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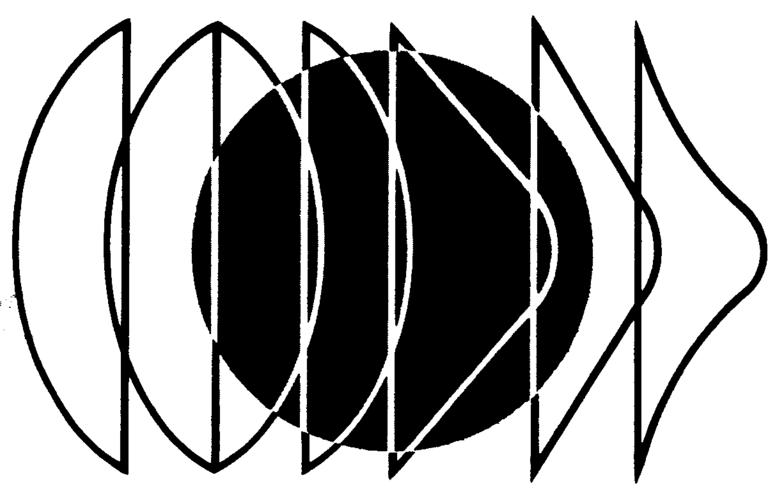
PART H RELIABILITY
PART I PLANETARY QUARANTINE
PART J OPERATIONAL SUPPORT EQUIPMENT
PART K INTERFACE ALTERNATIVES

VOYAGER CAPSULE PHASE B FINAL REPORT



VOLUME IV ENTRY SCIENCE PACKAGE

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MCDONNELL ASTRONAUTICS

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 IV, describes the McDonnell Douglas selected design for the Entry Science Package. It is arranged in 11 parts, A through K, and bound in 4 separate documents, as noted below.

Part A	Introduction and Summary	
Part B	Objectives and Requirements	
Part C	Design Criteria and Constraints	1 Document
Part D	Selected Design Concept	
Part E	Alternatives and Systems Analysis	
Part F	Future Mission Options	1 Document
Part G	Subsystem Equipment	1 Document
Part H	Reliability	
Part I	Planetary Quarantine	
Part J	Operational Support Equipment	1 Document
Part K	Interface Alternatives	

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

VOLUME IV CROSS REFERENCE INDEX

ITEM \ VOLUME IV PARTS		PART A INTRODUCTION AND SUMMARY	PART B OBJECTIVES AND REQUIREMENTS	PART C DESIGN CRITERIA AND CONSTRAINTS	PART D DESCRIPTION OF PREFERRED CONFIGURATION	PART E PRINCIPAL ALTERNATIVES AND SELECTION FACTORS	PART F FUTURE MISSION OPTIONS	PART G DETAILED DESCRIPTION OF ESP EQUIPMENT	PART H RELIABILITY	PART I PLANETARY QUARANTINE	PART J OPERATIONAL SUPPORT EQUIPMENT	PART K INTERFACE ALTERNATIVES
ESP ASPECT												
MISSION	Objectives	Sec. 1.0	1.0	–	–	–	√	–	–	–	–	–
	Operations (& Profiles)	2.0 6.3	2.0	–	2.0–d 4.1 5.0	5.1 5.8	√	d	2.3.3 3.1.1	2.0	4.3 4.4 4.5 8.0	–
DESIGN	Configuration	3.0 6.2	√	√	1.0	1.1	–	d	–	3.0	OSE Config	1.0 2.0
	Functional	4.0 5.0 6.0	√	√	1.0 2.0 3.0 4.0	1.0 2.0 3.0 4.0 5.0	√	d	1.0 2.0 3.3	–	OSE Functional Design	1.0 2.0
	Weight	3.0 4.0	–	√	1.4 2.0	3.0 d	–	d	2.3.2	–	–	–
Interfaces (See Also Volume V)		Introduction	–	1.0 2.0 3.0	1.3 2.0–d 3.0–d 4.0 5.3.4	1.1 3.0–d 4.1.3 5.0	–	d	–	–	√	1.0 2.0 3.0
Implementation (See Also Volume VI		–	–	–	6.0	–	–	–	–	d	–	1.0 3.0
ESP EQUIPMENT OR SUBSYSTEM												
Imaging		Sec. 2.0 4.0 6.0	1.2 2.2	6.1	1.2.1 2.1 4.3.2.4	1.1 2.2 3.2 5.3.2.6	√	1.1	3.3	3.2	5.5	1.2
Atmospheric Properties Measurement		2.0 4.0 6.0	1.1	6.2	1.2.2 2.0 4.0–d	1.1 2.1 3.1 5.0–d	√	1.2 1.3 1.4 1.5	3.3	–	5.5	1.2
Engineering Instrumentation		–	–	–	Figure 3.0–1	Figure 4.2–3 4.2.2.2	–	2.0	3.3	–	d	–
Data Storage		6.0	–	–	2.5.3 3.2.1	4.2.5	–	3.0	3.3	3.4	5.4	–
Telecommunications		5.1	–	6.3	2.5.3 3.2	4.2	√	4.0 5.0 6.0	3.3	–	5.4	2.0
Power		5.2	–	6.3	2.5.1 3.1	4.1	–	7.0	3.3	3.4	5.3 4.4.8	2.0
Structural/Mechanical		–	–	4.0	2.5.4 3.3	4.3	–	8.0	–	3.1	–	–
Cabling and Packaging		–	–	5.0 6.3	2.5.1 3.4	4.4	–	9.0	–	–	–	–
Thermal Control		5.3	–	6.3	2.5.7 3.5 4.3.2	4.5	–	10.0	3.3	3.3	5.6	2.0

√ Denotes that the part or section generally applies to the topic.
d Denotes that the topic is distributed throughout the part or section.

Figure 1

TABLE OF CONTENTS

This Document Consists of the Following Pages:

PART H

RELIABILITY

A summary of Engineering Reliability studies and results are contained herein. Significant attention was given to: 1) satisfying the constraints, 2) failure mode, effect and criticality analyses, 3) quantitative reliability estimates, 4) reliability program requirements and 5) component part reliability.

Reliability has been a key discipline in the VOYAGER system design for the development, integration, and selection processes of our preferred concept. "First time success" and capability for degraded mode operation were the key objectives that guided the reliability analyses. Each design concept was examined in detail to determine its contribution toward achieving these objectives. This was accomplished by utilizing four analytical and modeling techniques:

a. Failure Mode, Effect, and Criticality Analyses
b. Reliability-Weight-Effectiveness Analyses
c. Mission Effectiveness Model
d. Conceptual tradeoff studies

The most significant of these used by engineering reliability was the single-point failure modes, failure effects, and failure criticality analyses. With this technique, critical or potential single-point failure modes were identified early for the various engineering concepts. These analyses indicated the need for specific redundancies, so that no potential single failure mode could have a catastrophic effect on the mission, and to assure at least a degraded mode of operation.

The selection of the specific type of redundancy (functional, multi-channel, or block) was guided by the failure criticality of the mission event or equipment function. Incorporation of specific redundancies was influenced by the availability of a prime resource -- weight. The reliability-weight-effectiveness analyses resulted in the incorporation of redundancy in the most effective manner to meet the specific mission objectives. The probability of total mission success for our Entry Science Package preferred concept, given satisfactory operation of the Capsule Bus, is estimated at 0.901.

Recognition of equipment sensitivity to long-life storage (in transit) environment was taken into consideration in our design. Suggested design concepts were evaluated to assure their compatibility with the environments of decontamination, sterilization, and postulated Mars atmosphere and surface properties.

The study revealed that the following reliability program elements must receive increased major attention throughout the program:

a. Detail failure mode, effect, and criticality analyses

b. Specially planned parts and materials program

c. Positive failure evaluation and corrective action

d. Comprehensive design reviews

SECTION 1

VOYAGER RELIABILITY CONSTRAINTS

The VOYAGER reliability program constraints were identified by a study of the mission objectives, environmental requirements and predictions, mission profile analysis, total program constraints, and conceptual design studies. The results of this study emphasized the following four constraints which received major reliability attention:

a. No catastrophic single failure mode

b. Long-life storage

c. Unique environmental factors

d. Degraded mode capability

1.1 NO CATASTROPHIC SINGLE FAILURE MODE - The VOYAGER Capsule Systems Constraints and Requirements Document specifies a design requirement that no potential single-failure mode shall cause a catastrophic effect on the mission. Compliance with this requirement necessitated the identification, evaluation, and resolution of all potential catastrophic failure modes. This was accomplished by using results of our failure mode, effect, and criticality analyses.

1.2 LONG-LIFE STORAGE - Conservative designs, including possible material degradation, influenced our concept selections. Specific details are discussed within the functional descriptions of each subsystem.

1.3 UNIQUE ENVIRONMENTAL FACTORS - The effects of decontamination, sterilization, and the Martian atmosphere and surface properties are unique to the VOYAGER program and were considered in the concept designs to minimize the resultant effect on system reliability.

The system design incorporated the estimated extremes of these characteristics (Reference Volume II, Part A, Appendix A); therefore, for conditions less severe than these extremes, the probability of reliable operation is significantly increased.

1.4 DEGRADED MODE CAPABILITY - A design requirement of system and subsystem concepts was to provide for degraded mode operational capability if primary operational failures occurred. This capability has been provided throughout the design to assure at least some measure of success for unexpected circumstances. For example, the telemetry subsystem has been designed such that minimum data are lost if a portion of the subsystem becomes inoperative. Specific design details are discussed within the functional descriptions of each subsystem.

SECTION 2

FAILURE MODE, EFFECT, AND CRITICALITY ANALYSIS (FMECA)

Continual engineering reliability analyses were used in identifying and evaluating the failure modes and failure effects of the candidate concepts. Evaluation of the failure mode criticality led to redundancy considerations. These analyses identified the potential single point failure modes. The analyses also provided many design redundancy considerations which are tabulated in Figure 2-1.

2.1 FMECA METHOD - The method of performing the FMECA was to first identify the mission objectives:

a. Achievement of Flight Capsule landing
b. Performance of Entry Science experiments
c. Performance of Landed Science experiments
d. Measurement and transmission of engineering data

After identification of the mission objectives, the candidate concepts were evaluated by:

a. Identifying the major component or function
b. Identifying their failure modes
c. Classifying the effects of the failure modes

The depth of the analysis was confined to the detail of the design. In most cases design detail was available down to the component or function level. Figure 2.1-1 is a FMECA performed on the Entry Science Package Telecommunications Subsystem and is representative of the methodology used for all the subsystems. The numbers in the failure category column classify the effects as:

(1) No effect on the mission objective
(2) Degrading effect on mission objective
(3) Possible catastrophic effect on mission objective

2.2 FMECA RESULTS - Several failure modes, identified by the Subsystem FMECA's, had significant effects on the achievement of the mission objectives. These modes are tabulated in the failure modes, effects, and criticality summary, Figure 2.2-1, along with the recommended solutions.

2.3 REDUNDANCY - Redundancy was necessary to meet the criterion that no potential single failure mode shall cause a catastrophic effect on the mission, and also to assure a high level of success in achieving the mission objectives. An initial prime requirement for the Flight Capsule design was to find an optimum breakdown,

ENTRY SCIENCE PACKAGE DESIGN CONCEPT REDUNDANCY CONSIDERATIONS

ENTRY SCIENCE PACKAGE FUNCTION OR EVENT	PRIMARY CONCEPT	REDUNDANCY CONSIDERATION	TYPE OF REDUNDANCY
Supply ESP Power	Single battery	Provide two active redundant batteries	Multichannel
		Sense low ESP battery voltage, switch SLS battery to ESP	Block
Charge ESP battery	Single float charger	Provide standby redundant float charger	Block
Power control relay	Single relay	Provide redundant relays, parallel normally open relays and series normally closed relays	Multichannel
Transmit low rate entry science data	Transmit all data on entry science radio link	Interleave low rate ESP on CBS radio link	Multichannel
Entry science and engineering data programmer	Single programmer	Add standby programmer	Block
Monitor entry science package status during interplanetary cruise	Cruise commutator and encoder	Provide standby cruise encoder	Block
		Provide series active redundant commutator data switches and switch drivers	Multichannel
Entry science and communications power supply	Single power supply	Provide active redundant power supplies	Multichannel
TV data processor electronics	Single data processor	Active redundant TV data processor electronics	Multichannel
Descent sterio imaging	Two cameras	Provide two cameras per image axis with failure detection and switching to standby camera	Block
Atmospheric Composition	Mass spectrometer	(To be determined)	
Orthogonal Acceleration	Three orthogonally mounted	Provide three accelerometers	Multichannel

