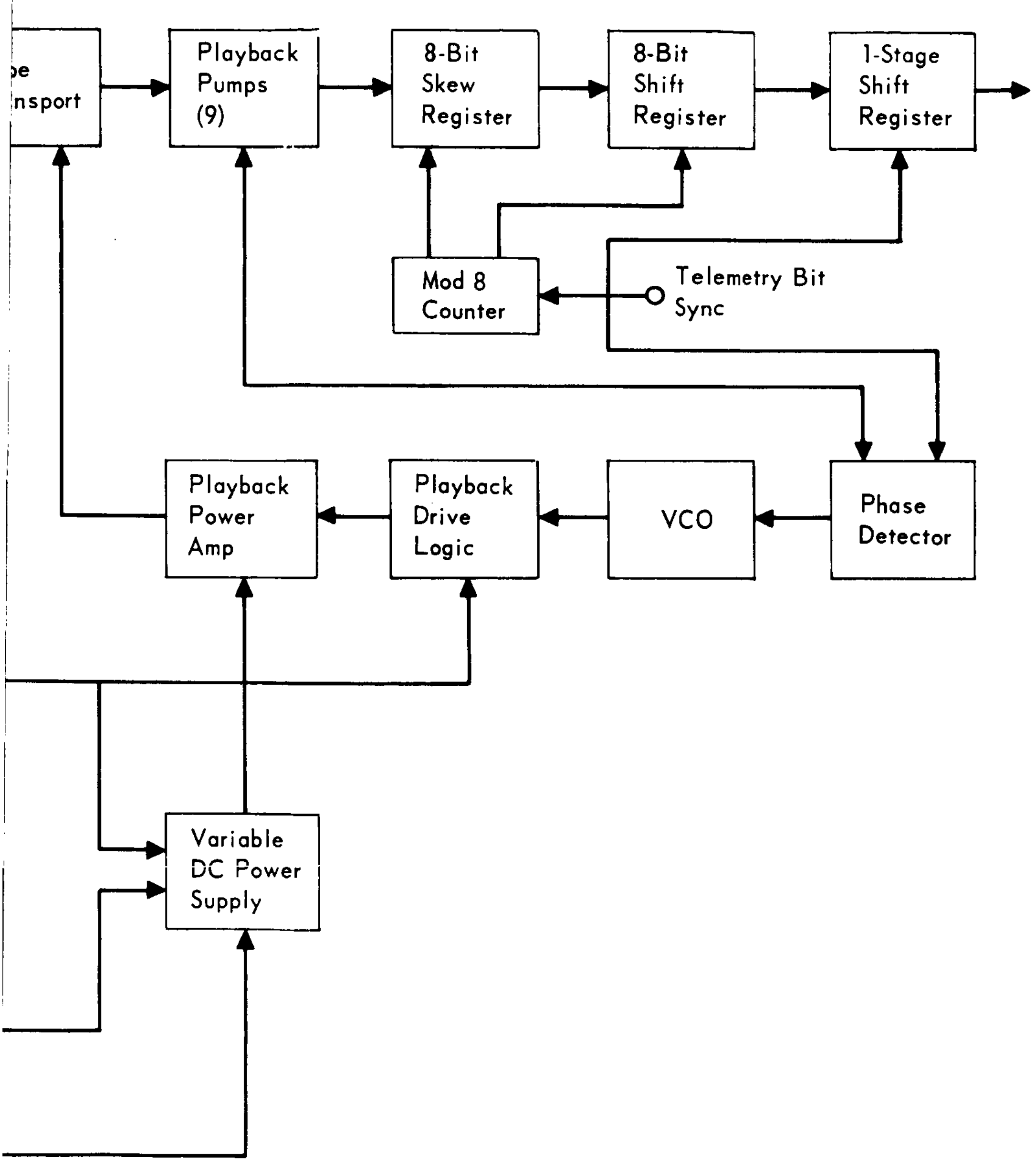
e. Playback stored data at 600 bps during the second day.

Versatility will be built into the design to allow non-destruction of the initial TV, i.e., Item (a) above, by allowing sufficient tape capacity so that Item (c) can be recorded on unused tape. In addition, the tape capacity will allow all data items (a), (c) and (d) to be stored prior to telemetry transmission. The bit pack density requirements are held to a conservative 500 bpi to provide additional

DSS BLOC


Data
8-Bit Shift Register
8-Bit Memory
Record Head Drivers (9)
Tap
Tra
Mod 8 Counter
Clock
AC Power
Speed Control
Record Power Amp
Mode Control
TM
Speed Control Logic
Record On/Off
S&T
TM
Or
Variable DC Power Supply
Playback On/Off
S&T
TM
Command
Or
AC Power

K DIAGRAM



8-3-2

Figure 8-1

96/

flexibility (i.e., recording high rate TV on the low record speed) and reliability.

The DSS will include as a part of its operational capability these additional features:

a. Provide for external control of tape speed, data mode, record, and playback functions.

b. Provide status signals for "recording data", "reproducing data", "recorder malfunction", "start-of-tape", "end-of-tape", and "middle-of-tape."

c. Provide signals to telemetry for case temperature, internal pressure, and operating status.

d. Internal supplies and inverters for operation of the tape transport and DSS electronics from the 28 volts (nominal) SL power bus.

8.5 PERFORANCE CHARACTERISTICS - The DSS performance characteristics are given below:

Capacity:	1.1×10^7 bits
Data Input:	9000 bits/sec (bps) serial NRZ 12,000 bps serial NRZ
Record Speeds:	3 in/sec (ips); 2.25 ips
Bit Packing Density:	500 bits per track inch
Max. Record/Reproduce Ratio	40:1
Reproduce Speeds:	0.3 ips; 0.15 ips; 0.075 ips
Data Output:	1200 bps serial NRZ; 600 bps serial NRZ, 300 bps serial NRZ
Wow and Flutter:	Not applicable
Bit Error:	Less than 1 bit in 10^5

8.6 INTERFACE DEFINITION - Figure 8-2 is the interface list for the DSS.

8.7 RELIABILITY AND SAFETY CONSIDERATIONS

8.7.1 Mission Success Definition - The SL Data Storage Subsystem (Tape Recorder) is required to successfully record the high rate television data and the nighttime data during the in-flight checkout phase and during the landed operations phase of the mission. Playback is required on command from the SLS at a rate compatible with the SLS-Earth link.

8.7.2 Reliability Model - The SL Data Storage Subsystem has an assessed reliability of a 0.981 probability of successful performance. Figure 8-3 is the reliability model for the tape recorder.

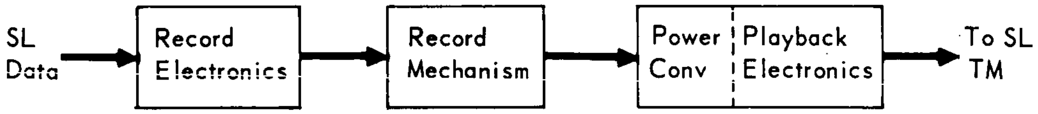
8.7.3 - Mission Failure Modes and Effects - Figure 8-4 shows the failure fault tree for the DSS Tape Recorder. Failure of the unit in either the record or playback mode will result in the loss of a part or all of either the television or nighttime

DSS INTERFACE DEFINITION

INTERFACE FUNCTION	SOURCE	DESTINATION
Record On/Off	Sequencer & Timer Telemetry Equipment	
Record Mode Control	Telemetry Equipment	
Input Data	Telemetry Equipment	
Input Clock	Telemetry Equipment	
Playback On/Off	Sequencer & Timer Command Subsystem Telemetry Equipment	
Output Data		Telemetry Equipment
Output Data Sync	Telemetry Equipment	
Status Signals		Telemetry Subsystem
Primary Power	Power Subsystem	

Figure 8-2

SURFACE LABORATORY DATA STORAGE RELIABILITY MODEL



$$P_S(\text{Stored Data, 149 hr}) = e^{-0.018846} = 0.981331$$

Figure 8-3

SURFACE LABORATORY DATA STORAGE RELIABILITY FAULT TREE

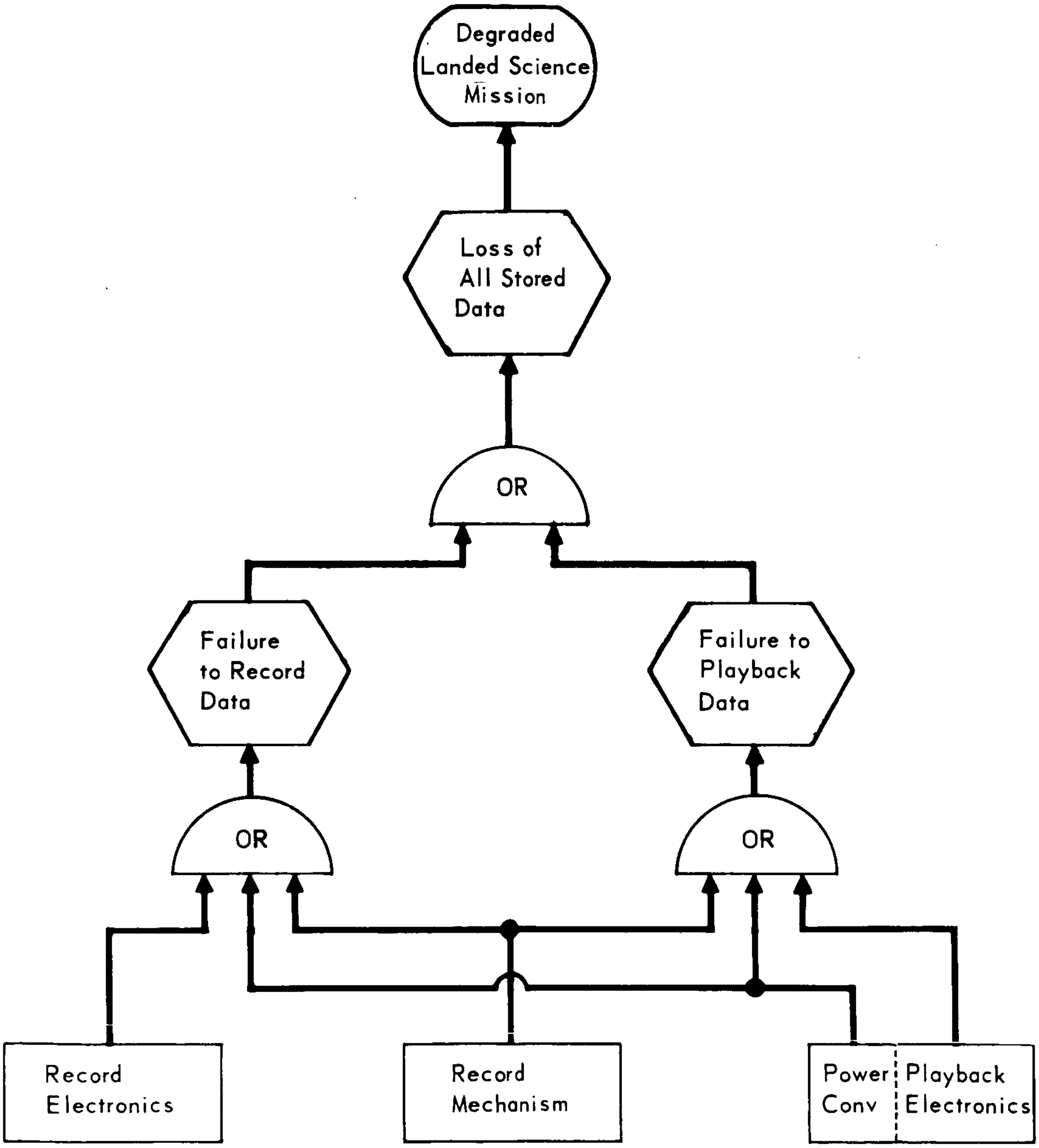


Figure 8-4

data or both depending on the time of failure occurrence. Such a failure resulting in a loss of a portion of the landed science data would be a degradation of the Landed Operations Mission.

8.7.4 Complexity Estimate - The Tape Recorder is estimated to have a total piece parts count of 1,248 including electronic, mechanical, and electromechanical parts. Critical applications are bearings under shock and vibrational stresses and the magnetic tape, drive belts and lubricants in sterilization and storage environments, especially in maintaining critical tolerances that affect bit error rate. Figure 8-5 details the estimated tape recorder parts count.

8.7.5 Safety Considerations - Not applicable since no pyrotechnics or high voltages are employed.

8.8 TEST - Testing will be conducted as listed in the test matrix Figure 8-6 in accordance with the Integrated Test Plan.

Tests will be performed prior to canister enclosure, after enclosure prior to final sterilization, after sterilization and during pre-launch operations. All ground testing shall be performed with the use of Operational Support Equipment (OSE). In-flight checkout will be performed thru the DSIF. In-flight checkout (pre-separation) is initiated by the appropriate flight capsule test programmer upon command from the DSIF and monitored through the spacecraft telemetry system.

Tests of the SLS Data Storage Tape Recorder are accomplished as a part of end-to-end devices of the SLS Telemetry Subsystem. Check words are recorded and played back to verify recorder operation.

8.9 DEVELOPMENT STATUS - The problem of sterilization of tape recorders without reducing the reliability remains a design constraint as discussed in 8.2. Further development of sterile assembly techniques may provide a solution.

In addition, problems such as tape blocking, tape-to-head adhesion and migration of bearing lubricant as a result of long duration non-operation during the Interplanetary Cruise Phase will require additional study.

SURFACE LABORATORY DATA STORAGE RELIABILITY PARTS COUNT ESTIMATE

TAPE RECORDER

PART TYPE	λ	RECORD n	PLAYBACK n	TOTAL 2n	$\Sigma n\lambda$	RECORD MECHANISM PART TYPE	λ'	n	$n\lambda$
Capacitor									
Ceramic/Glass	11	14	121	125	125	Drive Belt	1000	4	4000
Solid Tantalum	2		50	50	100	Bearing Assembly	200	2	400
Diode						Pulley Shaft Assembly	1	2	2
General Purpose	0.1	28	166	194	213	Shaft Brg (Ball)	200	4	800
Zener/Refer.	10		11	11	110	Input Brg (Ball)	200	4	800
Resistor						Clutch Spring	250	2	700
Carbon Comp	0.1		2	2	0.2	Pulleys, Input	1	2	2
Film, Carbon/Metal	0.3	56	561	617	186	Tape Drive Belt	1000	1	1000
Variable	11.9		1	1	12	Springs	1	2	2
WW Power	0.5		2	2	1	Pivoted Sleeves	10	2	20
Potentiometer	108		1	1	108	Bearings	200	2	400
Transistor						Ball Brg Pair	200	1	200
General Purpose	5	18	168	186	930	Housing & Ctr Shift	1	1	1
Transformer	5	1	5	6	30	Hub Assy Rotating	1	1	1
Relay	10	1	1	2	20	Tape Roller Assemb	200	6	1200
Inductor	7.5		3	3	24	Mag. Tape	1	1	1
SCR	20		2	2	40				
Rectifier	120		2	2	240				
Record Head	20	2		2	40				
Playback Head	20		2	2	40				
Motor, Drive	300	1	2	3	900				
Totals	–	121	1100	1211	3119		–	37	9529
		(497)	(2611)		(3119)				(9529)

Figure 8–5

SURFACE LABORATORY SYSTEM DATA STORAGE SUBSYSTEM TEST MATRIX

In-Flight Checkout	Pre-Launch	System Test	Telemetry Points	TEST	ACCY REQ
				Non Operative Test	
		X		Input Bit Stream	Digital
		X		Output Bit Stream	Digital
	X	X	X	Memory "Overflow" Signal	Digital
	X	X	X	Memory "Empty" Signal	Digital
X	X	X	X	Power Supply Voltage	2%
X	X	X	X	Power Supply Current	2%
		X		Sequencing Clock Frequency	Digital
		X		Tape Speed	0.1%
X	X	X	X	Tape Direction	Digital
X	X	X	X	Tape Bias Voltage	2%
X	X	X	X	Tape Motor Drive Voltage	2%
X	X	X	X	Command Verification	Digital

Figure 8-6

SECTION 9

SURFACE LABORATORY STRUCTURE SUBSYSTEM

9.1 EQUIPMENT IDENTIFICATION AND USAGE - The Surface Laboratory Structure Subsystem provides support for mounted equipment and structural attachment to the Capsule Bus Lander. Included is integral incorporation of a Thermal Control Subsystem defined in Section 13, Part C, of this Volume. Major elements which comprise the Structure Subsystem are:

a. Support beam framework
b. Heat distribution plate
c. Secondary structure

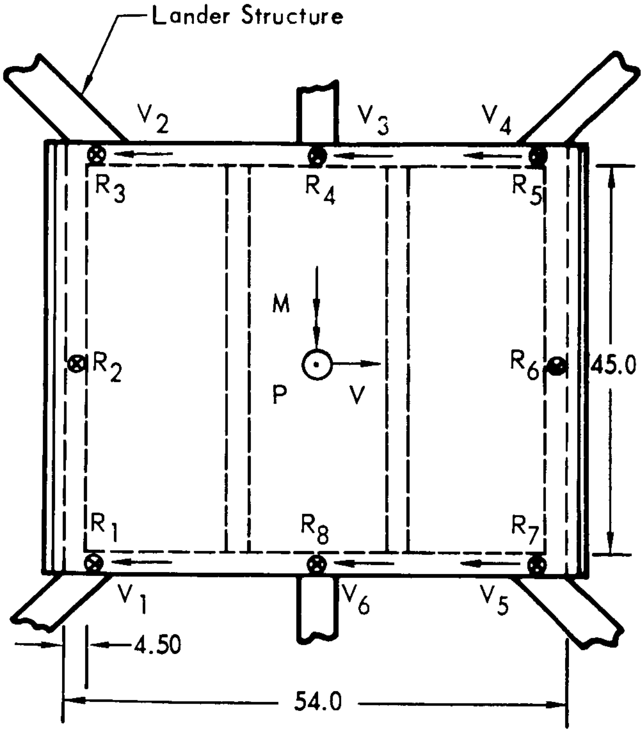
Support Beam Framework - The support beam framework consists of six 6A-4V titanium I-beams. Four beams form a continuous rectangular perimeter and two attach internally so that the four beams are parallel and at 18-inch spacing. This framework provides a rigid multidirectional load path and a four-inch insulating area between the laboratory and the Lander. Attachment of the laboratory to the Lander is accomplished at eight points in the support beam framework. Local stiffeners are provided in the I-beams at the attachment points to provide rigid backup for the interface loads. The critical loading conditions at this interface, which are encountered during landing, are shown in Figure 9.0-1. The framework also supports the heat distribution plate, thermal radiators, secondary structure, insulation, science instruments, telecommunication equipment and associated support equipment.

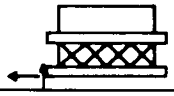
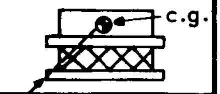
Heat Distribution Plate - This plate is a flat structural sandwich panel of 5456-H343 aluminum alloy shown in cross section in Figure 9.0-2. Stiffeners and bossed areas for equipment attachment are integrally machined into the panel. The panel is continuous over the support beam framework and carries equipment inertia loads to the framework. The panel contains the coolant wicking for the Thermal Control Subsystem defined in Section 13 and provides for coolant gas flow to the thermal radiators. Equipment mounting to the heat distribution plate is shown in Figure 9.0-3.

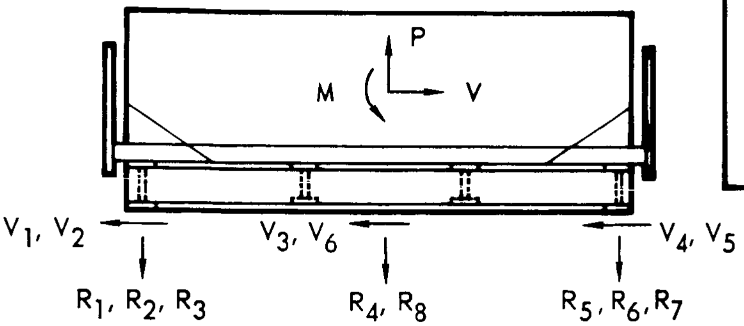
Secondary Structure - Figure 9.0-4 illustrates the equipment mounted externally to the laboratory. Secondary structural support is provided for this equipment.

9.2 DESIGN REQUIREMENTS AND CONSTRAINTS - The Structure Subsystem will support a minimum of 130 pounds of science instrumentation for the critical loading conditions shown in Figure 9.0-1.

SURFACE LABORATORY INTERFACE LOADS



CONDITION	LANDING MAXIMUM ROTATIONAL ACCELERATION	LANDING MAXIMUM LATERAL ACCELERATION
Load		
P (lb)	−6200	− 5760
V (lb)	6200	− 13240
M (in lb)	170,000	0
R_1 (lb)	−2495	−720
R_2 (lb)	−2495	−720
R_3 (lb)	−2495	−720
R_4 (lb)	− 775	−720
R_5 (lb)	945	−720
R_6 (lb)	945	−720
R_7 (lb)	945	−720
R_8 (lb)	−775	−720
V_1 (lb)	1035	− 2210
V_2 (lb)	1035	− 2210
V_3 (lb)	1035	− 2210
V_4 (lb)	1035	− 2210
V_5 (lb)	1035	− 2210
V_6 (lb)	1035	− 2210



Notes: 1) All loads are ultimate and positive as shown.

2) Landed Weight = 2500 lb total, Laboratory Weight ≈ 915 lb.

3) Interface loads are based on an elastic distribution; plane sections remaining plane.

Figure 9.0-1

VOYAGER SURFACE LABORATORY STRUCTURAL ARRANGEMENT

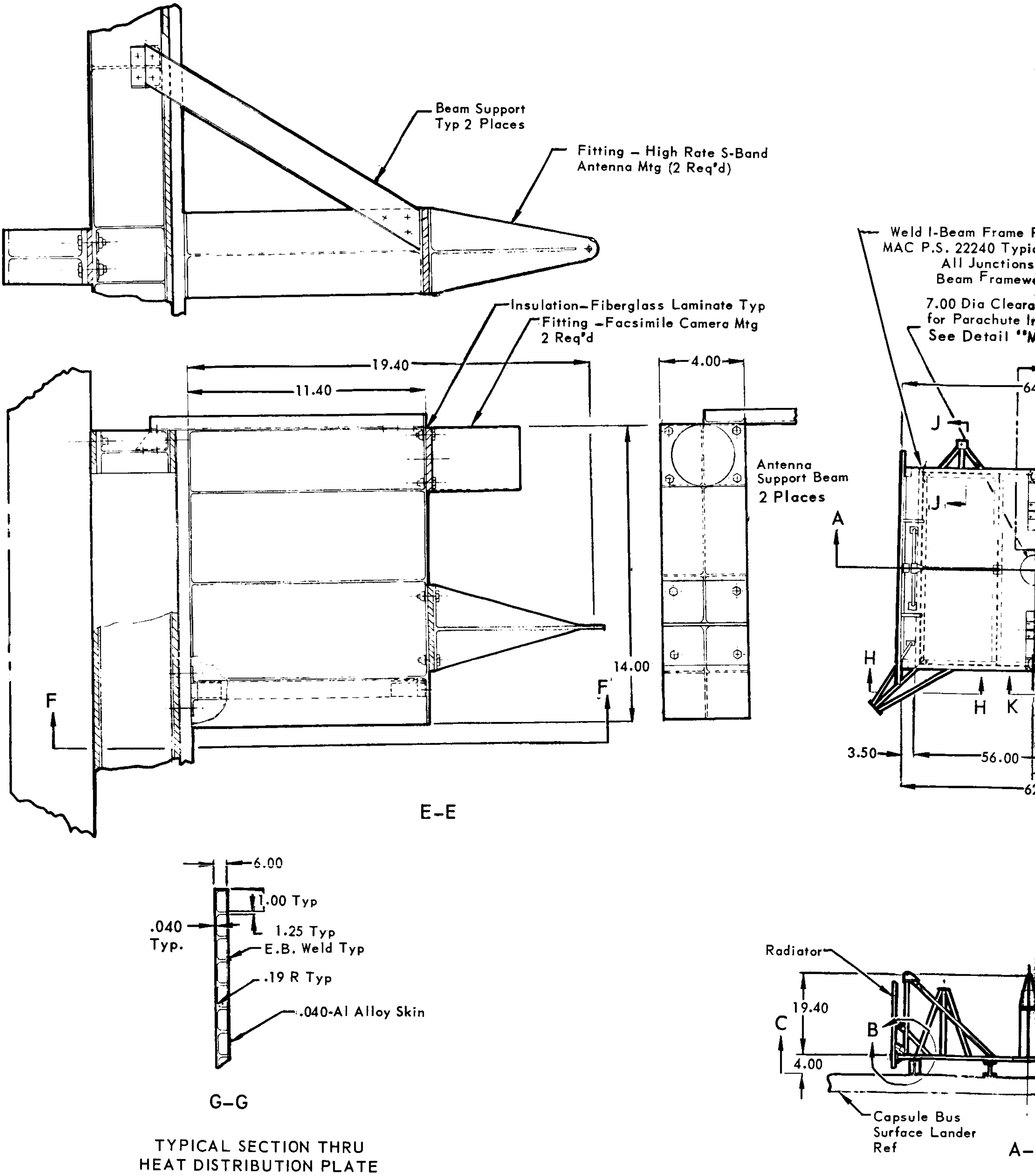
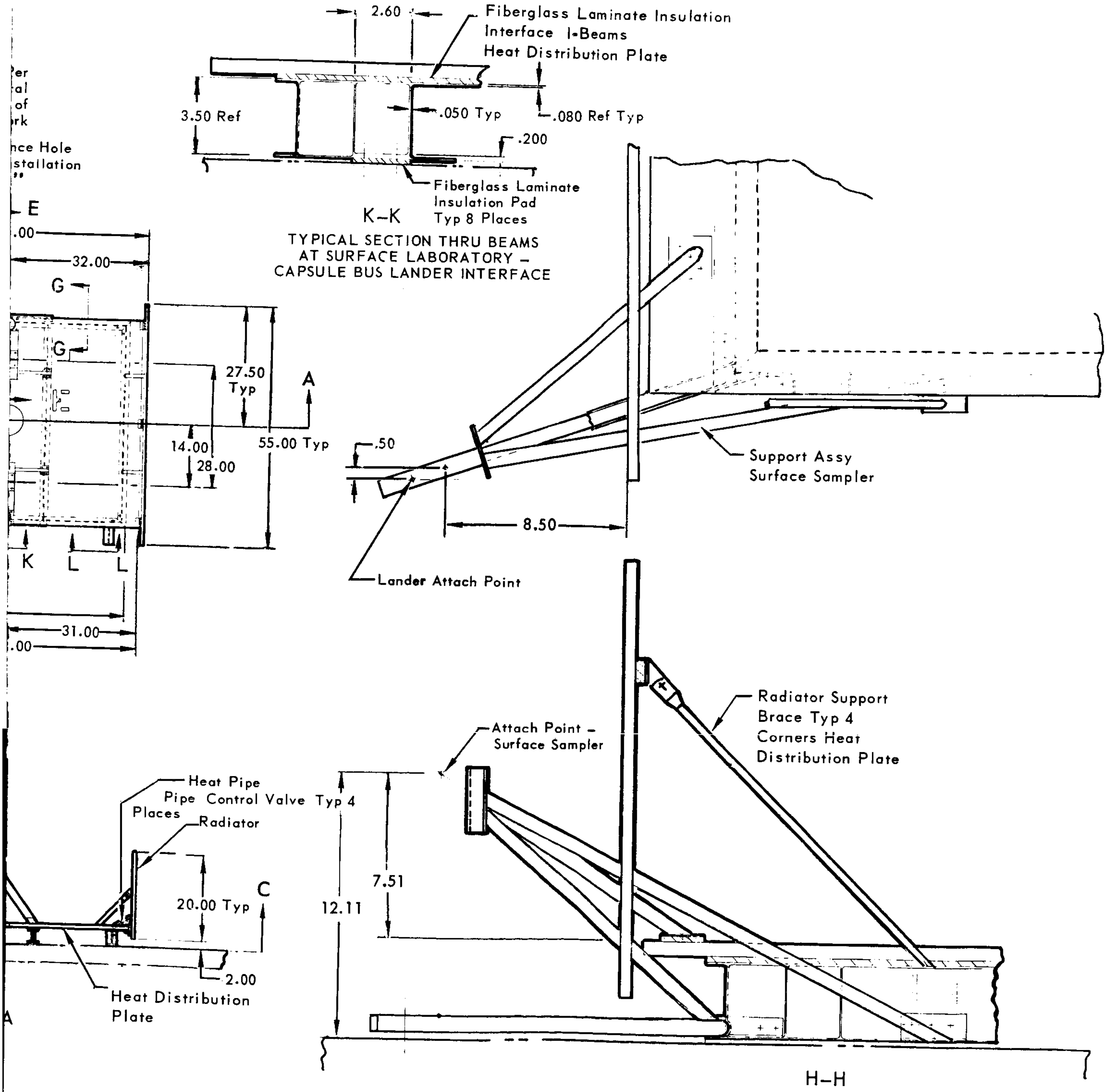