Figure 2-1

	accelerometers	per axis with majority voting logic circuitry	
Total stagnation region temperature	Stagnation temperature transducer	(To be determined)	
Total base region temperature	Base region temperature transducer	(To be determined)	
Stagnation pressure	Stagnation region pressure transducer	(To be determined)	
Base region pressure	Base region pressure transducer	(To be determined)	
Sense Mach 5, initiate mass spectrometer, stagnation temperature and base temperature experiments	Entry science package sensor	Capsule Bus radar altimeter	Functional
Turn on entry science package telemetry subsystem	Capsule Bus test programmer	Mission operations system (MOS) command	Functional
Turn off entry science package telemetry subsystem	Capsule Bus test programmer	MOS command	Functional
Switch entry science package telemetry subsystem to checkout mode	Capsule Bus test programmer	MOS command	Functional
Initiate descent T.V. Camera sequencing	Capsule Bus Sequencer and Timer	● Capsule Bus .05g Sensor ● Capsule Bus radar altimeter	Functional
Release descent T.V.	Capsule Bus radar altimeter	Capsule Bus landing radar	Functional
Shut down entry science package	Capsule Bus sequencer and timer	● Surface Laboratory sequencer and timer ● Capsule Bus test programmer	Functional

ESP TELECOMMUNICATIONS FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS
TELEMETRY SUBSYSTEM

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	FAILURE CATEGORY: ENTRY SCIENCE	FAILURE CATEGORY: LANDED SCIENCE	FAILURE CATEGORY: ENG. DATA	REMARKS
Cruise Monitor Control	Inoperative or partial loss of sequencing and control.	Loss of flight capsule status monitoring data throughout cruise mission phase.	1	1	1	2	Design features series active redundant data switches and switch drivers.
Data Combiner	No output or data mixing.	Loss of Engineering and Science Data in ESP radio link.	1	1	1	1	Low rate ESP Engineering and Science Data is interleaved on the CBS radio link.
S.C. Data Distribution Unit	Inoperative or steering logic errors.	Loss of all flight capsule status monitoring data throughout cruise mission phase if inoperative. Loss of all entry/descent CBS and ESP data if inoperative.	1	2	1	2	Design features series active redundant data switches and switch drivers.
TV Data Process Electronics	Inoperative or video processing error.	Loss of all TV data if inoperative	1	2	1	1	Electronics are dormant for major portion of mission and therefore short operating life requirement.
RT/DT Data Interleaver	No output or data mixing.	Loss of low rate Engineering and Science Data in ESP radio link.	1	1	1	1	Low rate ESP data is interleaved on the CBS radio link. Series active redundant interleaver switches are being considered.
Programmer	Inoperative or partial loss of sequencing and control.	Loss of all Engineering and Science Data if inoperative.	1	2	1	2	Design features decentralization of sequencing and controlling functions for minimum failure effect.
Clock Generator	Inoperative, unstable clock	Loss of Engineering and	1	1	1	1	Clock generator crystals are

Figure 2.1-1

	frequency or partial loss of clock rates.	Science Data if inoperative.					redundant and temperature compensated. The clock is free running and externally synchronized by the CBS clock generator which in turn is synchronized by the CBS sequencer and timer primary frequency clocks.
Telemetry Power Supply	Inoperative or degraded output.	Loss of Engineering and Science Data if inoperative.	1	2	1	2	Active redundant (load sharing) circuit components are being considered.
Instrumentation Equipment	Inoperative data sensor, signal process unit or power converter.	Partial or total loss of Engineering Data dependent on failure.	1	1	1	2	Power converter failure would result in the major loss of data. Active redundant (load sharing) converter circuit components are being considered.
Cruise Commutator	Group, subgroup or individual data channel inoperative.	Partial loss of Engineering Data	1	1	1	2	Data switches are series active redundant.
Cruise Encoder	Inoperative or digital bit errors.	Loss of Engineering Data if inoperative.	1	1	1	2	Standby redundant encoder available, switchable by Earth MOS command.
ADC/Multiplex	Group, subgroup or individual data channel inoperative. Encoder (ADC) inoperative or digital bit errors.	Partial loss of Engineering and Science Data with a multiplex failure. Loss of all Engineering Science Data if encoder is inoperative.	1	2	1	2	Series active redundant multiplex data switches are required in output switching decks. Encoder is dormant for major part of mission.
ESP/CBS Data Interleaver	No output or data mixing.	Loss of descent TV data.	1	2	1	1	Series active redundant interleaver switches are being considered. Low rate ESP data is interleaved on the CBS radio link.

ESP TELECOMMUNICATIONS FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS

RADIO SUBSYSTEM

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	FAILURE CATEGORY: ENTRY SCIENCE	FAILURE CATEGORY: LANDED SCIENCE	FAILURE CATEGORY: ENG. DATA	REMARKS
High Rate VHF Radio Transmitter Assembly	No power output or degraded power output.	Loss of descent TV data if inoperative.	1	2	1	1	Design features duplex transmitter operation. ESP low rate Engineering and Science Data are interleaved on the CBS radio link.
VHF Diplexer	RF breakdown or mechanical damage.	Degradation or loss of RF transmitted power. Loss of descent TV data if inoperative	1	2	1	1	Diplexer is passive, high reliable function. ESP low rate Engineering and Sciecne Data are interleaved on the CBS radio link.
*S.M. VHF Radio Receiver Assembly	Inoperative or poor sensitivity.	Loss of ESP radio reception if inoperative. Result is loss of descent TV data.	1	2	1	1	Design features duplex receiver operation. ESP low rate Engineering and Science Data are interleaved on the CBS radio link.
*S.M. Diversity Combiner	Buffer or operational amplifier inoperative.	Inoperative buffer results in degraded ESP link data receipt. Inoperative amplifier results in loss of descent TV data.	1	2	1	1	Buffers and operational amplifiers are high reliable functions. These functions are dormant for the major portion of mission and therefore have a short operating life requirement. ESP low rate Engineering and Science Data are interleaved on the CBS radio link.
* S.M. – Spacecraft Mounted							

Figure 2.1–1 (Cont)

ESP TELECOMMUNICATIONS FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS

RADIO SUBSYSTEM

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
*S.M. Bit Synchronizer	Inoperative or random synchronization error.	Earth data reconstruction and correlation degraded.	1	2	1	2	Bit synchronizer is high reliable function. ESP low rate Engineering and Science Data are interleaved on the CBS radio link.
* S.M. – Spacecraft Mounted							

Figure 2.1–1 (Cont)

ESP TELECOMMUNICATIONS FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS

DATA STORAGE SUBSYSTEM

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	FAILURE CATEGORY: ENTRY SCIENCE	FAILURE CATEGORY: LANDED SCIENCE	FAILURE CATEGORY: ENG. DATA	REMARKS
Delay Storage	Inoperative or erroneous output.	Loss of ESP radio link low rate Engineering and Science Data during blackout communications period.	1	2	1	2	ESP radio link low rate Engineering and Science Data are interleaved on the CBS radio link.
*S.M. Tape Storage	Inoperative in record or playback modes of operation.	Loss of ESP radio link Engineering and Science Data.	1	2	1	2	ESP radio link low rate Engineering and Science Data are interleaved on the CBS radio link.
*S.M. Data Buffer	Inoperative or improper storage delay.	Loss of all flight capsule status monitoring data throughout cruise mission phase if inoperative. Loss of all entry/descent ESP and CBS data if inoperative.	1	2	1	2	Redundant clock electronics are being considered to assure buffer readout.

* S.M. – Spacecraft Mounted

Figure 2.1-1 (Cont)

ESP TELECOMMUNICATIONS FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS

COMMAND SUBSYSTEM

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	FAILURE CATEGORY: ENTRY SCIENCE	FAILURE CATEGORY: LANDED SCIENCE	FAILURE CATEGORY: ENG. DATA	REMARKS
Adaptor Command Decoder	Inoperative or improper decoding.	Loss of Earth MOS command distribution or command error to ESP or CBS.	1	2	1	2	Nominal mission objectives are achieved. Commands require verification prior to system distribution. Primary command for ESP radio turn on is supplied by the CBS sequencer and timer.
*S.M. Command Decoder	Inoperative or improper decoding.	Loss of Earth MOS command distribution or command error to spacecraft mounted capsule support equipment (SMCSE)	1	2	1	2	Commands require verification prior to system distribution. Primary command for spacecraft mounted CSE should be supplied by the spacecraft central computer and sequencer with Earth MOS command backup.
* S.M. – Spacecraft Mounted							

Figure 2.1–1 (Cont)

ESP TELECOMMUNICATIONS FAILURE MODE, EFFECT AND CRITICALITY ANALYSIS

ANTENNA SUBSYSTEM

Failure Category Definition
1. No effect on mission objective.
2. Degrading effect on mission objective.
Possible catastrophic effect on mission objective.

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	FAILURE CATEGORY: LANDING	FAILURE CATEGORY: ENTRY SCIENCE	FAILURE CATEGORY: LANDED SCIENCE	FAILURE CATEGORY: ENG. DATA	REMARKS
VHF Transmit Antenna	RF Breakdown	Loss of ESP radio link Engineering and Science Data.	1	2	1	2	Antenna design features consideration of possible spectrum of atmospheres and effect on radiated power atmospheric ionization. ESP radio link low rate Engineering and Science Data are interleaved on the CBS radio link.
*S.M. VHF Receive Antenna	Mechanical damage, connections or deployment mechanism.	Loss of ESP radio link Engineering and Science Data.	1	2	1	2	Deployment mechanism must be simple, reliable device. ESP radio link low rate Engineering and Science Data are interleaved on the CBS radio link.
*S.M. Parasitic Antenna	RF energy leakage from antenna cover base during in-flight checkout.	RF energy leakage imparting possible damage to other flight capsule subsystems.	2	2	2	2	Minimum RF leakage paths during in-flight checkout is mandatory.
	Nonseparation of antenna cover at flight capsule separation.	ESP transmit antenna RF radiation is blocked from separation through landing.	1	2	1	2	Nonseparation of antenna cover is remote. Cover and probe assembly are attached to flight capsule adaptor. ESP radio link low rate Engineering and Science Data are interleaved on the CBS radio link.
* S.M. – Spacecraft Mounted							

Figure 2.1–1 (Cont)

ENTRY SCIENCE PACKAGE

FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS SUMMARY

COMPONENT OR FUNCTION	FAILURE MODE	FAILURE EFFECT	CRITICAL MISSION PHASE	RECOMMENDED REDUNDANCY CONSIDERATIONS
Electrical Power				
Main Battery	Degraded or No Output	Minimum or No Power to Entry Science Package Systems	Entry Through Landing	Provide Redundant Battery Provide Backup Capability by Using Surface Laboratory Power
Battery Float Charger	Inoperative	Main Battery Energy Decays Normally at 4%/month Rate	Entry Through Landing	Provide Redundant Battery Float Charger Provide Battery Backup Capability by Using Surface Laboratory Power
Telecommunications				
Cruise Commutator and Primary Commutator	Group, Subgroup or Individual Data Channel Inoperative	Partial Loss of Engineering and Science Data	Interplanetary Cruise Through Landing	Provide Series Active Redundant Data Switches and Switch Drivers
Cruise Encoder and Primary Encoder	Inoperative or Digital Bit Errors	Loss of all Engineering and Science Data if Inoperative	Interplanetary Cruise Through Landing	Provide Standby Redundant Encoder to be Switched by Earth Command
Programmer	Inoperative or Partial Loss of Sequencing and Control	Loss of all Engineering and Science Data if Inoperative	Entry Through Landing	Provide Decentralization of sequencing and Controlling Functions for Minimum Failure Effect
Clock Generator	Inoperative or Unstable	Loss of All Engineering and Science Data if Inoperative	Entry Through Landing	Provide Redundant Temperature Compensated Clock Generator Crystals Provide External Clock Synchronization from C.B.S.
Telemetry Power Supply	Inoperative or Degraded Output	Loss of All Engineering and Science Data if Inoperative	Entry Through Landing	Provide Active Redundant Load Sharing Circuit Components
RT/DT Data Interleaver	No Output Or Data Mixing	Loss of Low Rate Engineering and Science Data if Inoperative	Entry and Descent	Provide Series Active Redundant Interleaver Switches Interleave Data With CBS Radio Link
ESP Data Interleaver	No Output Or Data Mixing	Loss of All Engineering and Science Data if Inoperative	Entry Through Landing	Provide Series Active Redundant Interleaver Switches Interleave Data On ESP Radio Link
S/C Mounted Data Distribution Unit	Inoperative or Steering Logic Error	Loss of Flight Capsule Data	Interplanetary Cruise Through Landing	Provide Active Redundant Data Switches and Switch Drivers
TV Data Process Electronics	Inoperative or Video Processing Error	Loss of all T.V. Data if Inoperative	Entry Through Landing	Provide Dual Channel (Active Redundant) Electronics
T.V.Data Buffer	Inoperative or Improper Storage Delay	Loss of all T.V. Data if Inoperative	Entry Through Landing	Provide Active Redundant Clock Electronics to Assure Buffer Readout

Figure 2.2-1

High Rate VHF Transmitter	Degraded or no Power Output	Loss of All Data if Inoperative	Entry Through Landing	Provide Redundant Transmitter Interleave Data on CBS Radio Link
S/C Mounted VHF Radio Receiver	Inoperative or Poor Sensitivity	Loss of all Data if Inoperative	Entry Through Landing	Provide Redundant Receivers Interleave Data on CBS Radio Link
Delay Storage	Inoperative or Erroneous Output	Loss of Low Rate Engineering and Science Data During Blackout	Entry and Descent	Interleave Data on CBS Radio Link
S/C Mounted Tape Storage	Inoperative in Record or Playback Mode	Loss of all Engineering and Science Data if Inoperative	Entry Through Landing	Provide Redundant Tape Storage Unit Interleave Data or CBS Radio Link
Experiments				
Entry Descent Imaging (Vidicon)	Inoperative or Degraded Resolution or Contrast	Loss of Entry/Descent T,V. Data if Inoperative	Entry and Descent	Provide Active Redundant Imaging System
Mass Spectrometer	Inoperative or Degraded Sensitivity	Loss of Atmospheric Constituent Data if Inoperative	Entry and Descent	Provide Redundant Vacuum Pump and Sampling Valve Provide Pressure and Temperature Sensors for Indirect Determination of Density and Constituents
Platinum Wire Temperature Sensors	Inoperative or Degraded Sensitivity	Loss of Atmospheric Temperature Data	Entry and Descent	Provide Active Redundant Temperature Sensors
Variable Capacitance Pressure Sensors	Inoperative or Degraded Sensitivity	Loss of Atmospheric Pressure Data	Entry and Descent	Provide Active Redundant Pressure Transducers
3 Axis Accelerometer Package	Inoperative or degraded Sensitivity	Loss of Entry and Descent Deceleration Data	Entry and Descent	To Be Determined

arrangement, or interlacing of subsystems. By such means it was desired to have a number of subsystems provide back-up to other subsystems to achieve functional redundancy. Such benefit, although in degraded mode, is accomplished without the expense of added weight. This approach is not based on equipment duplication but rather upon being able to accomplish the function in an alternate manner. As a result, functional redundancy is our preferred approach wherever practical. Three types of redundancies were considered and criteria for effective allocation of these redundancies was developed.