Figure 9.0–2


2.60
Fiberglass Laminate Insulation
Interface I-Beams
Heat Distribution Plate
3.50 Ref
.050 Typ
.080 Ref Typ
.200
Fiberglass Laminate
Insulation Pad
Typ 8 Places
K–K
TYPICAL SECTION THRU BEAMS
AT SURFACE LABORATORY –
CAPSULE BUS LANDER INTERFACE
er
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of
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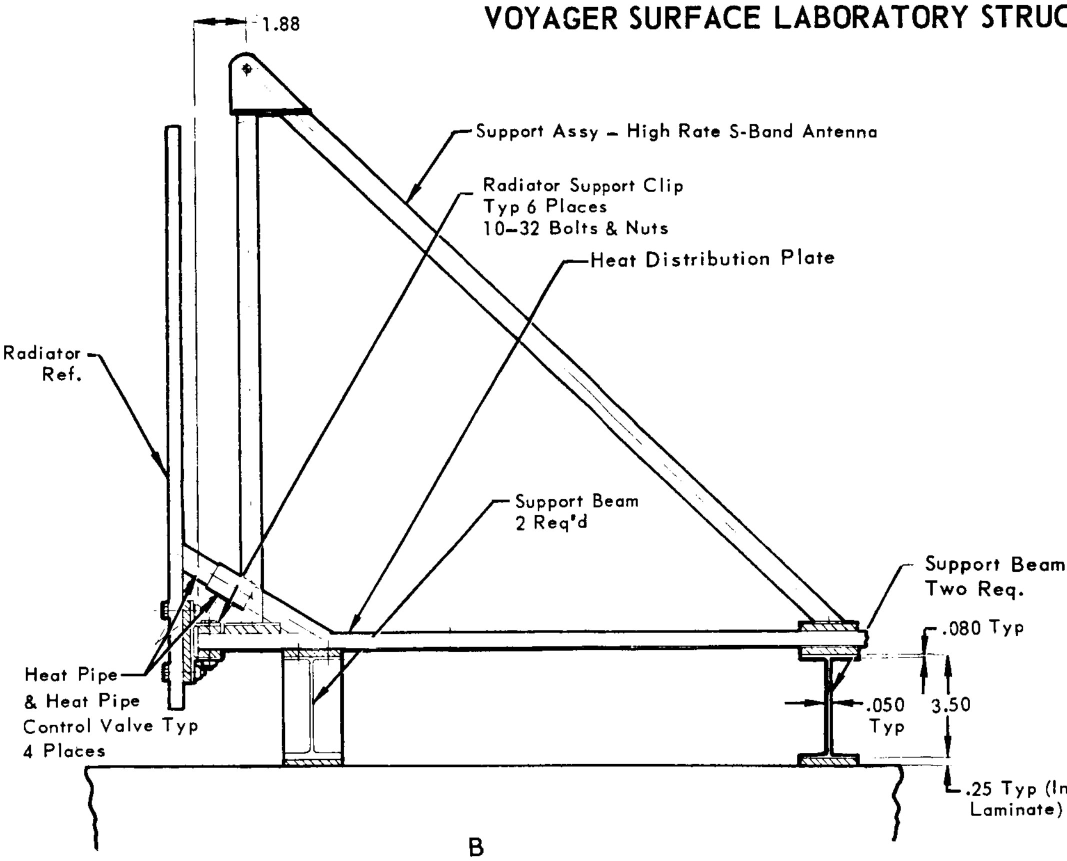
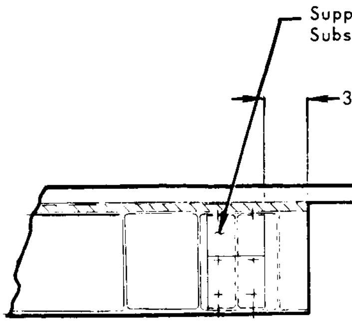
stallation
E
.00
32.00
G
G
27.50
Typ
A
14.00
28.00
55.00 Typ
K
L
L
31.00
.00
.50
8.50
Support Assy
Surface Sampler
Lander Attach Point
Radiator Support
Brace Typ 4
Corners Heat
Distribution Plate
Attach Point –
Surface Sampler
Heat Pipe
Pipe Control Valve Typ 4
Places
Radiator
20.00 Typ
C
2.00
Heat Distribution
Plate
A
7.51
12.11
H–H

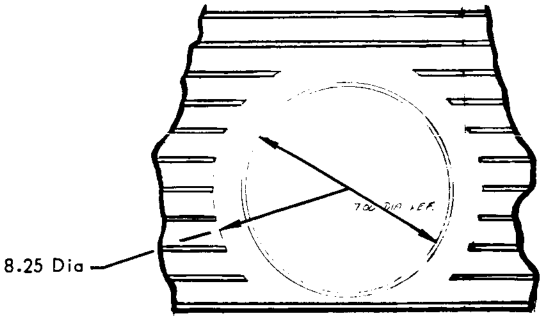
VOYAGER SURFACE LABORATORY STRUCTURAL ARRANGEMENT



B

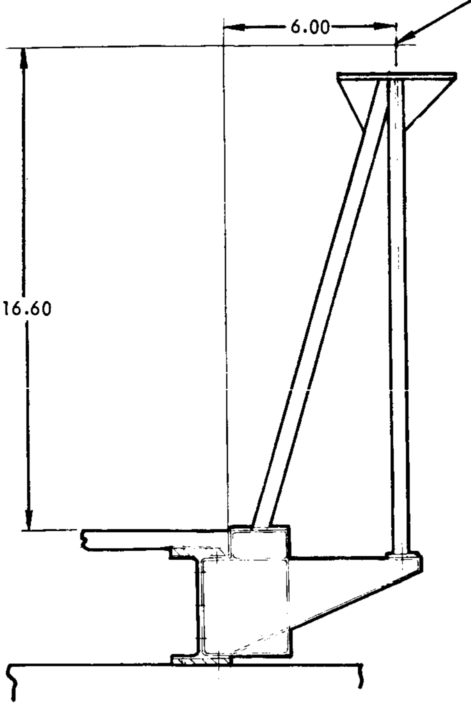


L–L



M

DETAIL AT CENTER HEAT DISTRIBUTION PLATE
.040 SKIN REMOVED FOR CLARITY



J–J

ROTATED 90°

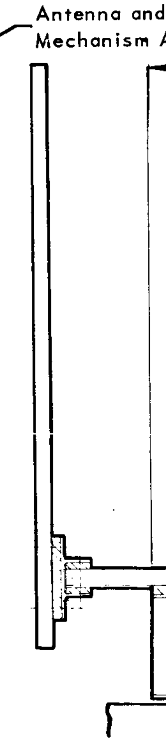
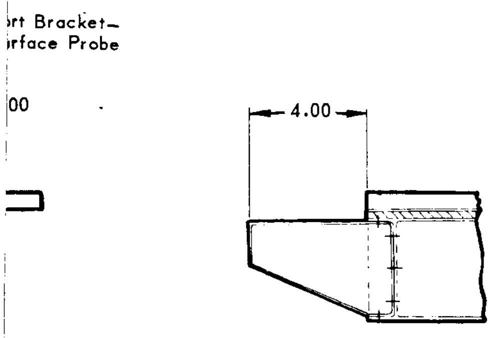
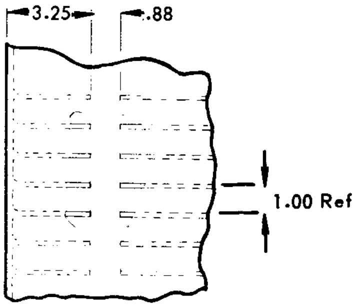


Figure 9.0–2 (Continued)

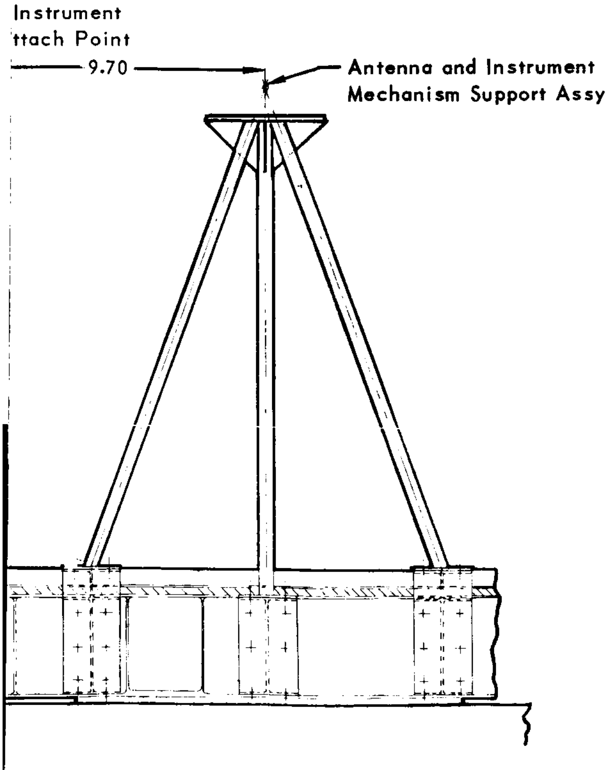
Continued)

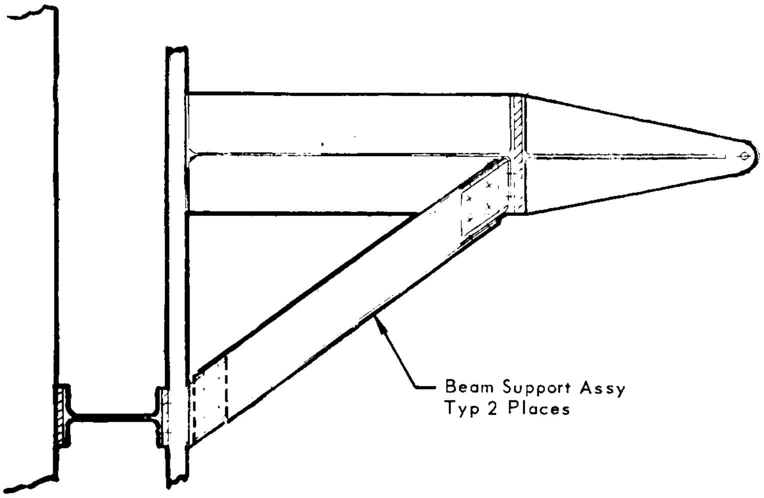




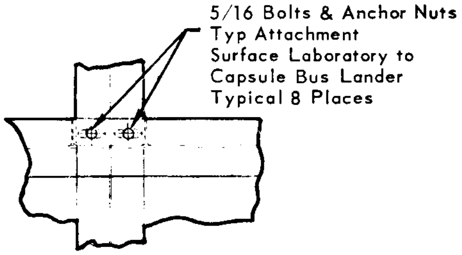
N

Detail of Heat Distribution Plate at Each End Typ.

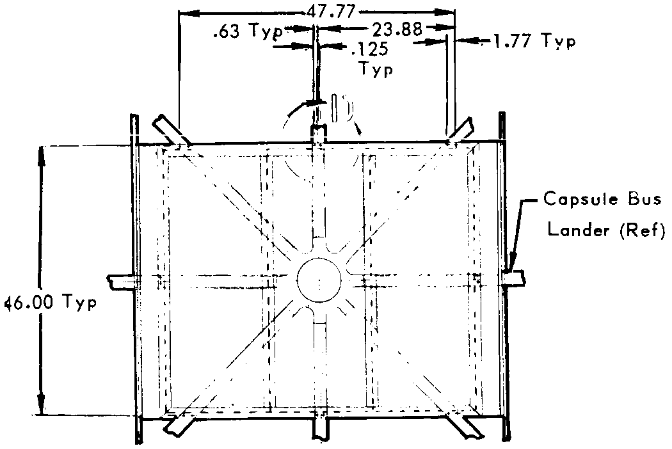




F–F



D



C–C

SURFACE LABORATORY – CAPSULE BUS LANDER INTERFACE

SURFACE LABORATORY EQUIPMENT – GENERAL INTERIOR ARRANGEMENT

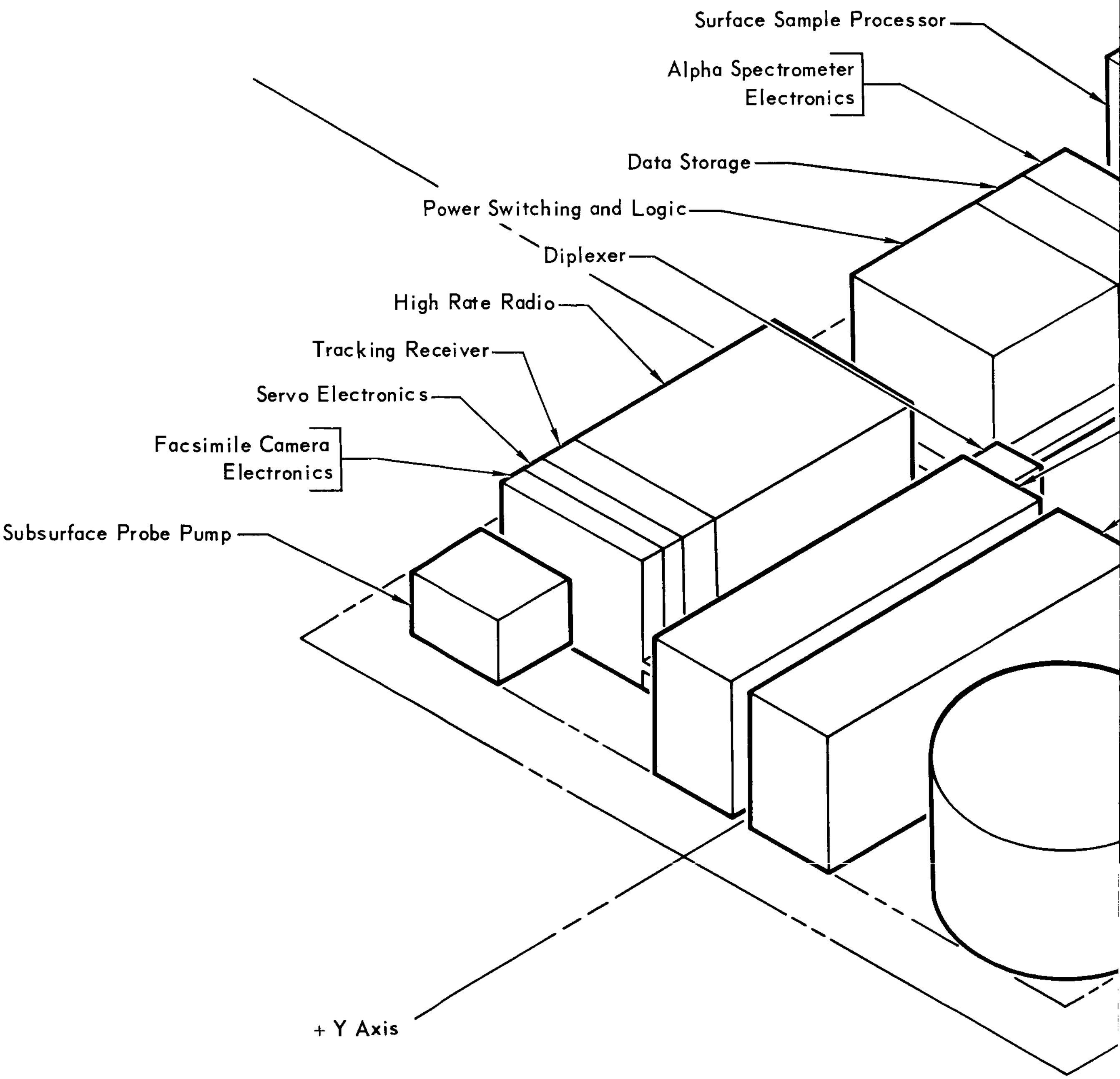
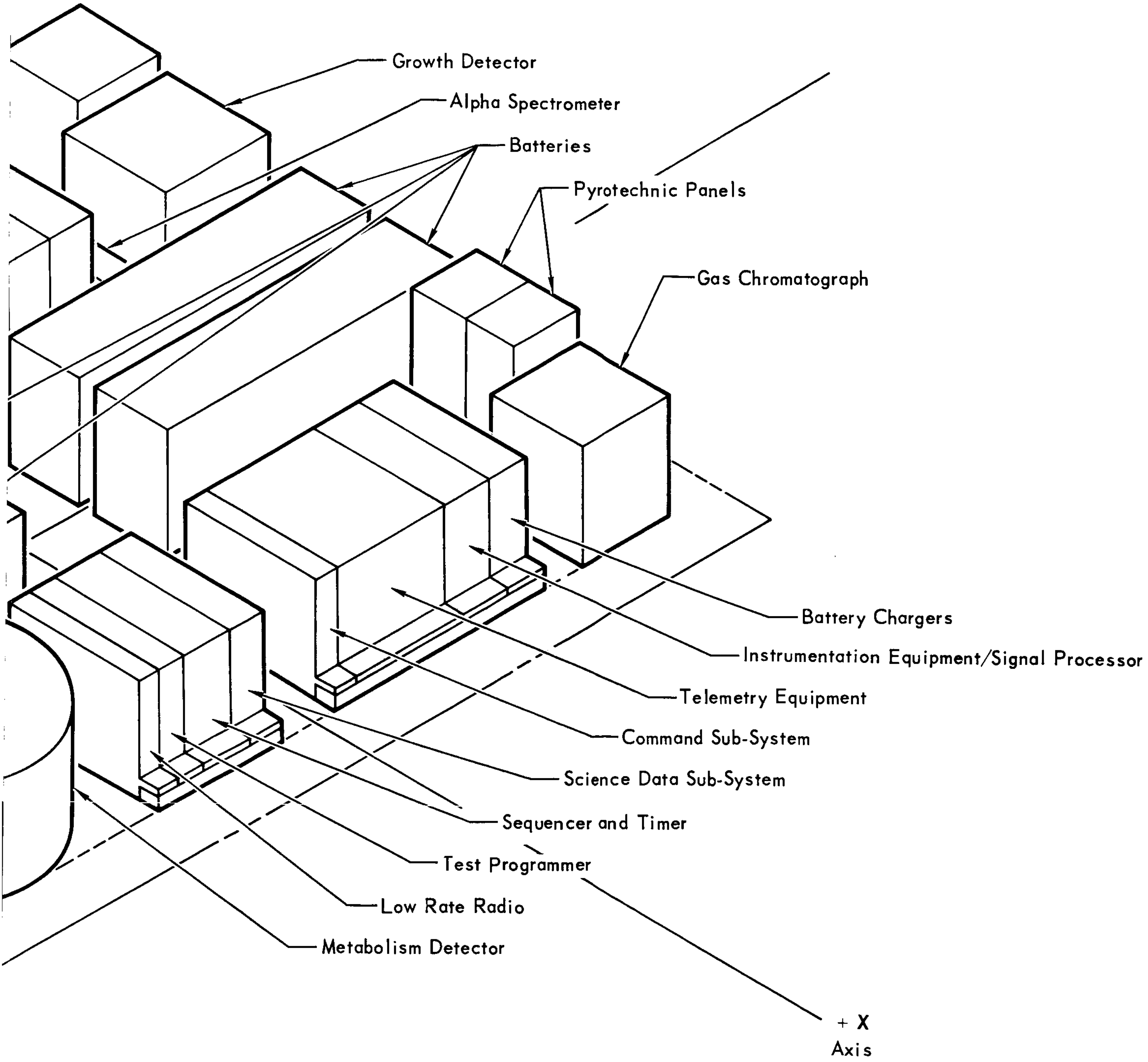


Figure 9.0–3


Growth Detector
Alpha Spectrometer
Batteries
Pyrotechnic Panels
Gas Chromatograph
Battery Chargers
Instrumentation Equipment/Signal Processor
Telemetry Equipment
Command Sub-System
Science Data Sub-System
Sequencer and Timer
Test Programmer
Low Rate Radio
Metabolism Detector
+ X
Axis

GENERAL ARRANGEMENT – SURFACE LABORATORY

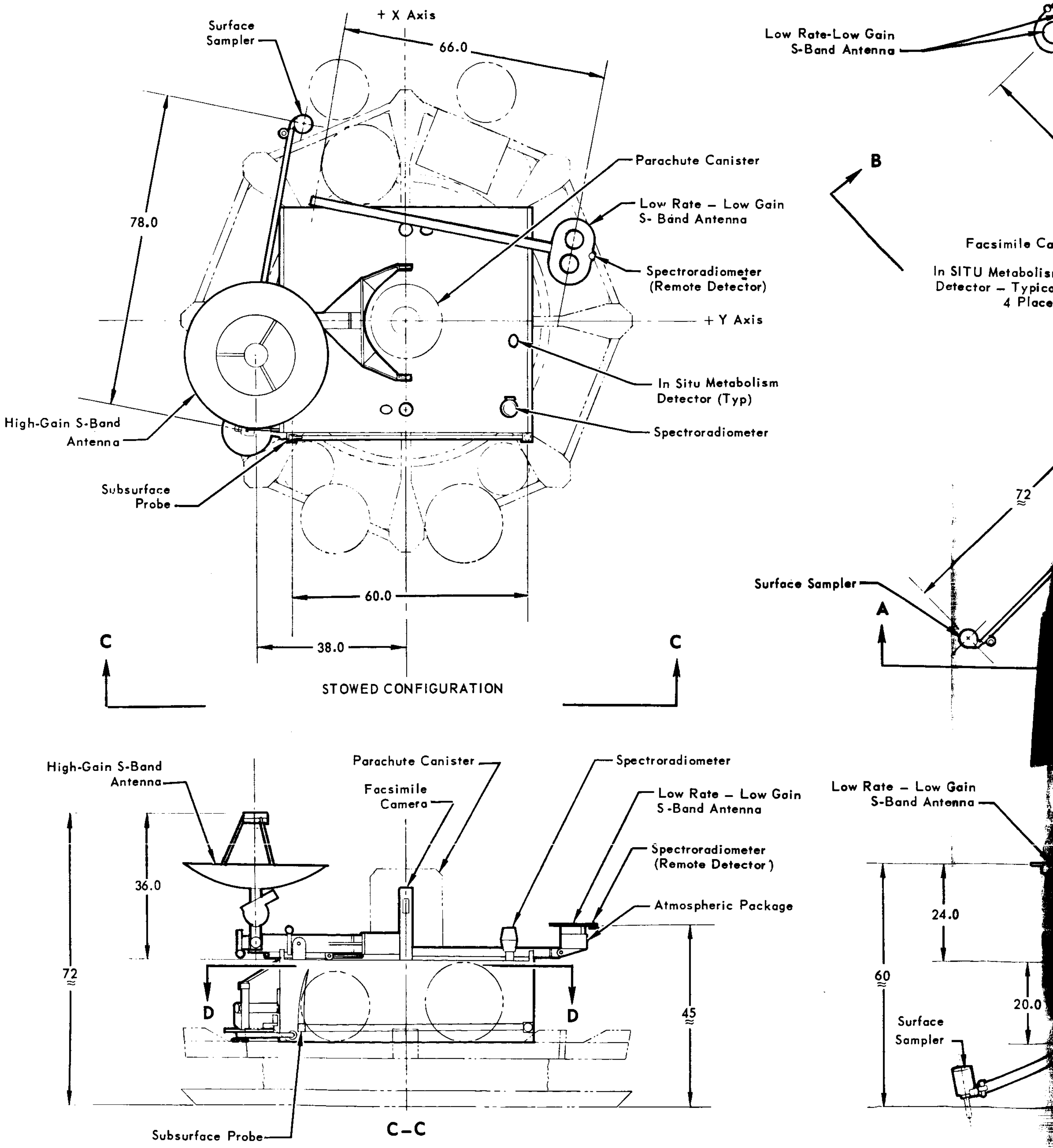
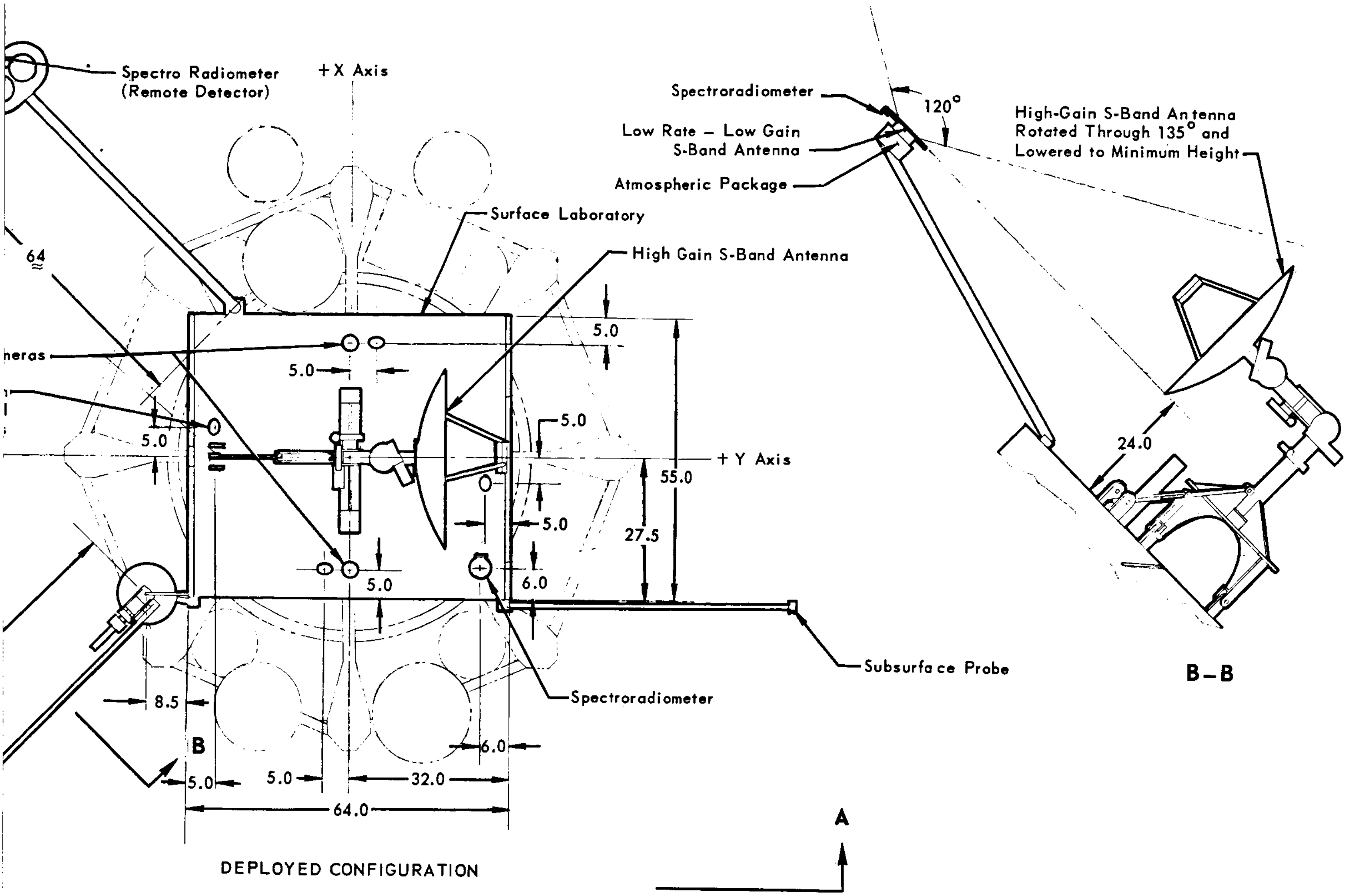
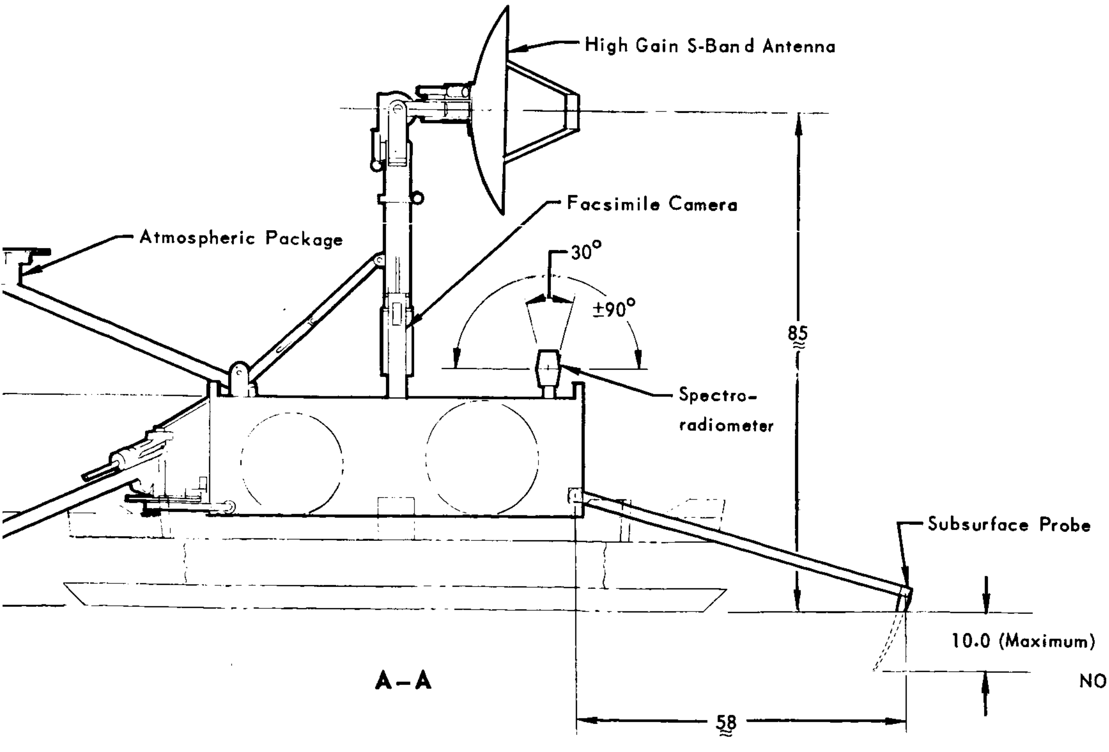


Figure 9.0–4



DEPLOYED CONFIGURATION

B–B



A–A

NOTES: Exterior Equipment Surfaces to be Flame Sprayed with Aluminum Oxide.