2.3.1 Types of Redundancies - Three redundancy schemes were studied and utilized in the system design. Each type of redundancy has its particular advantages. The decision to use one or another required careful consideration of the particular application and its possible consequences.

a. Alternate Path or Functional Redundancy Method - This redundancy is characterized by providing two or more physically different but functionally identical methods to accomplish a function. The prime objective in employing this method is to provide at least two separate and independent paths by which critical operations may be performed. This type is the preferred choice because it offers greater protection against generic failure modes and unknown environmental stresses. It can be designed into the system at relatively low penalties in terms of weight, volume, power, and system complexity.

b. Cooperative Multi-channel Methods - This redundancy is characterized by dividing the equipment for performing the function into two or more independent portions in such a manner that some portion can fail and the function can still be performed with minimum or no degradation. This type is the next choice because no failure detection or switching features are required with this method. It is normally designed into the system at moderate penalties in weight, volume, and power.

c. Ordinary Block or Element Redundancy Method - This redundancy is characterized by the paralleling of two identical units in which failure of the operating unit is sensed and identical equipment is switched in to accomplish the function. This type is the least desirable because both units are susceptible to the same failure modes if exposed to overstressed conditions. It also requires the addition of a detection and switching unit, therefore providing the least overall reliability improvement. In addition parallel units with a detection and switching unit more than doubles the weight and increases power requirements.

2.3.2 Reliability Versus Weight - The FMECA led to many suggested possibilities for the incorporation of redundancies. However, the addition of redundancies represents a corresponding weight increase. Thus an initial criterion for decision on redundancy incorporation needed to be established. This criterion was a requirement for achieving maximum increase in reliability with a minimum weight increase. An illustration of the implementation of this criterion is shown in Figure 2.3.2-1. The failure rate (λ) for each component, system or subsystem must be utilized in establishing the non-redundant reliability (R_o) from the equation:

$$R_o = e^{-\lambda t} \qquad (\ln R_o = -\lambda t)$$

Then the reliability improvement for each subsequent change ($\ln R_i$) was calculated by:

$$R_i = e^{\ln R_o + \Delta \ln R} \qquad [\Delta \ln R = \ln R_i - \ln R_o]$$

Preference was given the component with the lowest weight increase for an incremental change in reliability ($\Delta W/\Delta \ln R$) followed by units of increasing $\Delta W/\Delta \ln R$. Utilization of this criterion resulted in the redundancy considerations shown in Figure 2.3.2-2 and indicated the potential reliability improvement as shown in Figure 2.3.2-3. This technique of redundancy considerations was applied to the Entry Science Package, and placed equal emphasis on the achievement of each mission objective. The competing characteristics of the Performance and Design Requirements for the 1973 Mission indicates that equal emphasis should not be placed on each mission objective. Therefore, an additional analytical technique was needed based on the priority of these objectives. Fulfillment of this need was accomplished by an effectiveness analysis study for the redundancy considerations.

2.3.3 Effectiveness Analysis - The effectiveness analysis study is the adaptation of a technique which evaluated the redundancy in terms of the achievement of the mission objective. The equation developed was:

$$E = V_1 R_1 + V_2 R_2 + V_3 R_3$$

where V_1 = Value index for the achievement of landing

V_2 = Value index for the performance of Entry Science experiments

V_3 = Value index for the performance of Landed Science experiments

and, R_1 = Reliability index for the achievement of landing

R_2 = Reliability index for the performance of entry science experiments

ENTRY SCIENCE PACKAGE TELECOMMUNICATIONS
RELIABILITY vs WEIGHT

COMPONENT	BASELINE				ALTERNATE					
	τ_m (1)	λ (2)	(3) $-\ln R \times 10^6$	W (LB)	(4) $-\ln R \times 10^6$	(4) W (LB)	$\Delta \ln R \times 10^6$	ΔW (LB)	$\Delta W / \Delta \ln R$	CHANGE
Instrumentation Subsystem	140	50	7000	6.50						
Telemetry Equipment										
Programmer	124	10	1240	0.70	5	1.4	1235	0.70	567	T13E
Cruise Commutator	5596	6	33576	0.45	1127	0.9	32449	0.45	14	T14E
Cruise Encoder	5596	3	16788	0.15	282	0.3	16506	0.15	9	T15E
Science Data Remote Interface Unit	124	13	1610	1.60	5	2.4	1605	0.80	500	T16E
TV Data Process Electronics	124	30	3720	1.90	5	3.4	3715	1.50	405	T18E
Commutator and Encoder	124	35	4340	2.20	5	4.4	4335	2.20	507	T18E
Data Interleaver	124	7	870	1.00						
Telemetry Power Supply	124	4	500	2.00	<1	3.0	500	1.00	2000	T19E
Data Storage Subsystem										
Delay Storage	124	55	6820	3.00						
TV Buffer	124	55	6820	3.00	20	5.5	6800	2.50	368	T20E
High Rate VHF Radio Subsystem										
Transmitter – Power Supply Assembly	124	0.05	6	24.20						
Diplexer	124	0.10	13	1.80						
High Rate VHF Transmit Antenna	124	0.80	100	6.00						
S/C VHF Receive Antenna	94	4	380	1.00						
S/C Receiver – Power Supply Assy.	94	0.045	4	8.00						
S/C Pre-Amplifier	94	1	100	0.20						
S/C Diversity Combiner	94	6	570	0.80						
S/C Tape Storage	94	142	13350	6.00						
S/C Data Buffer	94	55	5200	2.00						
S/C Parasitic Antenna	80	0.50	40	2.00						

(1) Modified time factor x time (hours)
(2) λ = Failures per million hours
(3) $\ln R \times 10^6 = t m \lambda$
(4) Computed LnR and Weight based on added redundancy.

CONFIGURATION*	ΔW (LB)	$\Sigma \Delta W$ (LB)	$\Delta \ln R$	$\Sigma \ln R$
Baseline	–	0	0	0.103047
T1E	0.25	0.25	0.021806	0.081241
T13E	0.70	0.95	0.001235	0.080006
T14E	0.45	1.40	0.032449	0.047557
T15E	0.15	1.55	0.016506	0.031051
T16E	0.80	2.35	0.001605	0.029446
T17E	1.50	3.85	0.003715	0.025731
T18E	2.20	6.05	0.004335	0.021396
T19E	1.00	7.05	0.000500	0.020896
T20E	2.50	9.55	0.006800	0.014096

*Changes T1 , T13E, etc. to the Baseline Subsystem are cumulative.

T1E – Functional Redundant ESP Radio Link (Interleave Low Rate ESP Data on CBS Radio Link)
T13E – Standby Redundant Programmer
T14E – Series Active Redundant Cruise Commutator Data Switches and Switch Drivers
T15E – Standby Redundant Cruise Encoder
T16E – Active Redundant Science Data Remote Interface Electronics
T17E – Active Redundant TV Data Process Electronics
T18E – Standby Redundant Primary Commutator and Encoder
T19E – Active Redundant (Load Sharing) Telemetry Power Supply
T20E – Active Redundant TV Buffer

Figure 2.3.2-1

ENTRY SCIENCE PACKAGE REDUNDANCY CONSIDERATIONS

(RELIABILITY vs. WEIGHT)

ORDER OF PRIORITY	REDUNDANCY CONSIDERATION	SUBSYSTEM	TYPE
1	Standby redundant cruise encoder	Telecommunications	Block
2	Interleave low rate data on Capsule Bus radio link	Telecommunications	Functional
3	Series active redundant cruise commutator data switches and switch drivers	Telecommunications	Multichannel
4	Surface Laboratory power provides backup to entry science power	Electrical Power	Block
5	Standby redundant battery float chargers	Electrical Power	Block
6	Active redundant battery charger relays	Electrical Power	Multichannel
7	Active redundant TV buffers	Telecommunications	Multichannel
8	Active redundant TV data process electronics	Telecommunications	Multichannel
9	Active redundant science data remote interface electronics	Telecommunications	Multichannel
10	Standby redundant commutator and encoder	Telecommunications	Block
11	Standby redundant programmer	Telecommunications	Block
12	Active redundant heater thermostats	Thermal Control	Multichannel
13	Active redundant thermostatically controlled heaters	Thermal Control	Multichannel
14	Active redundant cruise heaters	Thermal Control	Multichannel
15	Active redundant telemetry power supply	Telecommunications	Multichannel
16	Quad redundant input power diodes	Electrical Power	Multichannel
17	Active redundant battery relays	Electrical Power	Multichannel
18	Active redundant subsystem power control relays	Electrical Power	Multichannel
19	Active redundant main battery	Electrical Power	Multichannel
20	Quad redundant battery power relays	Electrical Power	Multichannel

Figure 2.3.2-2

ENTRY SICENCE PACKAGE RELIABILITY IMPROVEMENT VS. ADDED REDUNDANCY WEIGHT

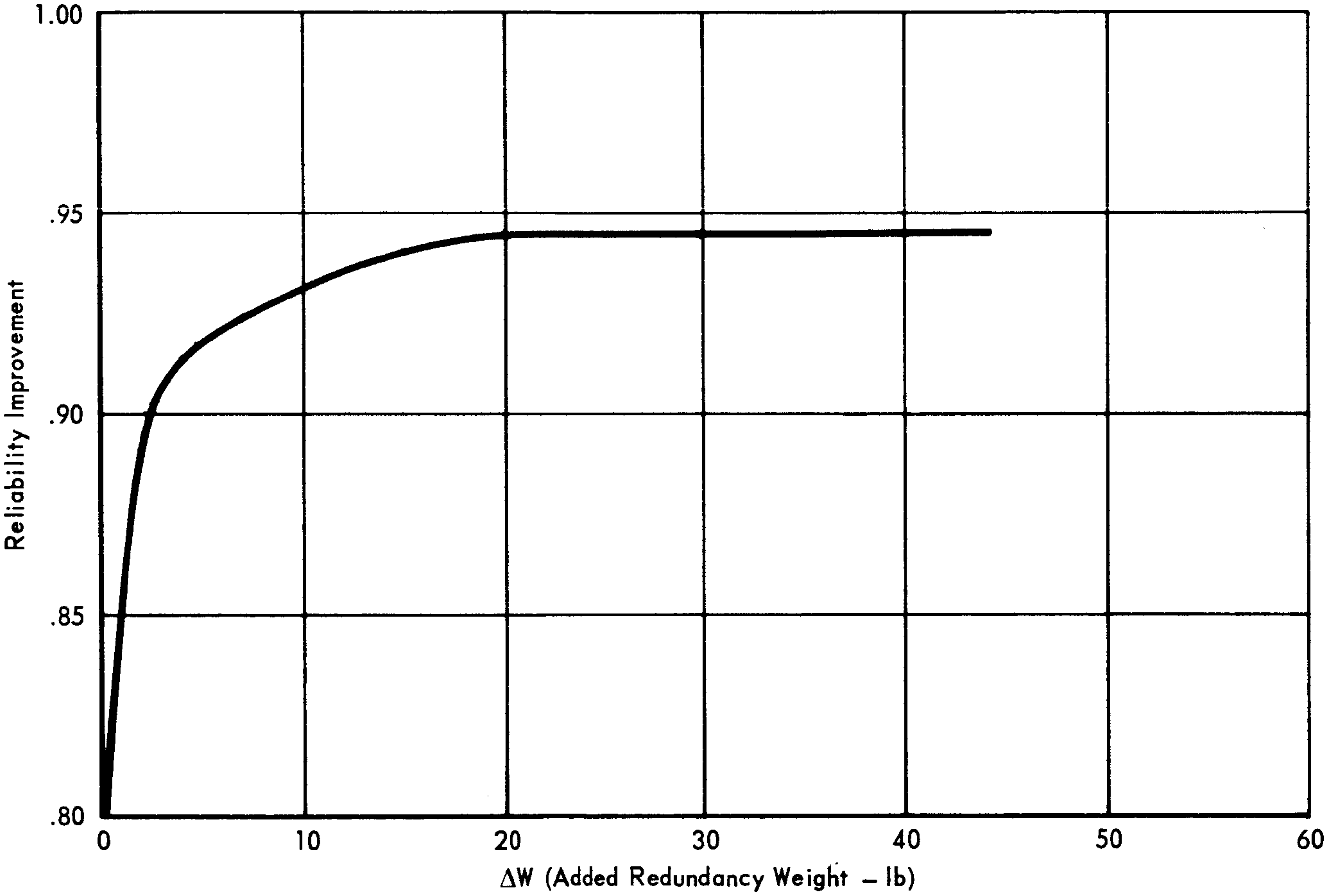


Figure 2.3.2-3

R_3 = Reliability index for the performance of landed science experiments
Based on the competing characteristics criterion described in the "Specification for Performance and Design Requirements for the 1973 VOYAGER Mission", it was established that the value index should have the relationship $V_1 + V_2 + V_3 = 1$ and $V_1 > V_2 > V_3$. An effectiveness model was developed to work the problem and is described and shown in Part B, Section 4.10 of Volume II.