GENERAL ARRANGEMENT — SURFACE LABORATORY (Continued)

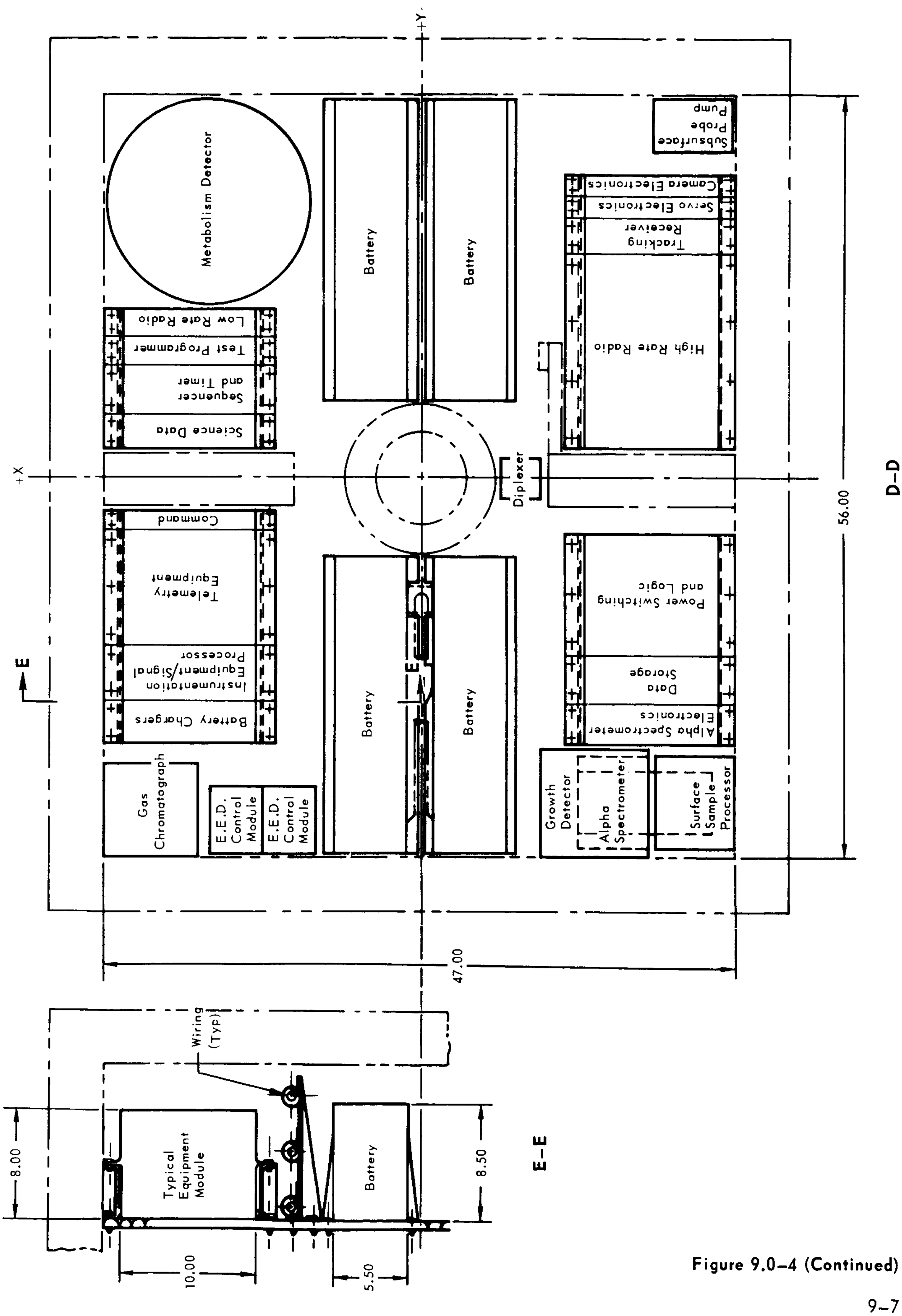


Figure 9.0–4 (Continued)

The Thermal Control Subsystem defined in Section 13 is integrated into the Structure Subsystem. Thermal radiator support, thermal insulation support and insulation attachment is provided.

Design of the structure and equipment mounting arrangement allows clearance for installation of the Capsule Bus Lander parachute through the laboratory.

Accessibility is provided for maintenance of the installed equipment.

9.3 PHYSICAL CHARACTERISTICS - The configuration of the Surface Laboratory Structure Subsystem is shown in Figure 9.0-2 and Figure 9.0-5. Maximum structural weight is 93.5 pounds.

9.4 OPERATION DESCRIPTION - The structure is passive and, as such, performs its function throughout the mission life.

9.5 PERFORMANCE OBJECTIVES - The structure provides a flat, stable rigid mounting surface.

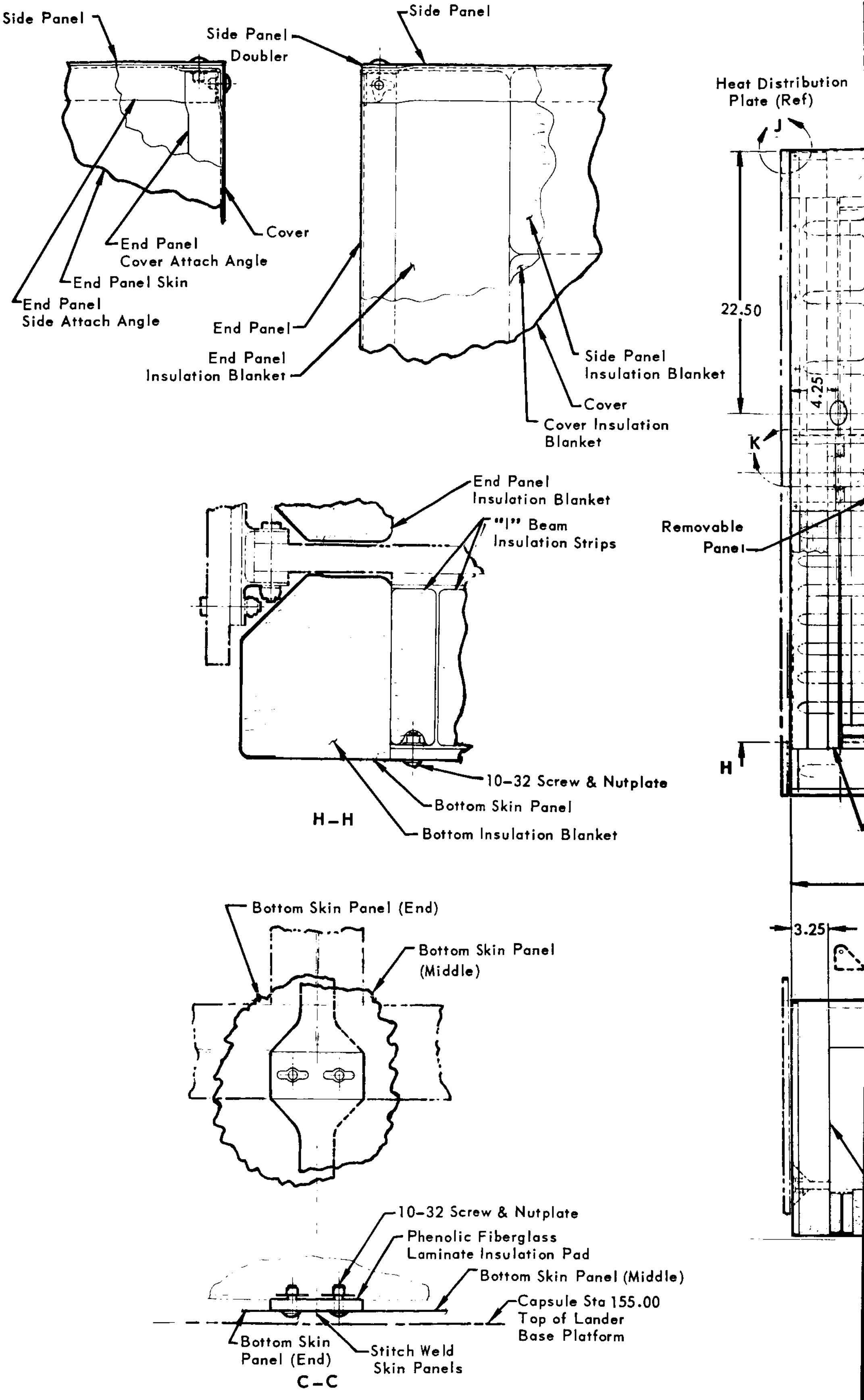
9.6 INTERFACE DEFINITION - The laboratory is mounted to the CB Lander at eight points by means of sixteen 5/16-inch titanium bolts. The heat distribution plate interconnects with the thermal protection radiators for structural support and coolant flow. Secondary structure is provided to brace the radiators. Laboratory structure and attachments support the weight of the thermal insulation.

9.7 RELIABILITY AND SAFETY CONSIDERATIONS - Reliability and safety considerations in the design of the structure are given major attention. The philosophy used on previous McDonnell Spacecraft embodies design with a mathematical reliability of 1.0. This philosophy has been applied to the VOYAGER design. Structural criteria are identified in terms of limit and ultimate design loads. Limit loads are those which result from the maximum expected flight or ground handling conditions. Ultimate loads are those determined by adjusting upward the limit loads by a factor of safety, normally 1.25 for flight conditions and 1.5 maximum for ground handling conditions which are potentially hazardous to personnel. Structural design and positive verification by test to ultimate design loads provide the assurance that structural integrity is consistent with a reliability of 1.0 from a statistical standpoint.

9.8 TEST REQUIREMENTS - No operational preflight tests are required.

9.9 DEVELOPMENT REQUIREMENTS - The Structure Subsystem is of proven design and no long lead item developments are required for subsystem elements.

INSULATION – VOYAGER SURFACE LABORATORY



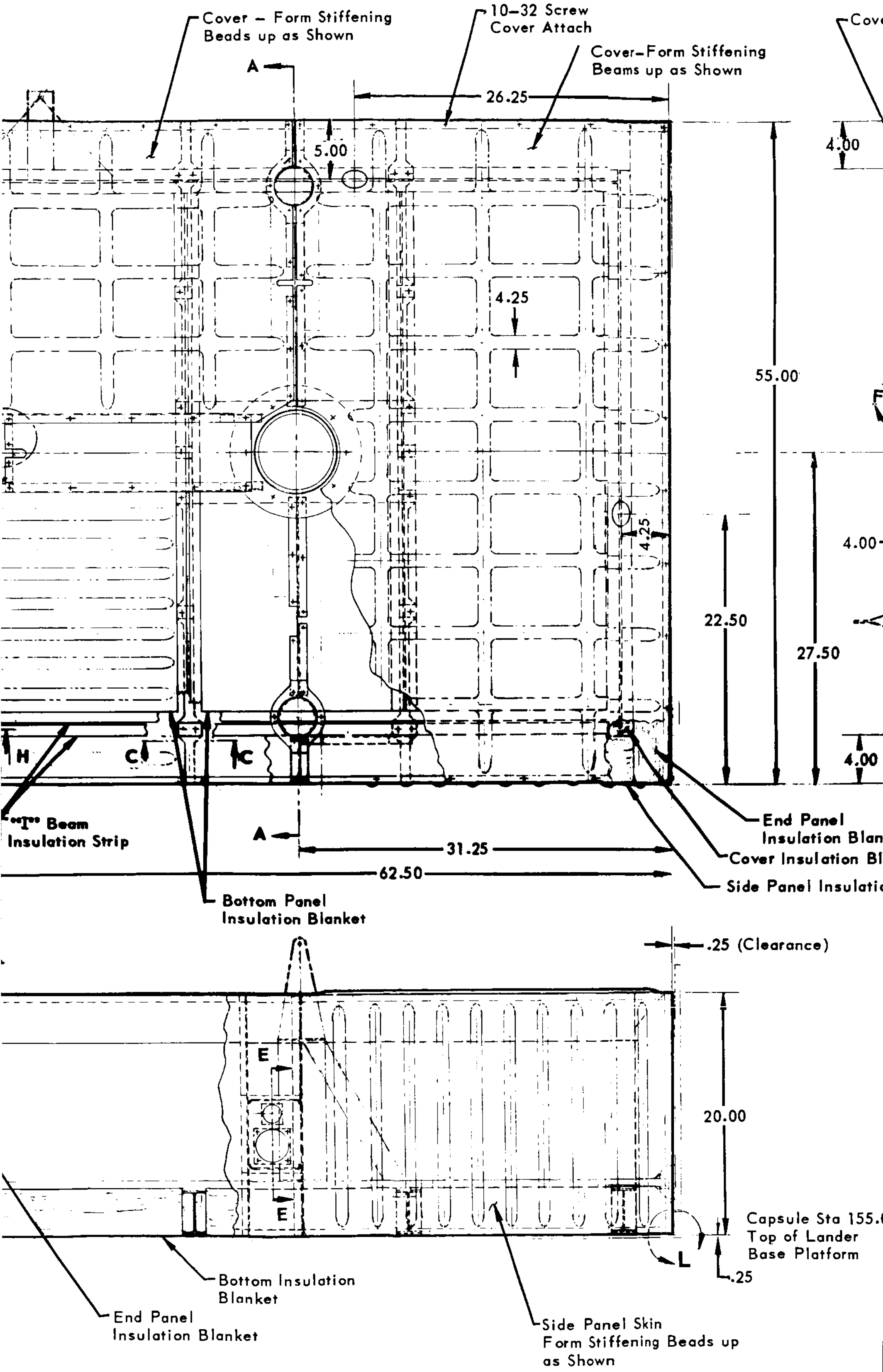
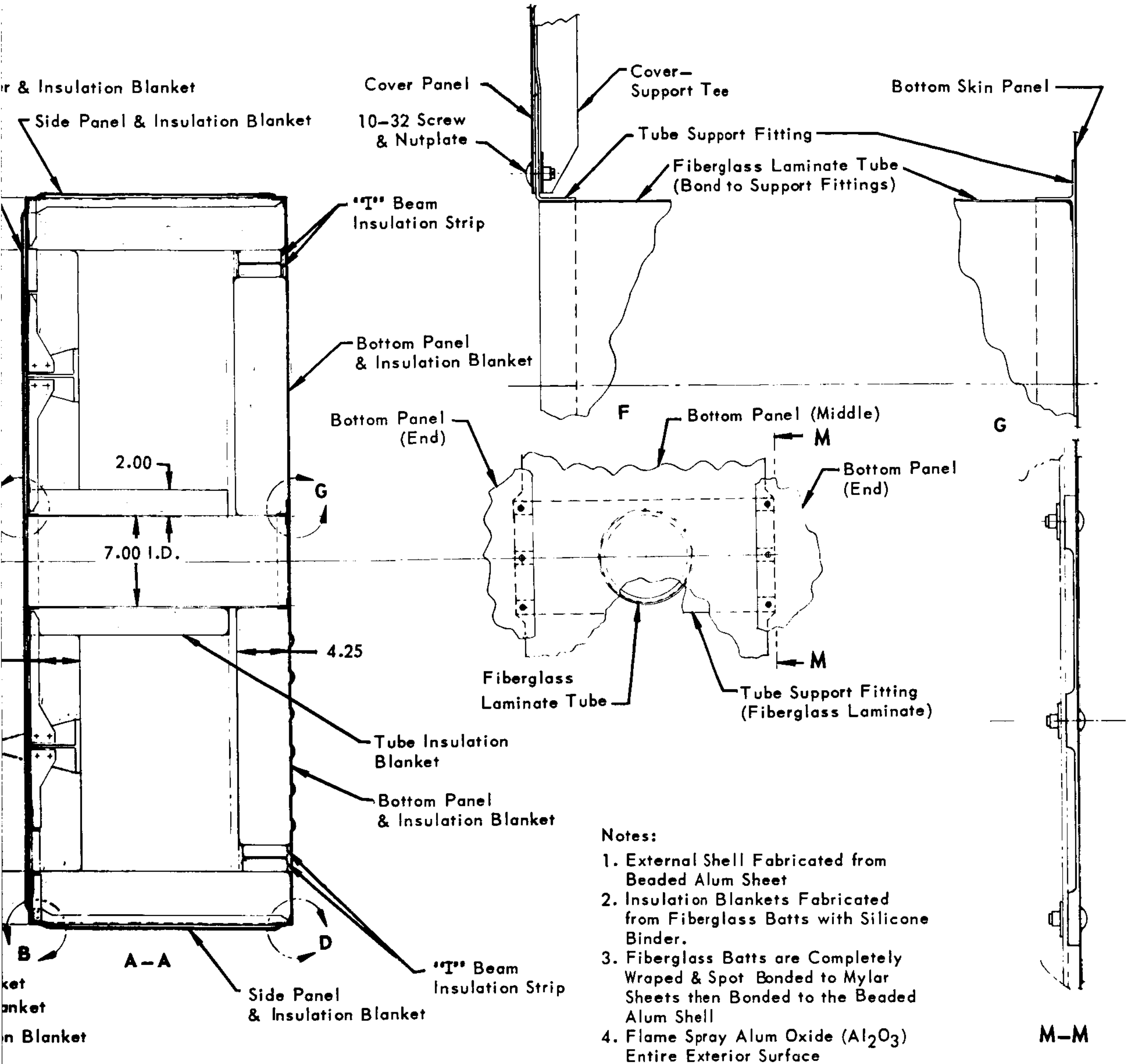
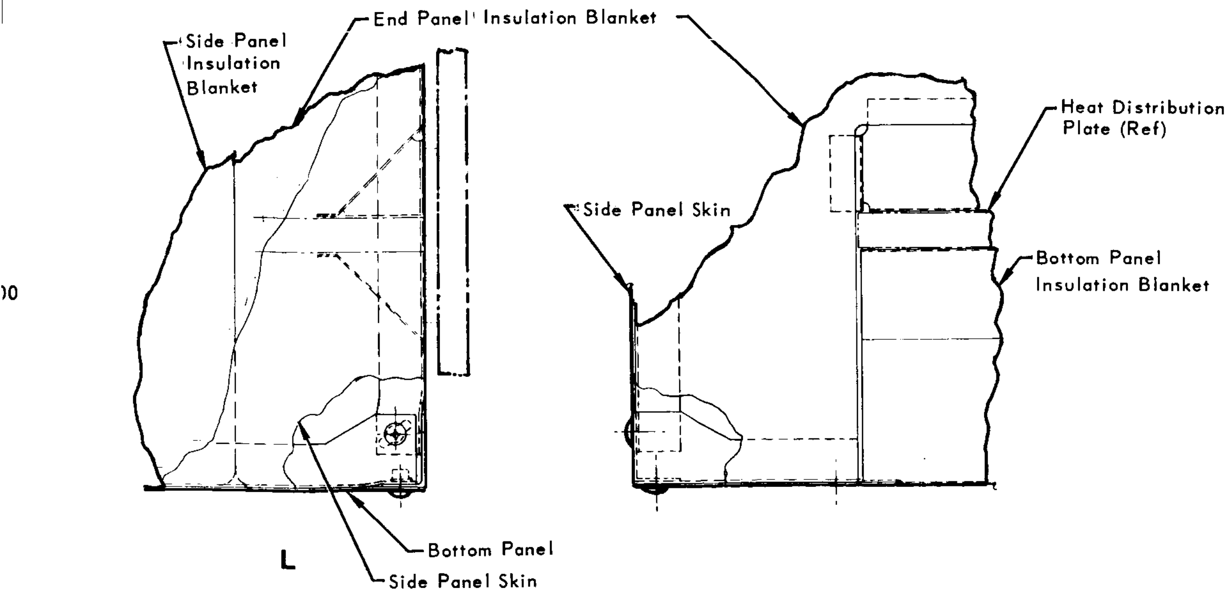