Based on the assignment of value indices: $V_1 = .40$, $V_2 = .35$ and $V_3 = .25$, comparisons of redundancy considerations from a reliability versus weight analysis and an effectiveness analysis were made and are tabulated in Figure 2.3.3-1. For the chosen indices, the redundancy considerations were identical.

2.3.4 Summary of Selected Redundancies - Engineering judgment and the effectiveness analysis results were used as the criteria for selecting the preferred system concept redundancies. The primary criterion engineering judgment, required backup capability for the performance of all critical mission events. This capability was provided regardless of the efficiency of weight increase to reliability. After providing this capability, the selection of additional equipment redundancies was guided by the effectiveness analysis. The sixteen (16) redundancies selected for the preferred concept are tabulated in Figure 2.3.4-1. Twelve (12) are functional and consequently added minimal weight.

2.3.5 Redundancy Implementation Policy - The basic redundancy implementation policy wasmodified as a result of the effectiveness analysis. Prior to this analysis, equal emphasis was placed on the redundancy considerations for Capsule Bus, Entry Package and Surface Laboratory. As the design concepts evolved, it became apparent this policy of equal emphasis must be modiifed to most effectively utilize a prime resource weight. Therefore the effectiveness analysis technique was used as the redundancy implementation policy.

RELIABILITY vs. WEIGHT AND EFFECTIVENESS ANALYSIS

REDUNDANCY PRIORITY COMPARISON

REL. vs. WT.	EFF. ANAL.	REDUNDANCY CONSIDERATION	SUBSYSTEM	TYPE
1	1	Standby redundant cruise encoder	Telecommunications	Block
2	2	Interleave low rate data on capsule bus radio link	Telecommunications	Functional
3	3	Series active redundant cruise commutator data switches and switch drivers	Telecommunications	Multichannel
4	4	Surface laboratory power provides backup to entry science power	Electrical Power	Block
5	5	Standby redundant battery float chargers	Electrical Power	Block
6	6	Active redundant battery charger relays	Electrical Power	Multichannel
7	7	Active redundant TV buffers	Telecommunications	Multichannel
8	8	Active redundant TV data process electronics	Telecommunications	Multichannel
9	9	Active redundant science data remote interface electronics	Telecommunications	Multichannel
10	10	Standby rendundancy commutator and encoder	Telecommunications	Block
11	11	Standby redundant programmer	Telecommunications	Block
12	12	Active redundant heater thermostats	Thermal Control	Multichannel
13	13	Active redundant thermostatically controlled heaters	Thermal Control	Multichannel
14	14	Active redundant cruise heaters	Thermal Control	Multichannel
15	15	Active redundant telemetry power supply	Telecommunications	Multichannel
16	16	Quad redundant input power diodes	Electrical Power	Multichannel
17	17	Active redundant battery relays	Electrical Power	Multichannel
18	18	Active redundant subsystem power control relays	Electrical Power	Multichannel
19	19	Active redundant main battery	Electrical Power	Multichannel
20	20	Quad redundant battery power relays	Electrical Power	Multichannel

Figure 2.3.3-1

ENTRY SCIENCE PACKAGE SELECTED REDUNDANCIES

TYPE	EVENT	PRIMARY SOURCE	REDUNDANT SOURCE
Functional	• Switch Entry Science Package, Cruise Commutators to Capsule Bus Telemetry Control Mode	Capsule Bus Test Programmer	Mission Operations System
	• Turn on Entry Science Package Telemetry Subsystem	Capsule Bus Test Programmer	Mission Operations System
	• Switch Entry Science Package Telemetry Subsystem to Checkout Mode	Capsule Bus Test Programmer	Mission Operations System
	• Turn Off Entry Science Package Telemetry Subsystem	Capsule Bus Test Programmer	Mission Operations System
	• Switch Entry Science Package, Cruise Commutators to Cruise Mode	Capsule Bus Test Programmer	Mission Operations System
	• Switch Entry Science Package to Internal Power	Capsule Bus Sequencer and Timer	Flight Spacecraft Central Computer and Sequencer or Mission Operations System
	• Switch Entry Science Package Cruise Commutators to Capsule Bus Control Mode	Capsule Bus Sequencer and Timer	Mission Operations System
	• Turn on Entry Science Package Telemetry Subsystem (Switch to Entry Mode), Turn on Base Pressure Experiment, Descent TV (Warmup), Accelerometer Experiment, Stagnation Pressure Experiment, and Radio Subsystem	Capsule Bus Sequencer and Timer	.05g Sensor or Capsule Bus Radar Altimeter
	• Initiate Descent TV Camera Sequencing	Capsule Bus Sequencer and Timer	.05g Sensor or Capsule Bus Radar Altimeter
	• Sense Mach 5 and Initiate Mass Spectrometer Experiment, Stagnation Temperature Experiment, and Base Temperature Experiment	Entry Science Package Sensor	Capsule Bus Radar Altimeter
	• Switch Entry Science Package Telemetry Subsystem to Terminal Descent Mode.	Capsule Bus Sequencer and Timer	Capsule Bus Radar Altimeter
	• Shut Down Entry Science Package	Capsule Bus Sequencer and Timer	Surface Lab Sequencer and Timer

TYPE	SUBSYSTEM EQUIPMENT REDUNDANCIES	SUBSYSTEM
Block	Standby Redundant Cruise Encoder	Telecommunications
Functional	Interleave Entry Science Package Low-Rate Data on Capsule Bus Radio Link	Telecommunications
Multi-Channel	Series Active Redundant Cruise Commutator Data Switches and Switch Drivers	Telecommunications
Block	Surface Lab Power Provides Backup to Entry Science Package Power	Electrical Power

Figure 2.3.4–1

SECTION 3

QUANTITATIVE RELIABILITY ESTIMATES

The primary purpose of the reliability estimates is to show relative comparisons of reliability potentials of the many concepts considered, rather than to accurately predict the reliability of a given concept or the preferred concept.

3.1 RELIABILITY ESTIMATE METHODS - The methods used in performing reliability estimates for the studies were maintained consistent with the level of design maturity. The primary elements necessary for establishing a quantitative reliability estimate are discussed in the following paragraphs.

3.1.1 <u>Mission Profile Analysis</u> - The mission profile presented in the VOYAGER Specification was examined in detail, and a representative mission for the Entry Science Package was established for reliability estimates. Mission events were examined to determine the possible effect of the events on subsystem reliability. This examination resulted in the establishment of failure rate modifiers to be applied in determining an equivalent mission duty cycle. The mission events and applicable failure rate modifying factors are listed in Figure 3.1.1-1. Modifying factors are shown for both operating and non-operating equipment. The factors depict the significant relative environmental and application stresses for the different events.

3.1.2 <u>Subsystem Configuration Definition</u> - A necessary step in the computation of a reliability estimate is to determine the function and operations of the subsystem and its major components or assemblies. This was accomplished by a study of the subsystem functional block diagram. A typical subsystem functional block diagram is illustrated by Figure 3.1.2-1.

From this information a reliability logic diagram was prepared for the subsystem. This is a "success path" diagram showing those components and/or subassemblies which must function in order for the subsystem to successfully complete its mission. The reliability diagram expands in detail as the design matures. A typical reliability block diagram is illustrated by Figure 3.1.2-2.

3.1.3 <u>Failure Rate Determination</u> - With a subsystem reliability diagram defined, the next step in performing a reliability estimate was to determine a failure rate for each item or block in the reliability deagram. For the less complex subassemblies and/or components which appear in the diagram, the historical failure rate of a similar item was used. The parts count technique, as illustrated by

VOYAGER MARS MISSION PROFILE AND FAILURE RATE MODIFYING FACTORS FOR RELIABILITY ANALYSIS

MISSION EVENT	TIME (HRS)	MODIFYING FACTOR		MODIFIED TIME - t_m	
		OPERATING EQUIPMENT	NON-OPERATING EQUIPMENT	OPERATING EQUIPMENT	NON-OPERATING EQUIPMENT
Launch	0.20	150	150	30	30
Parking Orbit	0.54	1	.01	.54	.0054
Interplanetary Injection (Powered Flight)	0.09	3	3	.27	.27
Interplanetary Cruise (222 days + 4 days)	5424	1	0.01	5424	54.24
Trajectory Corrections (Powered Flight)	0.10*	3	3	.30	.30
Orbit Insertion (Powered Flight)	0.10*	3	3	.30	.30
Orbit Cruise (7.5 Orbits)	105	1	.01	105	1.05
De-orbit Maneuver (Powered Flight)	0.02	3	3	.06	.06
Orbit Descent	5	1	.01	5	.05
Entry	.10	6	6	.60	.60
Terminal Descent Aero	0.02	3	3	.06	.06
Terminal Descent Prop	0.02	6	6	.12	.12
Impact	.01	3,000	3,000	30	30
Landing Erection	.02	3	3	.06	.06
Landing Operation					
Exterior	≤ 50	5	.01	≤ 250	≤ .50
Interior	≤ 50	1	.01	≤ 50	≤ .50

* Estimate

Figure 3.1.1-1

ESP TELECOMMUNICATIONS FUNCTIONAL BLOCK DIAGRAM

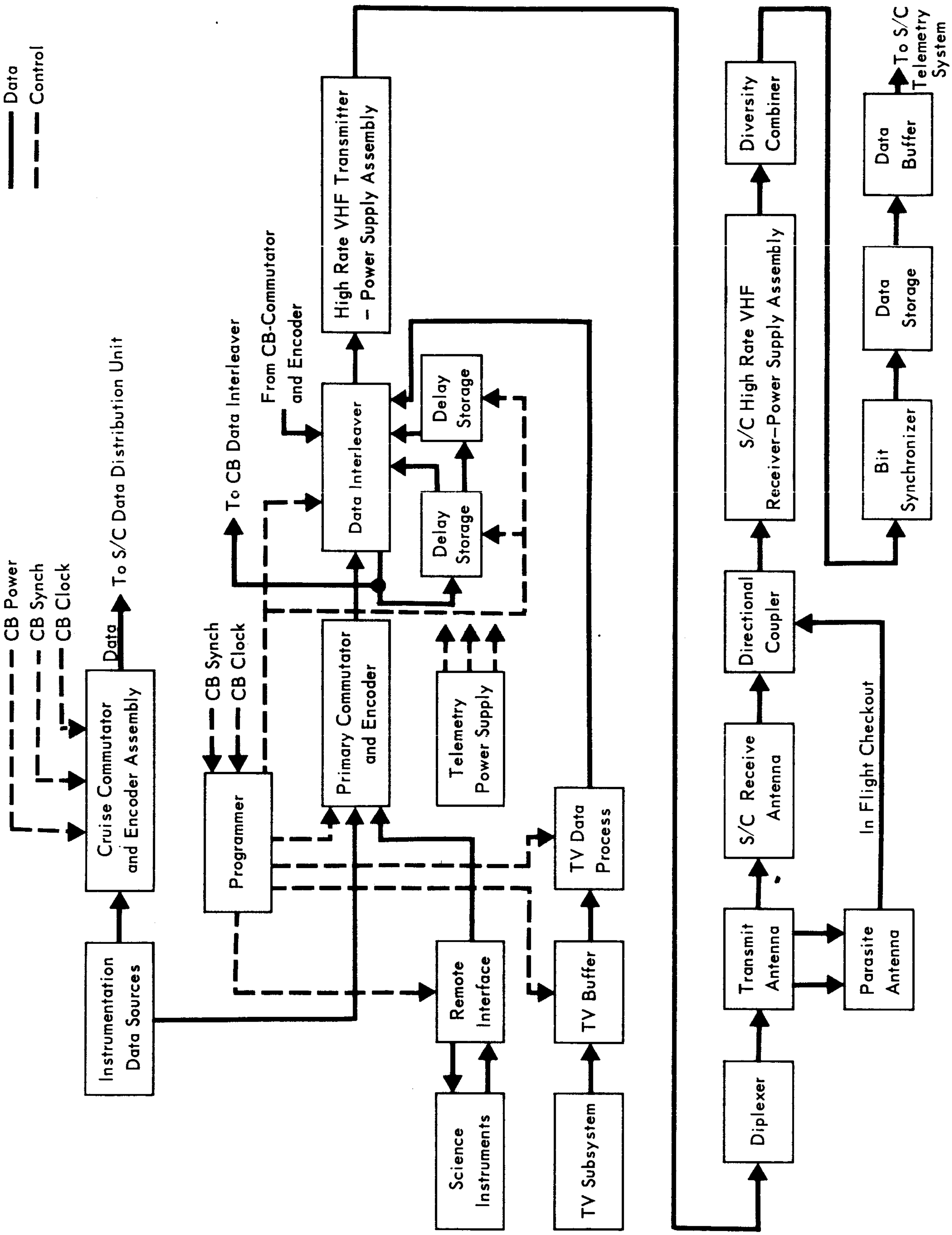
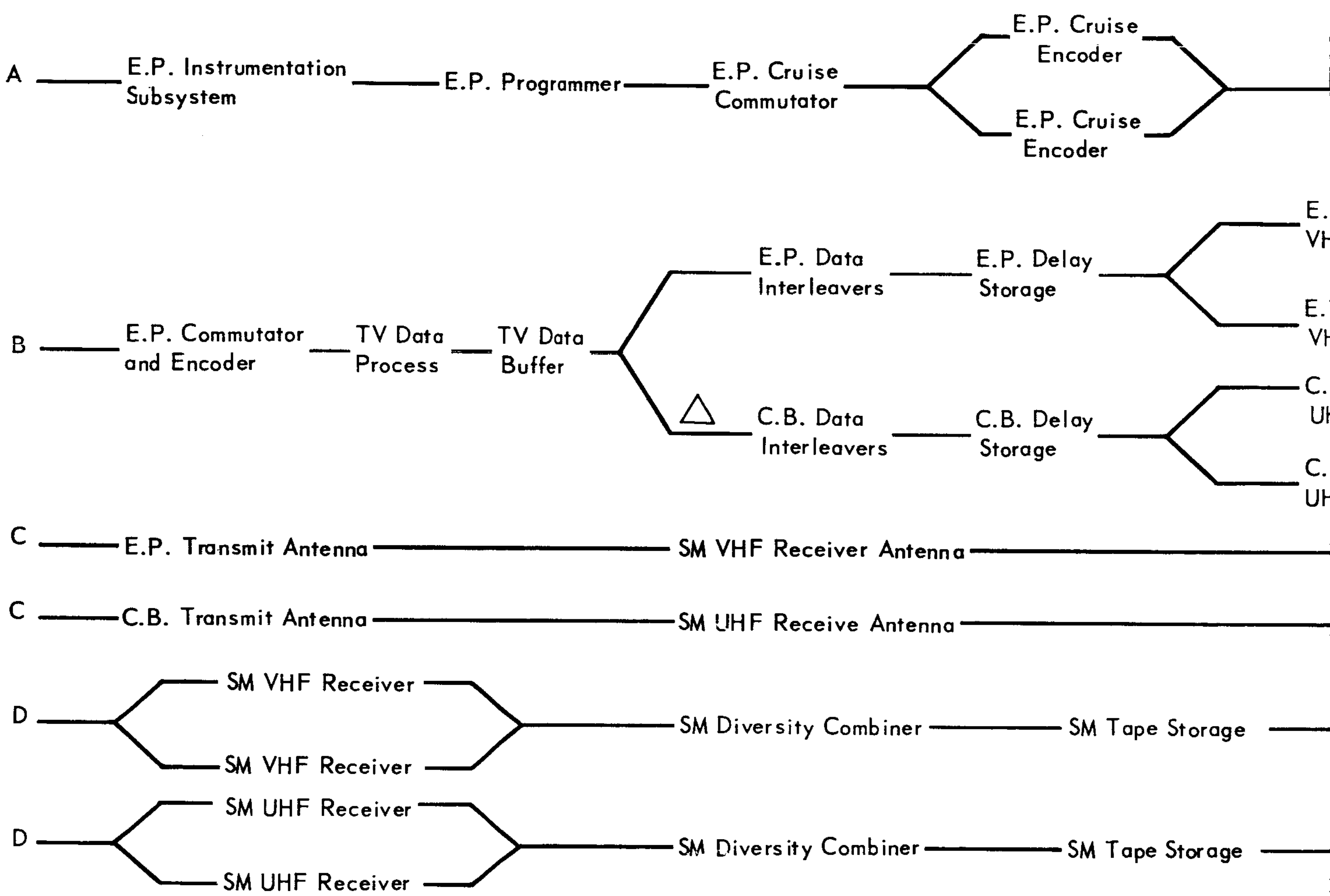


Figure 3.1.2–1

RELIABILITY LOGIC DIAGRAM

ENTRY SCIENCE PACKAGE TELECOMMUNICATIO



E.P. – Entry Package
C.B. – Capsule Bus
S.M. – Spacecraft Mounted Capsule Support Equipment
Δ TV Data Transmitted on Entry Science Package High Rate Radio Link only

Figure 3.1.2-2

IS (TCM)

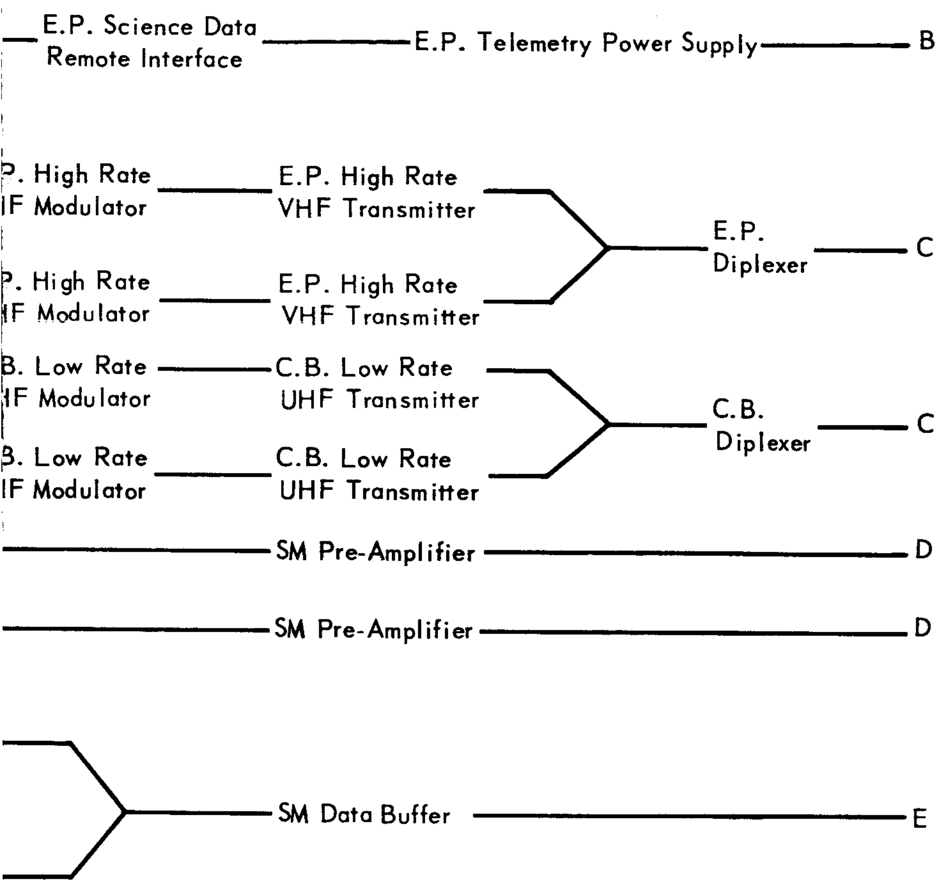

E.P. Science Data Remote Interface
E.P. Telemetry Power Supply
B
P. High Rate
IF Modulator
E.P. High Rate VHF Transmitter
P. High Rate
IF Modulator
E.P. High Rate VHF Transmitter
E.P. Diplexer
C
B. Low Rate
IF Modulator
C.B. Low Rate UHF Transmitter
B. Low Rate
IF Modulator
C.B. Low Rate UHF Transmitter
C.B. Diplexer
C
SM Pre-Amplifier
D
SM Pre-Amplifier
D
SM Data Buffer
E

Figure 3.1.3-1 was used for all other assemblies and/or components. Average failure rates were used for the different component parts with no attempt to predict part derating or environmental stresses internal to the assembly. To insure good relative comparisons of the estimated reliability of competing concepts, a list of standard failure rates for electrical and electronic piece parts was established and used for all parts count estimates. This same technique can be extended to include the effects of part derating and operating environments as the detailed design of the assemblies materializes. The part count technique provides an effective tool for determining areas in which reliability can be improved by effective part derating or by incorporating redundancy within the assembly.

3.1.4 Subsystem Reliability Estimate - The final step in arriving at a subsystem or concept quantitative reliability estimate was to combine the above elements. Figure 3.1.4-1 illustrates one technique for arriving at the subsystem estimate. A modified time (t_m) was determined for each subassembly by applying the modifying factors as previously shown in Figure 3.1.1-1 to the mission duty cycle of the subassembly. This time (t_m), for time dependent items, was then multiplied by the failure rate of the item to find the mission failure rate for each item. The summation of these mission failure rates gives the subsystem mission failure rate. The subsystem mission reliability was determined by use of the formula

$$R = e^{-\lambda t_m}$$

3.2 RELIABILITY ESTIMATE LIMITATIONS - The limitations of quantitative reliability estimates must be recognized if results are to be interpreted properly. Quantitative estimates for system and subsystem reliability made during this concept definition phase have accuracy limited to the level of design maturity. Quantitative reliability estimates are a valuable input to early design decisions and will become more and more significant as the design becomes more detailed. The emphasis will gradually shift from comparative estimates toward predictive estimates as the design evolves, with the failure mode, effect and criticality analyses being of primary importance in shaping the design.

3.3 SUMMARY of RELIABILITY ESTIMATE RESULTS - The primary use of the quantitative reliability estimates has been for comparative evaluation of competing subsystem concepts rather than to predict the actual reliability of a given concept or the preferred concept. A quantitative reliability estimate was a standard input to major design trade studies and was a major factor in many decisions. The estimates have served to highlight areas for reliability improvement. The reliability

PARTS COUNT ESTIMATE
ENTRY SCIENCE PACKAGE
HIGH RATE VHF TRANSMITTER SUBASSEMBLY

COMPONENT	QUANTITY (n)	FAILURE RATE $\lambda \times 10^6$/hr	$n\lambda \times 10^6$
Capacitors			
Glass	20	.005	.100
Variable	15	.10	1.5
Ceramic	30	.005	.15
Resistors			
Metal Film	25	.003	.075
Carbon Comp.	25	.001	.025
Transistors			
RF Power	12	.30	3.6
Inductors			
RF Choke	12	.075	.90
Transformers			
RF/IF/Signal	12	.05	.60
Diodes			
General Purpose	20	.05	1.0
Subassembly Failure Rate $= \Sigma n\lambda = 7.95 \times 10^{-6}$			

Figure 3.1.3-1

RELIABILITY ESTIMATE
ENTRY SCIENCE PACKAGE TELECOMMUNICATIONS

COMPONENT OR SUBASSEMBLY	t_m (hr)	Failure Rate $\lambda \times 10^6$	$\lambda t_m \times 10^6$ ($-\ln R \times 10^6$)
Instrumentation Subsystem	140	50	7000
Programmer	124	10	1240
Cruise Commutator (Internally Redundant)	5596	–	1127
Cruise Encoder Standby Redundancy (2)	5596	–	282
Science Data Remote Interface Unit	124	13	1610
Telemetry Power Supply	124	4	500
Commutator and Encoder	124	35	4340
TV Data Process	124	30	3720
TV Data Buffer	124	55	6820
Multichannel Cooperative Redundant ESP Radio Link (Low Rate ESP Data Interleaved on CBS Radio Link)	124	–	378
Spacecraft Mounted Data Buffer	94	55	5200
			$\Sigma\lambda t_m = 32{,}217$
			$R = e^{-\Sigma\lambda t_m} = .9682$

Figure 3.1.4-1

estimates were a necessary input to the reliability versus weight and effectiveness analyses.

A quantitative reliability estimate of the selected Entry Science Package configuration has been computed and is presented in Figure 3.3-1. This estimate indicates that the experiments and telecommunication subsystems, will have the greatest influence on Entry Science Package reliability.