Cover – Form Stiffening Beads up as Shown
10–32 Screw Cover Attach
Cover–Form Stiffening Beams up as Shown
Cov
A
5.00
26.25
4.00
4.25
55.00
F
22.50
27.50
4.00
4.25
4.00
H
C
C
"I" Beam Insulation Strip
A
31.25
62.50
Bottom Panel Insulation Blanket
End Panel Insulation Blan
Cover Insulation Bl
Side Panel Insulatio
.25 (Clearance)
E
E
20.00
Capsule Sta 155.
Top of Lander Base Platform
L
.25
Bottom Insulation Blanket
End Panel Insulation Blanket
Side Panel Skin Form Stiffening Beads up as Shown

Figure 9.0–5



Notes:

1. External Shell Fabricated from Beaded Alum Sheet
2. Insulation Blankets Fabricated from Fiberglass Batts with Silicone Binder.
3. Fiberglass Batts are Completely Wraped & Spot Bonded to Mylar Sheets then Bonded to the Beaded Alum Shell
4. Flame Spray Alum Oxide (Al_2O_3) Entire Exterior Surface



INSULATION – VOYAGER SURFACE LABORATORY (Continued)

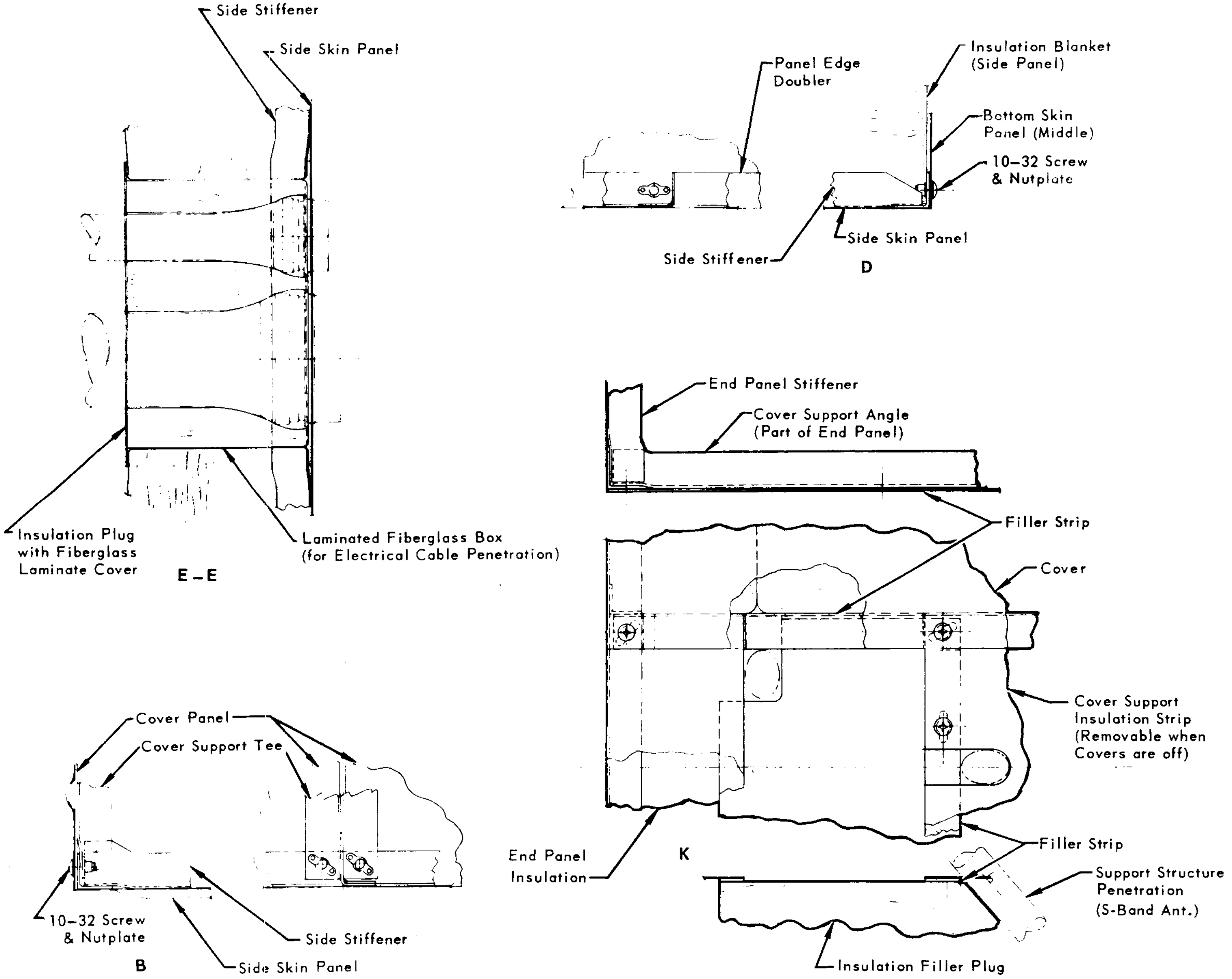


Figure 9.0-5 (Continued)

SECTION 10

HIGH GAIN ANTENNA MECHANISM

10.1 EQUIPMENT IDENTIFICATION AND USAGE - The High Gain Antenna Mechanism consists of the mechanical and electro-mechanical elements necessary to erect and drive the high gain antenna in response to Control Subsystem commands after the Surface Laboratory is landed on Mars. The mechanism, indicated in Figure 10-1, is composed of:

a. Four gimbal axis pivots and interconnecting structure to implement a sequential freedom of the reflector in declination, hour angle, elevation and azimuth. The preferred approach for the pivots is to employ sleeve bearings of "Duroid" or "Rulon."

b. The erection yoke and gimbals support member to mate the structural attachment points provided on the upper side of the Surface Laboratory.

c. Five similar drive units (differing in mounting details only) provide the power for erecting the mechanism and positioning the reflector about each of the gimbal axes. The drive units consist of an integrally housed incremental stepper motor and gear train. A stepper motor in the range of 2 in-oz torque at approximately 1400 rpm drives two intermediate stages of planetary gearing (10:1) and a single worm wheel output stage of 85 to 1. The worm gear stage is designed to be self-locking to permit axis hold without electrical power applied.

   The drive units use dry lubrication throughout. Motor bearing utilizes Barden "Bartemp", or equivalent, ball bearings; the planetary gearing uses silicate bonded molybdenum disulfide films; and the worm wheel stage employs a wheel fabricated with an aluminum hub and a peripheral toothed member of MO_2 impregnated Teflon or a metal backed TFE coating.

d. A conductive plastic potentiometer on each of the four gimbal axes and the erection axis. The conductive plastic sensors are utilized to permit unlubricated-low pressure operation. Although wire wound units are capable of higher accuracy, extreme precision is not needed. Furthermore, they are susceptible to cold welding and wear problems.

e. A spring locked strut which combines with the yoke to form a tripod upon erection. A switch is provided to indicate the latched up condition.

f. Limit switches to remove drive motor power when a given gimbal has reached its maximum position of travel.

HIGH GAIN ANTENNA PEDESTAL MECHANISM

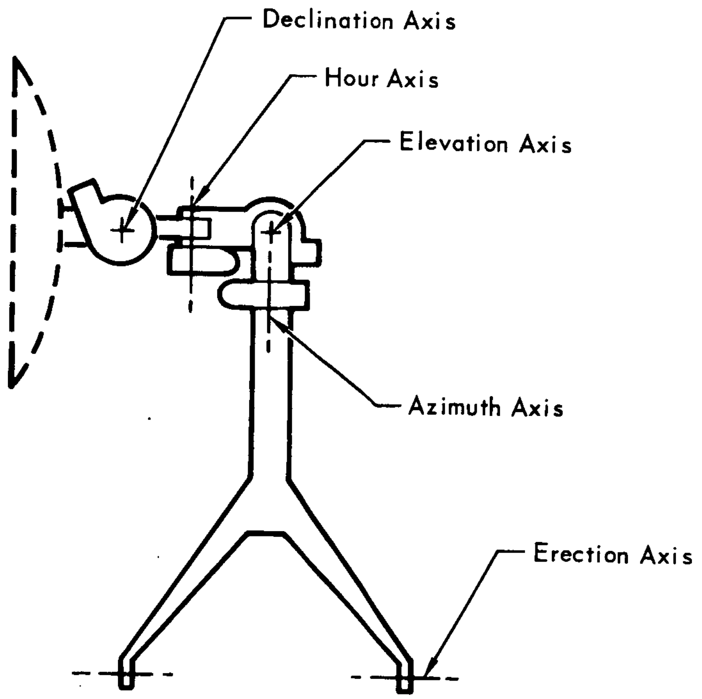


Figure 10-1

g. A gravity sensing pendulum attachment on the hour-axis gimbal.

h. A sun sensor and preamplifier attachment on the hour-axis gimbal.

i. Precision attachment provisions on the azimuth and elevation gimbals for mounting gyroscope packages.

j. R.F. coaxial line, made of a solid aluminum outer conductor with longitudinal Teflon tubing spacers, and choke type coaxial rotary joints.

10.2 DESIGN REQUIREMENTS AND CONSTRAINTS - The Antenna Mechanism must be capable of operating within the following requirements and constraints;

a. Operate normally after ethylene oxide decontamination, heat sterilization and long term vacuum exposure.

b. Possess the capability to point the antenna to Earth in the presence of local ground slopes of 34 degrees over the range of landing latitudes.

c. Have the required rigidity and power for satisfactory static and dynamic performance under worst case (VM-2) wind conditions.

d. Perform satisfactorily in the presence of wind blown dust.

e. Accommodate a 36 inch diameter parabolic reflector and feed.

f. Provide for establishment of a polar axis so that a single (hour) axis can be clock driven for minimum power consumption.

g. Accommodate a one degree per second rate for slewing and a 0.004 degree per second rate for Earth tracking.

h. Ability to hold any antenna position with no power applied under maximum wind load plus gravity imbalance torque.

i. Capability for alternate mode operation.

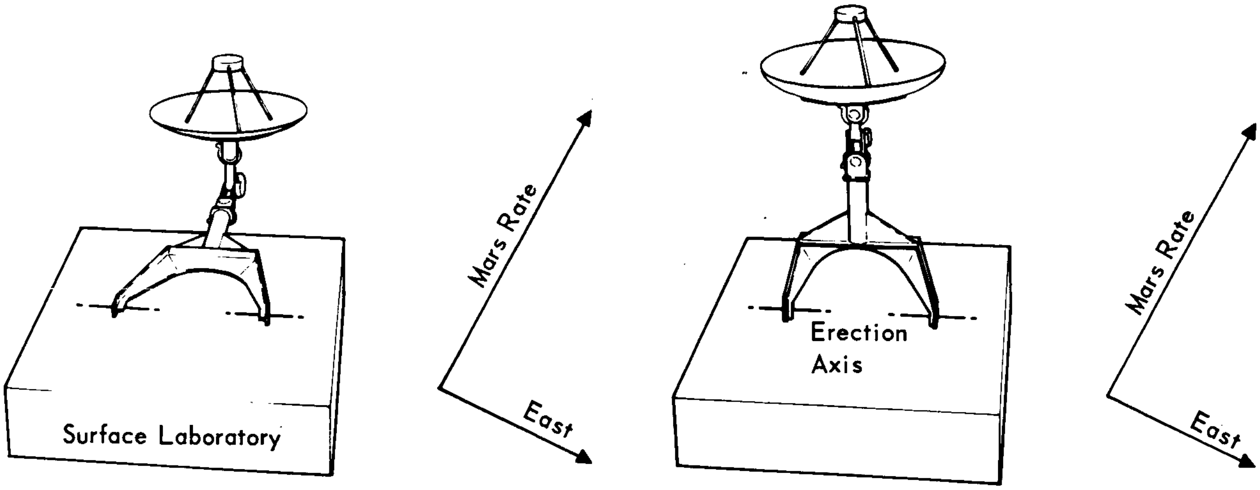
j. Operate normally while exposed to a temperature range between 120°F and minus 190°F.