VOYAGER ENTRY SCIENCE PACKAGE RELIABILITY ESTIMATE SUMMARY

SUBSYSTEM	MISSION RELIABILITY ESTIMATE
Telecommunication Telemetry Radio Antenna Command Data Storage	.968
Electrical Power Power Switching & Logic Battery Battery Charger	.990
Thermal Control	.999
Experiments	.941
Total Package Reliability	.901

Figure 3.3-1

SECTION 4

RELIABILITY PROGRAM REQUIREMENTS

The Phase B study has revealed several reliability program elements which must receive increased major emphasis throughout the program. These elements are: (1) Failure modes, effects, and criticality analysis, (2) Specially planned parts and materials program, (3) Positive failure analysis, evaluation and corrective action, and (4) Comprehensive design reviews.

4.1 FAILURE MODE, EFFECTS, AND CRITICALITY ANALYSIS - FMECA is a powerful reliability technique for highlighting potential design weakness. It must be a primary continuing reliability task performed concurrently with the detail design and operational contingency analysis. The FMECA carried to the detail level provides the basis for design considerations which minimize mission failures or degradation.

4.2 PARTS AND MATERIALS PROGRAM - The decontamination, sterilization, and long-life requirements demands the need for a specially planned parts and materials program. This program must provide for the selection, testing, and control of parts and materials to assure that the parts and materials meet these environmental and life requirements,and do not compromise equipment reliability.

4.3 FAILURE EVALUATION - "Failures" or performance irregularities must be expediently and positively identified, analyzed, and corrective action taken. This assures that no problem remains unidentified and immune to maximum corrective effort.

4.4 DESIGN REVIEWS - In depth design reviews must be conducted on all elements of the Entry Science Package. The design review process must also place equal emphasis on the review of the operational support equipment compatibility with the system and/or subsystems. The compatibility must be clearly evaluated by design review to assure that the interface design of the operational support equipment and flight equipment will not compromise the launch constraints.

SECTION 5

COMPONENT PART RELIABILITY

Recognizing that system reliability is influenced by the characteristics and application of the component parts, we have devoted our Phase B effort to: (1) determining the elements of a realistic component part plan, and (2) initiating certain elements of this plan.

The elements of the plan are:

a. An Approved Parts List (APL) listing those parts demonstrating ability to meet VOYAGER Capsule Bus requirements.

b. Specification control for all parts.

c. Parts Application Manual for electrical and mechamical parts.

d. Parts Test Program.

e. Traceability program.

During Phase B we have begun work on elements a, b, c, and d as reported in the paragraphs immediately following.

5.1 APPROVED PARTS AND MATERIALS LIST - During Phase B, a preliminary Approved Parts List (APL) was issued and used by the design functions as a guide where part information was required to conduct meaningful implementation studies. The data used to generate the list were taken from JPL Document ZPP-2010-SPL-C, "Electronic Parts Sterilization Candidates for Spacecraft Application." In addition an Approved Materials and Processes List was prepared based on data available to us from many sources and from in-house testing. Only those parts, materials and processes which exhibited evidence of meeting the VOYAGER Flight Capsule requirements were included in these lists. These two lists are McDonnell Douglas reports F189 and E936, respectively.

The APL includes tabulations of specific electrical and mechanical parameters to aid the design groups in proper part selections for particular applications. The APL subdivides the parts into three categories:

a. High Reliability - These parts are VOYAGER preferred parts which have been subjected to long term failure rate life tests and have established low failure rates.

b. Preferred Parts - These parts are tested and qualified for use in the VOYAGER Flight Capsule environment.

c. Nonstandard - These parts are Special or Limited application, and receive specific testing and justification for use.

It is recognized that modification to the Approved Parts, Materials and Processes Lists will be required as the VOYAGER Program progresses. The continuing component part reliability program plan for the Phase C and D effort is detailed in Part C, Section 10 of Volume VI.

5.2 SPECIFICATION - Several special specifications were produced for the VOYAGER Flight Capsule Program during the Phase B study in preparation for the Phase C design effort. These specifications delineate the part requirements and the approved sources of supply. Approved sources of supply candidates were selected from JPL Document ZZP-2010-SPL-C.

To minimize duplication, a two level specification system is used as described below:

a. General Specification - A specification covering the general requirements for generic types or families of parts.

b. Detail Part Drawings - A specification delineating the detail requirements for a specific part.

Examples of existing specifications are as follows:

a. General Specification, VOYAGER Flight Capsule, Semiconductors, Transistors, Diodes and Integrated Circuits (207-780003)

b. Detail Part Drawing, Integrated Circuit, Flip-Flop, RST (207-780007)

c. Detail Part Drawing, Semiconductor, Diode, General Purpose, Power, Silicon (207-780004)

d. General Specification, VOYAGER Flight Capsule, Capacitors, Fixed (207-780005)

e. Detail Part Drawing, Capacitor, Fixed, Ceramic (207-780009)

The Semiconductor General Specification and the Integrated Circuit Detail Part Drawing are included in Appendix (A) as examples.

The procedure established for the issuance of additional specifications is given in the component part, material and processes program plan, Part C, Section 10 of Volume VI.

5.3 APPLICATION MANUAL - Part parameter control alone is not sufficient to assure satisfactory operation of the part. Our approach for the VOYAGER Flight Capsule System places equal emphasis on use of the best part and best use of the part. In conjunction with the Approved Parts List, a Parts Application Manual was initiated in Phase B as a guide for the design groups, and is discussed in more detail in Part C, Section 10 of Volume VI. The following information as a minimum is included in the manual:

a. Function of the part
b. Application considerations and limitations
c. Electrical characteristics
d. Environmental limitations
e. Failure modes
f. Failure rates
g. Physical properties
h. Packaging, mounting and handling limitations

5.3.1 Electrical Considerations - In order to assure high reliability designs, conservative derating of electrical stress for component parts is necessary. These derating factors were established and included in the initial issue of our applications manual. The following are examples of derating factors used:

a. Integrated Circuits - Fan-in and fan-out shall be such that the power dissipation shall not exceed 50 percent of maximum rating.
b. Power Transistors - Power dissipation shall not exceed 30 percent of rated maximum, base and emitter currents shall not exceed 75 percent of rated maximum, and voltages shall not exceed 75 percent of rated maximum.
c. Wire Wound Resistors (1 percent tolerance and up) - Power dissipation shall not exceed 50 percent of rated maximum.

These derating values are generic, and further evaluation is required for each individual part within the general part category.

5.3.2 Mechanical Considerations - Consistent with the level of detail design existing in the Phase B study, a review of the packaging, mounting, and environmental factors affecting parts was performed and comparisons made with the part limitations. The following items were considered in the review:

a. Thermal inertia
b. Thermal conductivity
c. Thermal radiation on adjacent parts
d. Vibration
e. Encapsulation
f. Mounting
g. Interconnection

This type of review must continue in depth as the design proceeds into Phase C and D.

The results of the review and results of mechanical and process tests provided the data for proper parts applications, and was reflected in the Approved Materials and Processes List and in the Parts Application Manual.

5.4 TESTING - Tests were conducted prior to and during Phase B to evaluate the effects of heat sterilization and decontamination cycles and shock. These tests, involving thirteen part types, resulted in very few failures.

a. Power diodes failed due to dessicant liberating moisture during the heat cycle. Although a large percentage of one diode type group exhibited high reverse current leakage, none of the failures resulted directly from the sterilization or shock environment.

b. Powdered iron core inductors failed when subjected to shock beyond that expected in the Flight Capsule.

For a summary discussion of the above part testing see Part B, Section 1.1 of Volume VI.

Several insulation and encapsulation materials are presently being evaluated in our laboratories sterilization temperature, operating temperature and at a pressure of 10^{-10} Torr to assure that outgassing and sublimation will not create hazards to the part or surrounding parts.

5.4.1 Qualification - During Phase B, we have examined the required qualification testing to assure that all parts are suitable for the VOYAGER Flight Capsule requirements. Qualification testing must be performed and will include all environments deemed necessary to qualify the parts. The particular number of qualification samples will be selected in accordance with individual parameters, environments and failure rate requirements. Qualification environment will include heat sterilization temperatures, decontamination (ETO) atmospheres, shock, humidity, vibration, acceleration and others necessary to assure compliance with VOYAGER requirements. Part parameter limits consist of attribute as well as variables data. The required testing is reflected in the part specifications.

The amount and degree of testing required is tempered by information acquired during previous programs or received from cooperating agencies, such as the Interservice Data Exchange Program (IDEP) and Parts Reliability Information Center/ Appollo Parts Information Center (PRINCE/APIC).

5.4.2 Screening - Our study has reconfirmed that screening is a prime requisite to assure reliability for a long life space program such as VOYAGER. Screening provides for the selection, from a group of parts, having the potential for the desired reliability. Screening is nondestructive testing performed on a lot-by-lot basis in an effort to:

a. Eliminate product degradation
b. Identify and control process changes (planned or unplanned)
c. Prevent anomalous failures
d. Identify and control design changes
e. Eliminate infant mortality
f. Isolate design discrepancies

We recommend, and are presently using, a screening technique for integrated circuit to control workmanship defects. A color photograph at 100X magnification of each device is required just prior to final seal. This is extremely effective, when combined with the usual 100% visual inspection requirement, in improving quality of the delivered parts. These photographs, identified with the part serial number, allow elimination of devices with scratched metalization, foreign particles and other common failure causes attributable to workmanship.

5.5 CONTROL - In the course of our study the following control elements (Part Material and Process Controls, Flow Chart Documentation, Approved Parts List - APL, APL addition/deletions procedures, traceability requirements) were determined as necessary to assure that only acceptable and qualified parts are used in the assembly of subsystem and systems. A discussion of these controls is found in Part C, Section 10, of Volume VI.

Our study recommendations on implementation of these controls, including traceability requirements, are noted below.

5.5.1 Part Manufacturer - The manufacturer of parts for VOYAGER Flight Capsule equipment is required to apply adequate controls to incoming inspection, materials, processes, fabrication, testing, stocking and packaging. A McDonnell requirement is that Reliability and Quality Assurance Plans (including as a minimum, organizational relationships with other departments in such matters as part design, failure rate prediction, failure mode identification, and design proof testing) be made available on request by the parts manufacturer for review.

On critical parts, the manufacturer is required to submit a flow chart which shows the entire processing from incoming materials to final part shipment. All processes and inspection points are identified by the applicable internal specification including revision date. Subsequent to acceptance of the flow chart, changes must be reported by the supplier before shipment of parts incorporating process changes. Although this requirement is not expected to prevent changes in the manufacturer's processes, it establishes a baseline upon which an evaluation can be made of process changes as they occur on parts procured after the initial qualification of the manufacturer. Single lot procurement is used where practicable by the subcontractors. (All parts required for the system are purchased at one time and are from the same lot as the qualification sample.)

5.5.2 Subcontractor - Subcontractors are subject to the same controls as those used internally at the prime contractor. The subcontractors are monitored to ensure conformance. Part selection by the subcontractor is limited to those parts included in the VOYAGER Approved Parts List established and maintained by the prime contractor. In order to use parts not on the approved list, a procedure for revising the Approved Parts List is discussed in Part C, Section 10 of Volume VI.

Subcontractors are required to keep McDonnell apprised of all part application and selection activities. This information, coupled with the prime contractor's own part experience, is disseminated to all subcontractors to minimize parallel effort and encourage consideration of parts already proven by test.

5.5.3 Traceability - Traceability requirements provide for the identification of a particular piece part or group of parts through all phases of assembly and testing. All parts will be identified with either a serial number or lot number. Serial numbers will be used on critical parts only and will be minimized to the greatest extent possible. The traceability document (207-780002) prepared during our Phase B activity, lists the following parts as requiring serialization.

Transistors - power, field effect and RF

Diodes - microwave, varactor, controlled rectifiers

Integrated circuits

Tubes

Crystals

All other parts will be identified by lot number for traceability.

Any failures or deficiencies are isolated to the part level and proper corrective action taken. All failed parts are subjected to failure analysis to determine failure modes. After failure modes are identified, an analysis of the test data will enable determination of the proper corrective action.

APPLICATION		QTY/ ASSY	FIN. ART.	REVISIONS			
NEXT ASSY	USED ON			LTR	DESCRIPTION	DATE	APPROVED
				A	Added Paragraph 5.5	18 July 1967	[signature]

CODE NO.	PART NO.	DRAWING OR SPECIFICATION	NOMENCLATURE OR DESCRIPTION	STOCK / VENDOR NAME - ADDRESS	MATL

PARTS LIST

LIMITS UNLESS NOTED .x = ±.1 .xx = ±.03 .xxx = ±.010	DRAWN J. O'Montony 16 June 67 CHECK STRENGTH GR ENGR APPD	MCDONNELL ST. LOUIS, MO.			
		GENERAL SPECIFICATION VOYAGER FLIGHT CAPSULE SEMICONDUCTORS, TRANSISTORS, DIODES AND INTEGRATED CIRCUITS			
FINISH SPEC	PROJ ENGR [signature]	SIZE A	CODE IDENT NO. 76301	207-780003	
CONTRACT NO.	CUSTOMER	SCALE		SHEET 1 of 14	

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1. **SCOPE**

1.1 This specification establishes the general requirements for semiconductor, transistors, diodes and integrated circuits suitable for use in Voyager Flight Capsule application. Specific requirements for a particular semiconductor device are listed in applicable detail part drawings.

2. **APPLICABLE DOCUMENTS**

2.1 The following documents, of the issue in effect on the date of invitation for bids, form a part of this specification to the extent specified herein:

SPECIFICATIONS

Military

MIL-S-19500	Semiconductor Devices, General Specification
MIL-G-45204	Gold Plating (Electrodeposited)

National Aeronautics and Space Administration

NPC 200-3	Inspection system provisions for Suppliers of Space Materials, Parts, Components and Service

McDonnell

207-780011	Visual Inspection Criteria, Voyager Flight Capsule Semiconductor Devices

STANDARDS

Military

MIL-STD-130	
MIL-STD-202	Test Methods for Electronic and Electrical Component Parts
MIL-STD-750	Test Methods for Semiconductor Devices
MIL-STD-1276	Weldable Leads for Electronic Component Parts

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APPENDIX A

3. REQUIREMENTS

3.1 Conformance. The individual types of semiconductors shall conform to the detailed requirements specified in the applicable McDonnell detail part drawing and this specification.

3.1.1 Conflicting Requirements. In the event of conflict between this specification and the documents referenced herein, the order of precedence shall be as follows:

a. Purchase Order
b. Applicable McDonnell Detail Part Drawing
c. This Specification
d. NASA/Government Specification
e. Military Specifications.

3.1.2 Reference to Detail Part Drawing. For purposes of this specification, when the term "specified" or "as specified" is used without reference to a specific location the intended reference is to the McDonnell detail part drawing.

3.2 Qualification. Semiconductor devices furnished under this specification shall be a product which has been tested and passed the qualification and acceptance tests specified herein.

3.3 Request for Deviation. Any change from the requirements of this specification, or applicable documents listed herein, shall be considered a deviation. Request for a deviation shall be submitted in writing to McDonnell. Materials and processes used in the fabrication and assembly of the semi-conductor qualification test samples shall be documented at the time of qualification and any subsequent material and process changes for these parts shall be forwarded to McDonnell. Manufacturer shall obtain McDonnell approval before shipment of any parts for Voyager Flight Capsule application containing such changes.

3.4 Leads and Terminal Material/Finish. The lead material used shall conform to MIL-STD-1276, as applicable. The leads shall not show evidence of base metal corrosion after completion of the environmental tests specified herein.

The finish of the semiconductor case shall exhibit no peeling or cracking of the body surface area, of the marking, or of the color coding after completion of all tests performed thereon.

3.5 Mechanical Characteristics.

The mechanical characteristics of the semi-conductor shall be as specified herein and in the detail part drawing.

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3.5.1 Lead and Terminal Test. Each semiconductor shall be capable of withstanding the pull test, bend test, twist test, torque test and soldering heat test as specified in the detail part drawing without physical damage to the leads, terminals or the semiconductor body, and without degradation of the semiconductor electrical characteristics.

3.6 Electrical. Semiconductor electrical performance characteristics shall be as specified in the detail part drawing. Semiconductors furnished to the requirements of this specification shall have met the qualification and acceptance inspections specified in 4.2 and 4.3.

3.6.1 Maximum Ratings. Semiconductor maximum ratings shall be as specified in the detail part drawing.

3.7 Environmental. Semiconductors shall operate within the limits as specified in the detail part drawing before and after being subjected to the environmental conditions outlined in 3.7.1 thru 3.7.11.

3.7.1 Sterilization and Decontamination. Semiconductors shall operate within the limits as specified in the detail part drawing after being subjected to heat sterilization and ethylene oxide decontamination.

3.7.1.1 Heat Sterilization. Sterilization shall consist of six separate cycles of heat at a maximum temperature of 135°C. in a nitrogen atmosphere. The nitrogen shall have an initial dew point prior to heating of no greater than minus 54°C and the gas shall possess a purity so that no more than 50 parts/million of extraneous products shall be contained within the gas. The total time of application of the environment is 96 hours per cycle (the time at the stabilized 135°C is 92 hours per cycle). Each item shall be at an initial temperature of 20-25°C prior to the beginning of each cycle. Performance tests and other evaluation criteria for determining the effects of the environment on the units shall be as specified in the detail part drawing.

3.7.1.2 Decontamination. Devices shall meet the end point test limits of group B sub-group 2 before and after the ethylene oxide decontamination test. This test shall consist of six (6) separate cycles at a temperature of 50 ± 5°C and an environment of 88% Freon and 12% ethylene oxide at 50% relative humidity and a concentration of 600 m.g./liter of gaseous atmosphere. A test cycle shall consist of:

a. 1 hour during which the temperature is increased to 50 ± 5°C and the air atmosphere is maintained at 50% R.H.
b. 21 to 24 minutes during which the atmosphere is evacuated to 70 torr.

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3.7.1.2 (Continued)

c. 27.5 hours during which the atmosphere is maintained at 50% R.H. with a concentration of 600 m.g./liter of 88/12 mixture of Freon 12 and ethylene oxide.
d. 15 minutes - evacuate to 70 torr. and permit temperature to fall.
e. 45 minutes - permit temperature to fall to 20-25°C by introducing ambient air.

3.7.2 High Temperature Storage. Semiconductors shall operate within the limits specified in the detail part drawing after being tested in accordance with Method 1031.1 of MIL-STD-750. The ambient temperature for this test shall be 200°C minimum.

3.7.3 Temperature Cycling. Semiconductors shall operate within the limits as specified in the detail part drawing after being tested in accordance with Method 1051.1 of MIL-STD-750 (Test Condition C, Method 107 of MIL-STD-202)

3.7.4 Moisture Resistance. Semiconductors shall operate within the limits as specified in the detail part drawing after being tested in accordance with Method 1021.1 of MIL-STD-750 (Method 106, MIL-STD-202, omitting Step 7B and the initial 24 hour soak period.)

3.7.5 Hermetic Seal. Semiconductor shall not exhibit leak rates in excess of 1×10^{-8} atm - cc per second when tested in accordance with 4.3.3.4.

3.7.6 Shock. Semiconductors shall be capable of operation within the limits as specified in the detail parts drawing after being tested in accordance with Method 2016.1 of MIL-STD-750. A total of 30 impacts shall be applied in each of three mutually perpendicular planes (10 impacts each plane).

3.7.7 Vibration. Semiconductors shall be capable of operation within the limits specified in the detail part drawing when subjected to the Vibration Test Method 2046 of MIL-STD-750.

3.7.8 Low Temperature Operating. Semiconductors shall be capable of operating within the limits as specified in the detail part drawing after stabilizing parts at an ambient temperature -63^{+0}_{-5}°C for this test.

3.7.9 Acceleration. Semiconductors shall be capable of operation within limits as specified in the detail part drawing after subjected to a constant acceleration of 20,000g's per Method 2006 of MIL-STD-750, with the semiconductors so oriented that the acceleration vector is in the direction (normally in Y_1 orientation only) most likely to produce mechanical/bonded interconnection failure.

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3.7.10 Vacuum. Semiconductors shall be capable of operation within limits as specified in the detail part drawing after subjected to a pressure of 10^{-5} Torr (mm of mercury) at a temperature of -65°C $^{+0}_{-5}$°C for a period of 24 hours. No degradation or deteriorations of seal shall occur.

3.7.11 Operating Life. Semiconductors shall be capable of operation within limits as specified in the detail part drawing when tested in accordance with Method 1026.1 of MIL-STD-750.

3.8 Failure Rate. Semiconductors shall have a failure rate as specified in the detail part drawing.

3.9 Physical Dimensions. The physical dimensions of the semiconductors shall be as specified in the detail part drawing.

3.10 Marking. Manufacturer shall permanently and legibly mark each part in accordance with MIL-STD-130 with the following:

- Manufacturer's Name or Symbol
- Lot or Serial Number (as specified)
- Polarity (as applicable)

3.11 Part Identification/Traceability. Two-way traceability, that is, from a particular semiconductor to a known lot and from a known lot to a particular semiconductor from that lot shall be maintained when specified in the detail part drawing. This information shall be immediately available to McDonnell upon request. Part identification for this two-way traceability shall include part serialization per 3.11.1. Where this two-way traceability defined above is not required to a particular semiconductor, lot identification shall be provided as a minimum per 3.11.2.

3.11.1 Part Serialization. Semiconductors when required shall be marked with an individual serial number. The serial number shall consist of a three digit number ranging from "000" to "999" for each semiconductor part number. Deviations to this range of serial numbers will be considered and approved (by McDonnell) as justified. The serial numbers shall identify each semiconductor with the applicable recorded data and manufacturer's lot or lots. No serial number shall be duplicated for semiconductors with the same part number. The serial number shall be printed on the semiconductor body (or as specified on the detail part drawing).

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3.11.2 Lot Identification. Each semiconductor not requiring part serialization shall contain the manufacturer's lot identification number which shall identify the semiconductor with the applicable recorded data for a particular group or lot of parts included under the identifying lot number. A manufacturer's lot is defined as a quantity of parts produced in one week or less, from a single production line using the same design, materials, manufacturing processes and specifications, and presented to inspection for tests at the same time. A McDonnell Voyager Flight Capsule lot shall be the group of parts to be subjected to the acceptance inspection specified in 4.3. The lot of parts purchased to this specification shall be from a single manufacturer's lot except where deviations have been submitted and approved.

3.12 Documentation and Data Submittal. The variables data listed under (a) and (b) below shall be submitted with the semiconductor. In the addition to the parameter values, the punched card shall contain the individual semiconductor lot number or serial number, McDonnell part number, date, etc. Data recorded regarding a rejected McDonnell lot shall be forwarded to the McDonnell Company. A copy of all required data shall be kept on file by the manufacturer for a period of at least five years from the date of delivery of the components. At the completion of the test specified in 4.3.4 the component inspection report form per Figure 1 shall be completed and submitted with each shipment of parts and data cards. Data submittal shall include the following:

(a) Variables data on each of the critical parameters specified at the 100% level for each semiconductor given the acceptance inspection per 4.3.

(b) Variables data on all parameters specified in the applicable detail part drawing taken during final electrical measurements (post burn-in) final electrical inspection (Group A inspection).

(c) Data on all parameters specified in the applicable detail part drawing following the Group B environment test per 4.3.7.

4. RELIABILITY AND QUALITY ASSURANCE PROVISIONS

4.1 General. Implementation of the quality assurance provisions specified herein shall be in accordance with the applicable requirements of NPC 200-3. The examination and testing of semiconductor devices shall be classified as follows:

(a) Qualification Inspection

(b) Acceptance Inspection

4.2 Qualification Inspection. Qualification tests are those tests performed on devices to verify conformance to all requirements of this specification. Unless otherwise specified the total qualification test sample shall consist of 60 specimens which have not been previously subjected to life testing. The specimens shall be subjected to the 100% Process Preconditioning and Screening, the group A and B tests and the failure rate life test of the detail specification, as follows: All specimens shall be subjected to 100% Process-Preconditioning and Screening, Group A tests and the Failure Rate Life Test. For group B, testing the specimens shall be divided into three groups of 20 specimens each. The first group shall be subjected to the tests specified in Sub-group 1 and 2 of Group B; the second group shall be subjected to the tests specified in sub-group 3 of Group B; the third group shall be subjected to the tests specified in the remaining sub-group of Group B.

4.2.1 Post Qualification Test End Points - The end point tests specified in the individual detail specification shall be performed after the intermittent life test and after each Group B sub-group test where end points are specified. Failure of one device in one or more tests of a given sub-group will be charged as a single failure. Failures in excess of those allowed for each group shall constitute qualification failure. Devices subjected to qualification inspection may be shipped except for destructive tests which include solderability,soldering heat, moisture resistance, terminal strength, salt atmosphere and salt spray. Compliance with these requirements qualifies the manufacturer for the following 12 month period provided design changes are not made during this time.

4.3 Acceptance Inspection. Acceptance Inspection. Acceptance inspection consists of the following inspections:

(a) Dimensional

(b) Visual

(c) 100% Process-Preconditioning and Screening (Burn-in)

(d) Group A Electrical

(e) X-ray (diodes and transistors); Color (Micro-Photographs (Integrated Circuit - see 4.3.7)

(f) Group B Environmental

Electrical measurement methods shall conform to the applicable requirements of MIL-STD-750. The McDonnell Outside Production Quality Assurance Department shall be notified at least one week in advance of the scheduled date for performing acceptance inspection on semiconductors purchased to this

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4.3 Acceptance Inspection (Continued)

specification. Lots which are rejectable via sampling inspection may be screened 100 percent for the failing characteristics and may then be resubmitted one time to inspection. In addition, McDonnell reserves the right to sample test each 100 percent inspection requirement for each lot to a 2 percent LTPD level and reject any lot that does not meet the requirement. The 100 percent process-preconditioning and screening tests in 4.3.3 are not required to be repeated when they are already included in the manufacturers normal production processing.

4.3.1 Dimensional Inspection. Dimensional inspection shall be performed on the semiconductors at an LTPD of 15 percent as specified (Ref. Table I for minimum requirements).

4.3.2 Visual Inspection. Visual inspection shall be performed at a 100 percent level as specified in the detail part drawing and specification 207-780011 as applicable. Semiconductors not meeting the visual inspection criteria shall be rejected. Integrated circuits shall be micro-photographed in color, per 4.3.7.