10.3 PHYSICAL CHARACTERISTICS - The Antenna Mechanism is erected above the center of the Surface Laboratory for best Earth view under any condition of landing latitude, tilt or azimuth. Maximum weight of the Antenna Mechanism is 30 pounds.

10.4 OPERATION DESCRIPTION - The operation of the Antenna Mechanism is indicated by Figure 10-2.

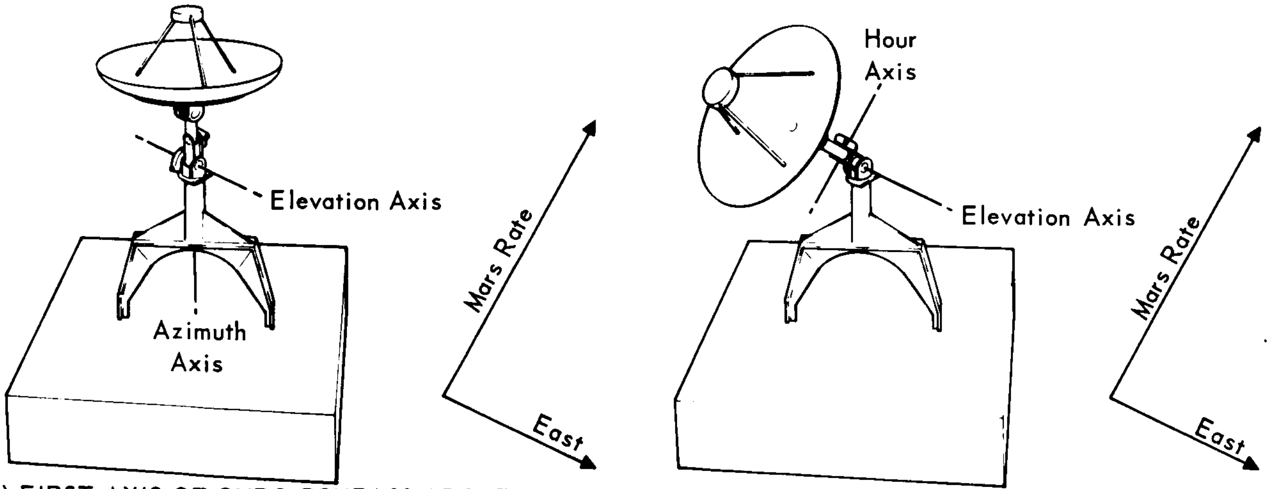
- In step (A) the Antenna Mechanism is shown in the stowed position after landing in a representative orientation.
- After receipt of the unlatch signal, the mechanism is driven about the erection axis by a motor drive. An angular rotation of 90 degrees about the erection axis is performed per step (B). A pivoting strut combines with the mechanism yoke to form a tripod upon erection and is spring loaded to

ANTENNA MECHANISM DEPLOYMENT



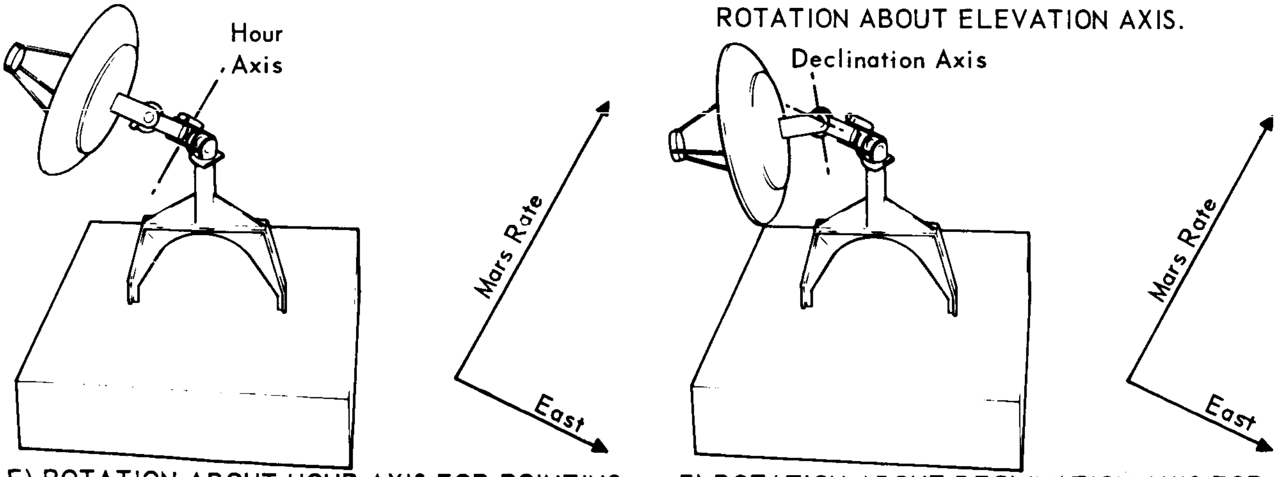
A) HIGH GAIN ANTENNA IN STOWED POSITION

B) ANTENNA ERECTED BY ROTATION ABOUT ERECTION AXIS



C) FIRST AXIS OF GYRO COMPASS ABOUT AZIMUTH AXIS ALIGNS ELEVATION AXIS NOMINALLY EAST

D) SECOND AXIS OF GYROCOMPASS ALIGNS HOUR AXIS PARALLEL WITH MARS RATE AXIS BY ROTATION ABOUT ELEVATION AXIS.



E) ROTATION ABOUT HOUR AXIS FOR POINTING TO EARTH IN CORRECT LONGITUDINAL PLANE.

F) ROTATION ABOUT DECLINATION AXIS FOR EARTH POINTING IN LATITUDE.

Figure 10-2

latch the mechanism when the full erected position is achieved. Consideration is being given to supplementing the erection motor with a cable wrapped onto a motor driven spool. This technique allows the possibility of maintaining a rigging force by providing a ratchet on the motor driven spool.

- The azimuth gimbal drives in response to commands from the Control Subsystem. Error signals derive from a gyroscope package mounted to the azimuth gimbal, and the Control Subsystem processes the gyroscope output signals to effect a null seeking servo system. Since the gyroscope is mounted so that its input axis is perpendicular to the azimuth gimbal, the azimuth gimbal performs as a mechanical feedback element being driven until no gyro output is sensed. As step (C) indicates, this orientation occurs when the gyro input axis (and the parallel elevation axis) is nominally East.
- The elevation axis drive also results from gyrocompassing command signals from the Control Subsystem. The second gyroscope package is mounted to the elevation gimbal with the gyro input axis perpendicular to the hour axis. In this case, elevation drive signals are received until the gyroscope senses null which results in the hour axis being oriented parallel to the Mars rate axis. This condition is shown in step (D).
- The output from the Mars pendulous gravity sensor, which is mounted on the hour axis, is processed by the Control Subsystem and, when combined with the predicted Mars landing longitude and ephemeris data, results in a Control Subsystem command to drive about the hour axis so that the antenna beam lies in the correct longitudinal plane to Earth. This condition is shown in step (E).
- A declination axis turn-off angle is commanded by the Control Subsystem based on ephemeris data. The declination axis is positioned so the antenna beam is pointed to Earth in latitude. Step (F) indicates the antenna after response to the declination angle command.

In addition to the normal operating mode, the Antenna Mechanism has considerable alternate mode capability. This capability includes, (A) the ability to compensate for a pivot axis failure by utilization of the remaining gimbal drives (for example, with any two orthogonal gimbals functioning,simple elevation over azimuth performance is retained),(B) if the erection should fail to occur, the mechanism retains ability to operate as a limited elevation-azimuth or X-Y mount, (C) all axis drives are mechanically and electrically similar so that a given command, whether from radio frequency direction finding or Earth command, produces the same angular motion.

10.5 PERFORMANCE CHARACTERISTICS - The Antenna Mechanism is configured to perform under; (A) any Mars longitude, (B) ± 40 degrees of Mars latitude, (C) local ground slopes of ± 34 degrees in any direction, (D) any random azimuth orientation of the landed vehicle.

To provide adequate antenna pointing under the above conditions, the mechanism incorporates;

A declination axis freedom of ± 100 degrees to accommodate a required ± 25 degrees with an additional ± 75 degrees for alternate mode performance.

An hour axis freedom of ± 129 degrees to encompass ± 90 degrees for horizon to horizon range plus 34 degrees for slope and a 5 degree allowance for lander settling.

An elevation axis freedom of 90 degrees to provide hemispheric capability for the hour axis.

An azimuth axis freedom of ± 180 degrees to provide for any lander azimuth orientation.

These ranges of angular freedom are shown in Figure 10-3.

10.6 INTERFACE DEFINITION - The Antenna Mechanism interfaces mechanically with the Surface Laboratory at the structurally supported points provided on the upper surface and electrically with the Control Subsystem and the Radio Subsystem.

10.7 RELIABILITY CONSIDERATIONS - The Antenna Mechanism has an assessed reliability of a 0.999960 probability of successfully performing its mission when the alternate functional paths are considered. The functional delineation of the mechanism assessment is as follows;

o Antenna erection:	$P_I = 0.9982$
o Mars polar axis alignment	$P_{II} = 0.9933$
o Declination and hour angle reference establishment:	$P_{III} = 0.9874$
o Primary mode of hour axis and declination scan/track:	$P_{IV} = 0.9864$
o Alternate hour axis-declination scan/track functional path:*	$P_V = 0.9_4960$
o Alternate hour axis, azimuth, elevation scan/track functional path:	$P_{VI} = 0.9970$
o Alternate declination, azimuth, elevation scan/track functional path:	$P_{VII} = 0.9970$
o Total success with alternate functional paths:	$P_{VIII} = 0.9_4960$

*In stowed mode

ANTENNA PEDESTAL AXES AND ANGULAR FREEDOM

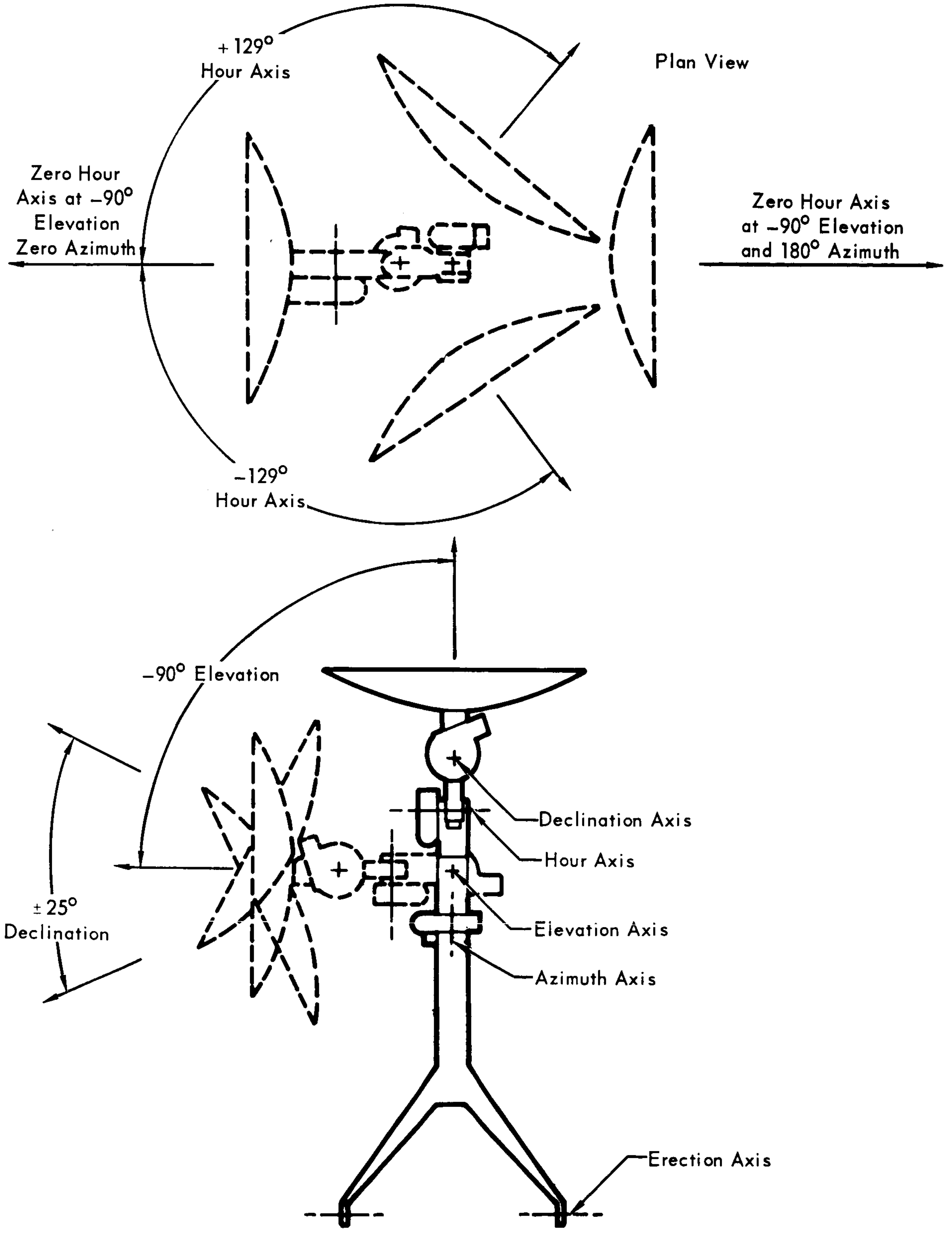


Figure 10-3

The functional flow diagram, the reliability assessment model and the reliability success model are shown in Figure 10-4.

Figure 10-5 is the fault tree fror the Antenna Mechanism. The high probability of success is attributed to the alternate functional paths in the design. The erection function is backed up by the antenna being able to slew with hour axis and declination drives. The antenna can also scan and track in the modes of hour axis-declination, hour axis-azimuth-elevation, or declination-azimuth-elevation. The failure effects of the alternate modes is insignificant except for RF scan and track in the stowed position which has slightly restricted slew angles due to capsule clearances. All alternate modes do require direct commands to maximize Earth time in view periods.

The Antenna Mechanism is estimated to have complexity in the order of 158 parts. A breakdown by generic part types is denoted in Figure 10-6.

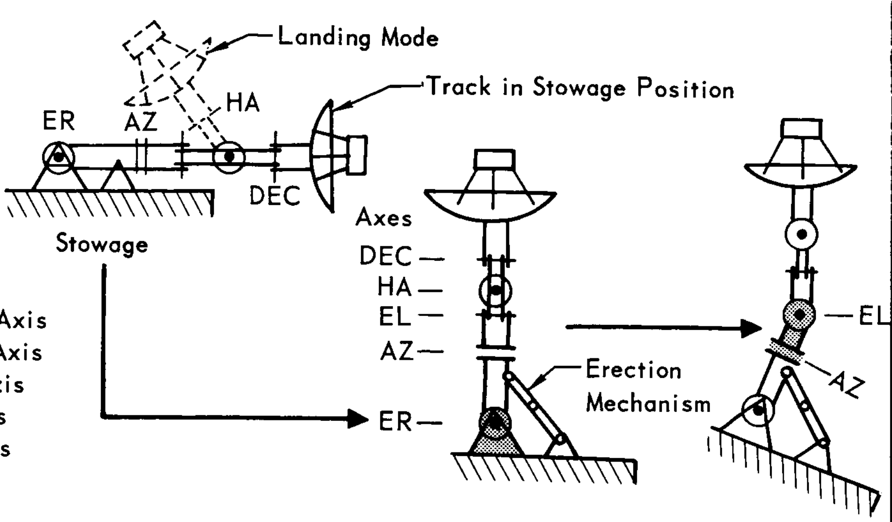
10.8 TEST - The Antenna Mechanism is capable of test after the final sterilization and during flight. Due to the rigid design which is required to withstand the Mars wind loading, the pointed antenna will require a minimum of latching in the stowed position. The installed mechanism will be verified by actual insertion of slight angular commands, permitting the mechanism to respond, and noting the angular response of the position potentiometers.

10.9 DEVELOPMENT REQUIREMENTS - The Antenna Mechanism will be required to satisfactorily withstand a wide range of temperatures, from the 275°F for sterilization to the -190°F on Mars, and exposure to high velocity wind and dust. Development tests required to verify acceptable performance over the range of environments are as follows:

- Static and dynamic tests to verify mechanism stability in the presence of the predicted Mars winds. This may include wind tunnel testing.
- Structural dynamic tests to verify integrity during vibration and to confirm latching.
- Functional tests over the predicted range of temperatures throughout the development phase for the motors, gearing and pivots.
- Functional tests in a simulated Mars wind blown dust environment to assess effects on gimbal bearings and drive units.
- Functional tests in a vacuum to simulate transit, and in a low pressure to simulate the Mars atmosphere. These tests will permit critical evaluation of mechanical effects (outgassing, sublimation and wear) and electrical effects (multipacting) on the mechanism elements and adjacent equipment.

PEDESTAL MECHANISM RELIABILITY MODEL

A. FUNCTIONAL FLOW DIAGRAM

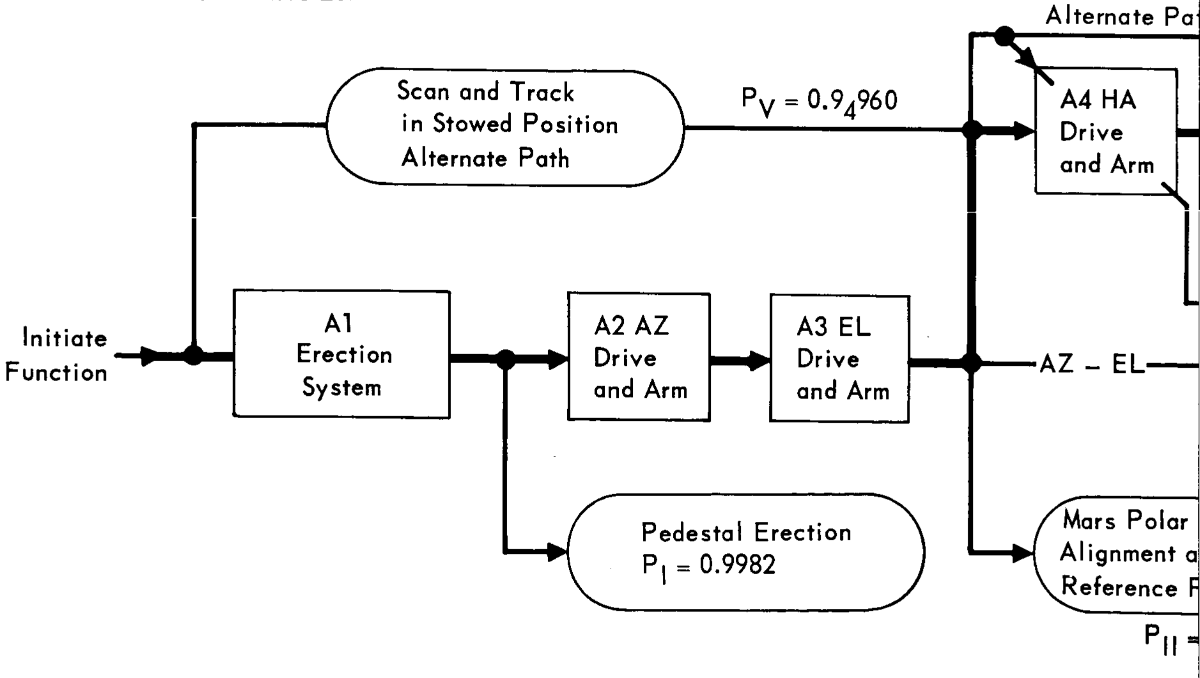


A5 DEC = Declination Axis
A4 HA = Hour Angle Axis
A3 EL = Elevation Axis
A2 AZ = Azimuth Axis
A1 ER = Erection Axis

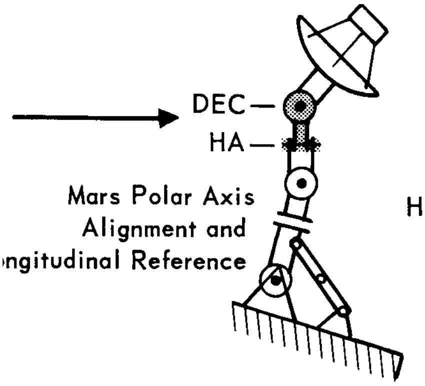
B. RELIABILITY ASSESSMENT MODEL

	A1A1	A1A2	A1A3	A1A4	A2A1	A2A2	A3A1
	Stow Support and Lock	Stowage Release	Erection Mech. and Linkage	Erection Arm	AZ Drive Mech.	AZ Arm	EL Drive Mech.
λ F/10^8 HR	100	70	610	740	1490	580	1490
ϵkt HR	117	117	117	117	118	118	118
$\lambda\epsilon$kt	.000117	.0000819	.000714	.000866	.00176	.000685	.00176
P_s	.999883	$.9_4 9181$	.999286	.999134	.99824	.999315	.99824

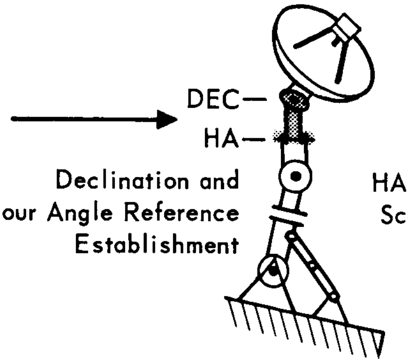
C. RELIABILITY SUCCESS MODEL



Figure



Mars Polar Axis Alignment and ngitudinal Reference

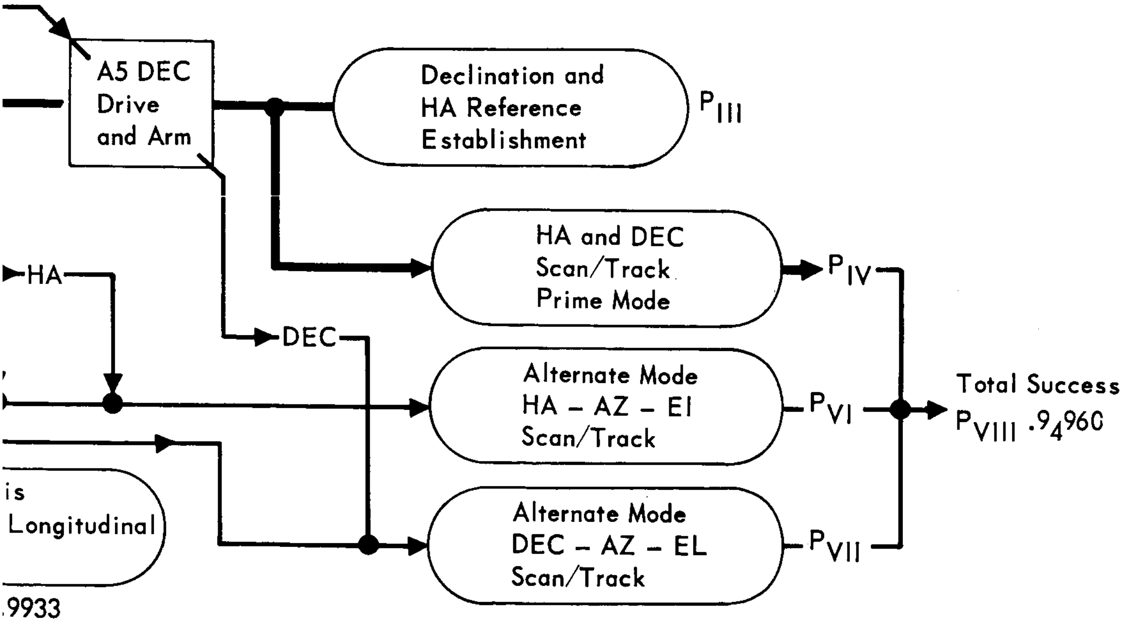


Declination and Hour Angle Reference Establishment

HA and DEC Scan/Track

3A2	A4A1	A4A2	A5A1	A5A2
EL Arm	HA Drive Mech.	HA Arm	DEC Drive Mech.	DEC Arm
80	1490	580	1490	580
18	142	142	142	142
0685	.00212	.000824	.00212	.000824
9315	.99788	.999176	.99788	.999176

Summary	
P_{I} = 0.9982	P_{V} = $.9_{4}960$
P_{II} = 0.9933	P_{VI} = .9970
P_{III} = 0.9874	P_{VII} = .9970
P_{IV} = 0.9864	P_{VIII} = $0.9_{4}960$



10-9-2

PEDESTAL MECHANISM FAULT TREE

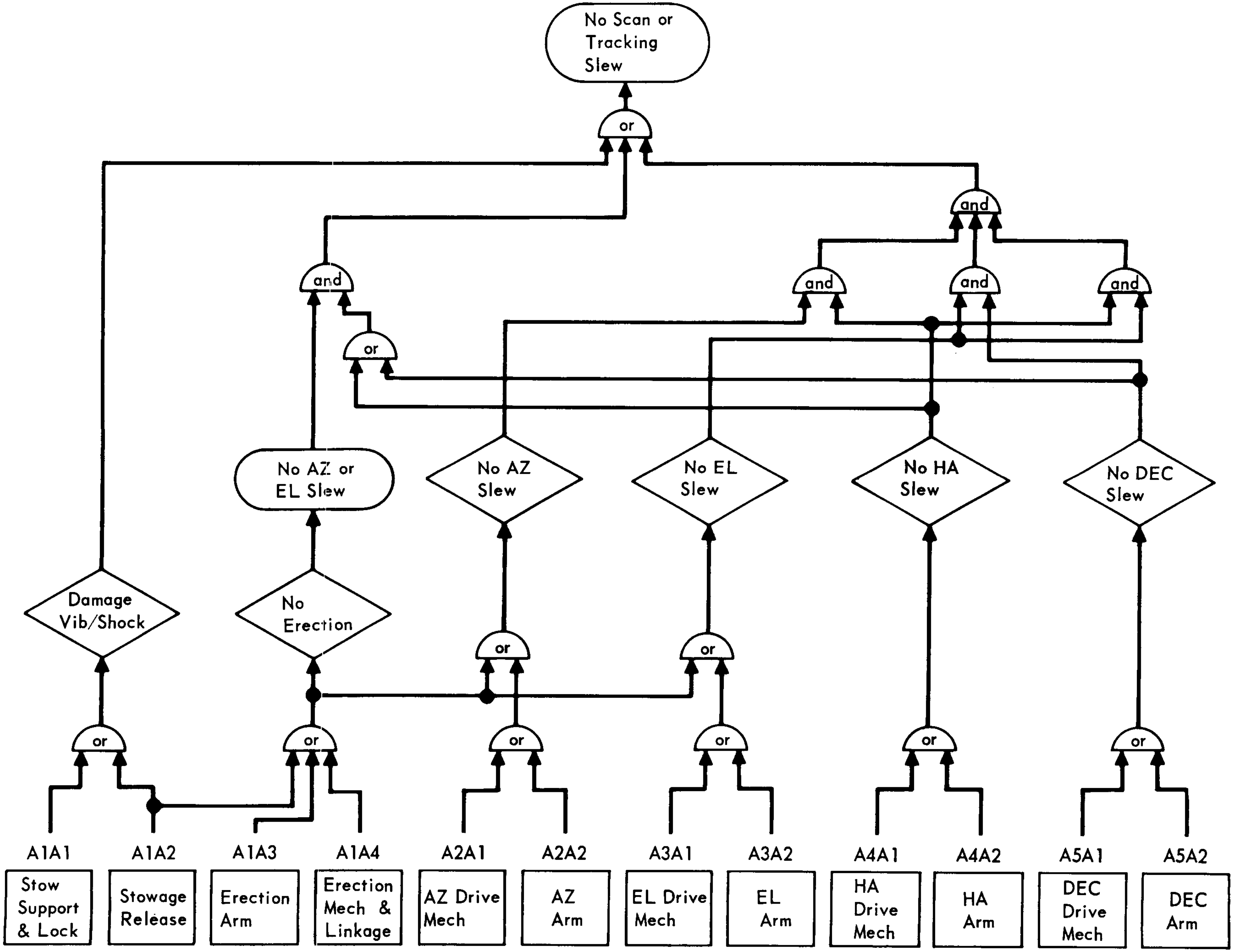


Figure 10-5

PEDESTAL MECHANISM COMPLEXITY ESTIMATE

PART TYPE	FAILURE RATE F/10^8 hr	QUANTITY n	TOTAL n x F.R.
Arms:			
Support	10	5	50
Bipod	20	1	20
Linkage, Erection	50	2	100
Journals:			
Axle Bearing	75	10	750
Gear Bearing	30	20	600
Bearings:			
Axle	150	10	1500
Gear	70	20	1400
Seals:	25	36	900
Pads, Thrust	30	8	240
Coupling, Spive	30	4	120
Gears			
Planet 10:1	300	8	2400
Worm	70	4	280
Bull	60	4	240
Housing, Gear	10	9	90
Axles	50	6	300
Fanges, Support	20	7	140
Doubler, Antenna Support	30	1	30
Mechanisms,			
Erection	500	1	500
Stow Support/Lock	100	1	100
Release	70	1	70
Total		158	9830 F/10^8 hr

Figure 10-6