4.3.3 100% Process-Preconditioning and Screening. The semiconductors in the lot shall be subjected to the following tests. The test methods employed shall be in accordance with MIL-STD-750. The environmental tests shall be performed prior to the burn-in inspection of 4.3.3.7. Test 4.3.3.1 thru 4.3.5 shall be performed in the following sequence.

4.3.3.1 High Temperature Storage. The semiconductors shall be subjected to a high temperature storage per MIL-STD-750, Method 1031.1 at a temperature of 200°C minimum.

4.3.3.2 Temperature Cycling. The semiconductors in the lot shall be temperature cycled in accordance with MIL-STD-750, Method 1051.1 (MIL-STD-202, Method 107B, Test Condition C).

4.3.3.3 Constant Acceleration. The semiconductor shall be subjected to constant acceleration in accordance with MIL-STD-750, Method 2006. A minimum centrifugal acceleration of 20,000g's shall be applied, with the semiconductor so oriented that the acceleration vector is in the Y_1 axis direction (or that axis which will most likely produce mechanical bonded interconnection failure).

4.3.3.4 Hermetic Seal Tests

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4.3.3.4.1 Gross Leaks. Each semiconductor shall be tested in accordance with MIL-STD-202, Method 112, Test Condition A. Any indication of air escapement from within the semiconductor case shall be cause for device rejection.

4.3.3.4.2 Fine Leak. Each semiconductor and metal cased diode shall be tested in accordance with MIL-STD-202, Method 112, Test Condition C, Procedure IIIA or IIIB. Semiconductors with leak rates in excess of 10^{-8} atm-cc per second shall be rejected.

4.3.3.4.3 Glass Diode Seal Test. Each glass cased diode shall be subject to an hydraulic pressure of 100 psig in a solution of isopropyl alcohol with coloring dye for two hours. Following pressurization, rinsing, and drying, each diode shall receive a reverse current test and an operating vibration test (see 4.3.3.5). The time interval between pressurization test completion and start of the electrical tests shall be at least two hours, but not to exceed eight hours. Diodes exhibiting reverse leakage in excess of the limits specified in the detail part drawing, ionic contamination (indicated by mobile hysteresis progressing in the high current direction) or dye penetration shall be rejected.

4.3.3.5 Operating - Vibration Test. Where specified, each semiconductor shall be subjected to a simple harmonic vibration having a minimum of 0.1 inch double amplitude displacement at a frequency of 60 ± 2 cps for a minimum period of 30 seconds. During vibration continuously monitor the reverse characteristic, swept at 60 cps, to the inverse current or voltage specified. Devices displaying flutter, drift, dynamic instabilities or shift in trace shall be rejected.

4.3.3.6 Pre-Burn-In Electrical Measurements. Each semiconductor in the Voyager Flight Capsule lot shall be subjected to electrical measurements of the critical parameters (100% level) specified in the applicable detail part drawing. All variable data shall be recorded.

4.3.3.7 Burn-In Operational Life Test. Each semiconductor shall be subjected to a burn-in (operational life test) at the electrical level and temperature for 168 hours as specified in the detail part drawing.

4.3.3.8 Post Burn-In Electrical Measurements. Same as pre-burn electrical measurements except that limits including delta or parameter incremental changes shall be as specified in the detail part drawing.

4.3.4 Group A Electrical Inspection. Group A electrical inspection shall be performed by lot sample as specified in the Group A inspection, Table II of the applicable detail part drawing. The minimum sample size to assure a Lot Tolerance Percent Defective (LTPD) specified with 90% confidence for various failure acceptance numbers (a) is shown in Table I of this specification. The rejection number (r), equals a + 1. The acceptance sample size required to assure the specified LTPD shall be selected from Table I of this specification by the manufacturer.

4.3.5 Final Visual Inspection. Final visual inspection shall be performed at a 100 percent level. Only those semiconductors which meet the visual inspection criteria specified shall be shipped.

4.3.6 X-ray Examination. Unless otherwise specified in the detail part specification, each transistor and diode not permitting internal visual inspection shall be photographed using an X-ray machine of sufficient power to show the internal construction. Integrated circuits shall be micro photographed per 4.3.7. Sufficient definition is achieved when free particles of solder or other foreign matter one mil in diameter can be determined. A series of x-ray photographs shall be taken perpendicular to the longitudinal axis (in two mutually perpendicular planes). The x-ray photographs shall be identified to assure traceability to the individual semiconductor when part serialization is required. Acceptance criteria shall be in accordance with McDonnell 207-780011.

4.3.7 Photographic Records. Each integrated circuit shall be photographed at 100X magnification, in color, just prior to final seal. Photographs shall be identified with device part number and serial number and delivered with the devices. Photographs shall have sufficient resolution to show scratches in the conductor paths, particle inclusions, etc.

4.3.8 Group B Environmental Inspection. Semiconductor parts from the same lot to be shipped per this specification shall be sample tested as specified in the Table III Group B Inspection of the applicable detail part drawing.

4.4 Failure Accountability. A complete accounting of failures and modes (i.e., human error, instrumentation, parametric, or catastrophic) shall be submitted to McDonnell on all accountable and unaccountable failures occurring during acceptance inspection.

5. PREPARATION FOR DELIVERY

5.1 Unit Packaging. The semiconductors shall be individually packaged to protect the case and leads during shipment. Each unit package shall be clearly marked as to semiconductor types, serial number and lot number. Package design shall be subject to McDonnell approval prior to usage by the manufacturer.

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5.2 **Packaging of Shipping Containers.** The unit packages shall be packed in the shipping containers in a manner to provide maximum protection from shock and vibration during transit; and in the order of ascending serial number or groups of serial numbers, to facilitate and minimize handling subsequent to delivery.

5.3 **Marking of Shipping Containers.** Each shipping container shall be marked with the manufacturer's name, part designation number, date code and lot number.

5.4 **Shipping/Data Documentation.** The certificate of compliance and the data required in 3.12, 4.3 and 4.4 shall accompany each shipment of parts. The IBM cards shall be punched and interpreted, and packed in numerical sequence in suitable boxes, labeled as to component type, lot number and serial number range. The data cards for rejected parts shall be segregated from the cards for accepted parts and all cards submitted with the lot. For integrated circuits the photographs required in Paragraph 4.3.7 shall also accompany the shipment.

5.5 **Process Flow Chart Documentation.** The vendor shall submit to McDonnell for acceptance a flow chart showing the entire processing from incoming materials to final shipment. All processes and inspection points shall be identified by the applicable internal specification numbers to include revision and date. The disposition of this documentation shall also be indicated. Subsequent to McDonnell acceptance, changes must be reported to McDonnell before shipment of parts.

6. **NOTES.** Not applicable.

Lot Number__________ Specification__________

Part Number__________ P. O. Number__________

Manufacturer__________ Date Received__________

Lot Size__________ Sample Size__________

Quantity Accepted__________ Date Completed__________

Quantity Rejected__________ Lot Disposition__________

Date Code__________ Part Description__________

Lot S/N Range__________ Sample S/N Range__________

	Tests Performed	No. Rejects Initial Meas.	Date	No. Rejects 2nd Meas.	Date	No. Rejects 3rd Meas.	Date	Insp. Stamp
1	Initial visual							
2								
3								
4								
5								
6								
7								
8								
9	Final Visual							

Serial Numbers of Rejected Parts

Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9

Remarks:

____
Quality Assurance Manager

Figure 1. Sample Component Inspection Report Form

DRAWN	[illegible]	APPRD			GENERAL SPECIFICATION VOYAGER FLIGHT CAPSULE SEMICONDUCTORS, TRANSISTORS DIODES AND INTEGRATED CIRCUITS	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780003			SHEET 13

REVISED:

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301

APPROVED JUNE 1967 REVISED

TABLE I

Minimum Sample Size to be Tested to Assure an LTPD for Small Lot Quantities

Maximum LTPD	15	10	5	1
Acceptance Number	Minimum Sample Size			
0	17	22	45	231
1	28	38	77	390
2	38	52	105	533
3	49	65	132	668
4	58	78	159	798
5	68	91	184	927
6	77	104	210	1054
7	87	116	234	1178
8	95	128	258	1300
9	104	140	282	1421
10	113	152	307	1541

APPROVED JUNE 1967 REVISED

DRAWN		APPRD			GENERAL SPECIFICATION VOYAGER FLIGHT CAPSULE SEMICONDUCTORS, TRANSISTORS DIODES AND INTEGRATED CIRCUITS	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780003			SHEET 14

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CODE IDENT NO. 76301

APPLICATION		QTY/ ASSY	FIN. ART.	REVISIONS			
NEXT ASSY	USED ON			LTR	DESCRIPTION	DATE	APPROVED

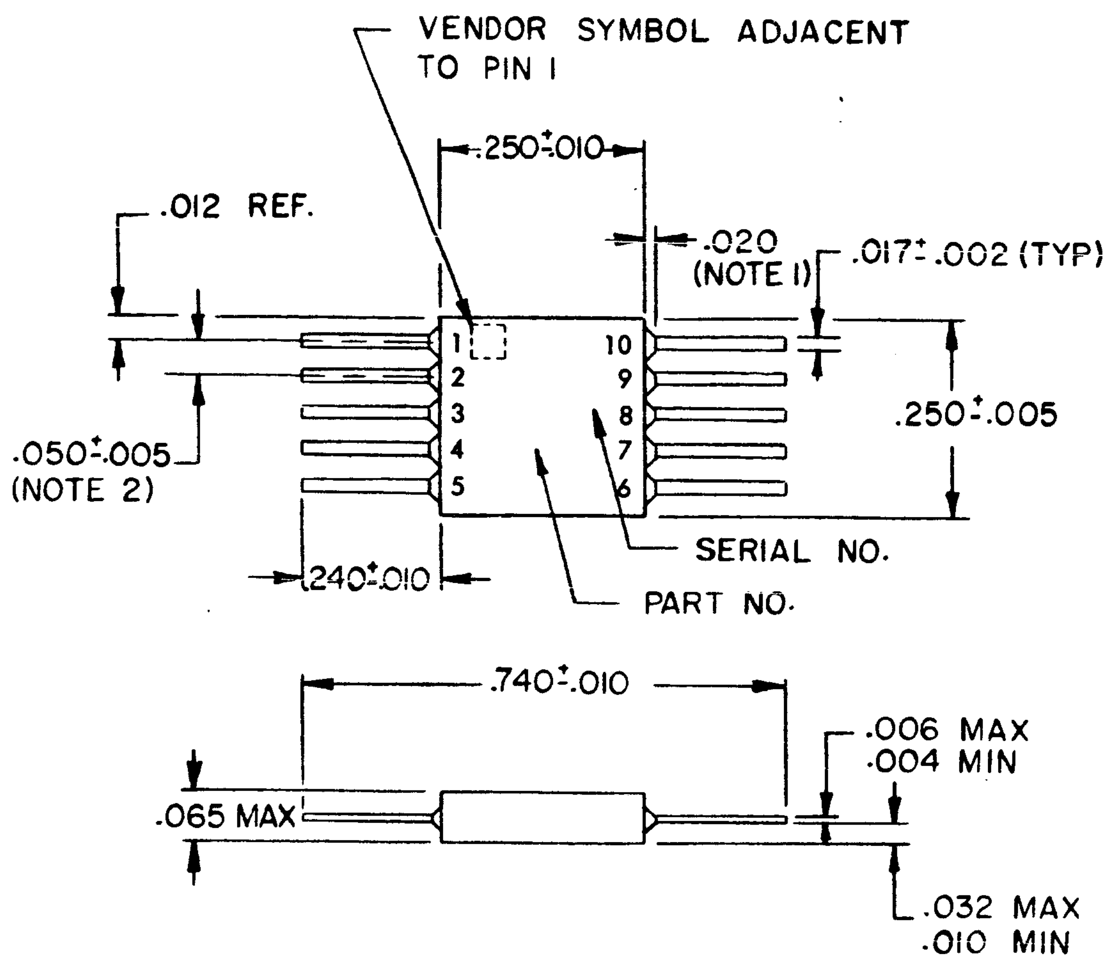
DETAIL PART DRAWING

CODE NO.	PART NO.	DRAWING OR SPECIFICATION	NOMENCLATURE OR DESCRIPTION	STOCK / VENDOR NAME - ADDRESS	MATL

PARTS LIST

LIMITS UNLESS NOTED .x = ±.1 .xx = ±.03 .xxx = ±.010	DRAWN J. D. Montenye 26 June 67	MCDONNELL ST. LOUIS, MO.	
	CHECK		
	STRENGTH	INTEGRATED CIRCUIT FLIP FLOP, RST	
	GR ENGR		
	APPD		
FINISH SPEC	PROJ ENGR [signature] 17 July 67	SIZE A / CODE IDENT NO. 76301	207-780007
CONTRACT NO.	CUSTOMER	SCALE	SHEET 1 OF 15

MAC 1197A (REV 24 NOV 65)



Notes:

1. Lead spacing dimensions apply in this area only.
2. Tolerances are noncumulative.
3. Pin numbers for reference only and do not appear on part.

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST
CHECK		APPRD			
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.

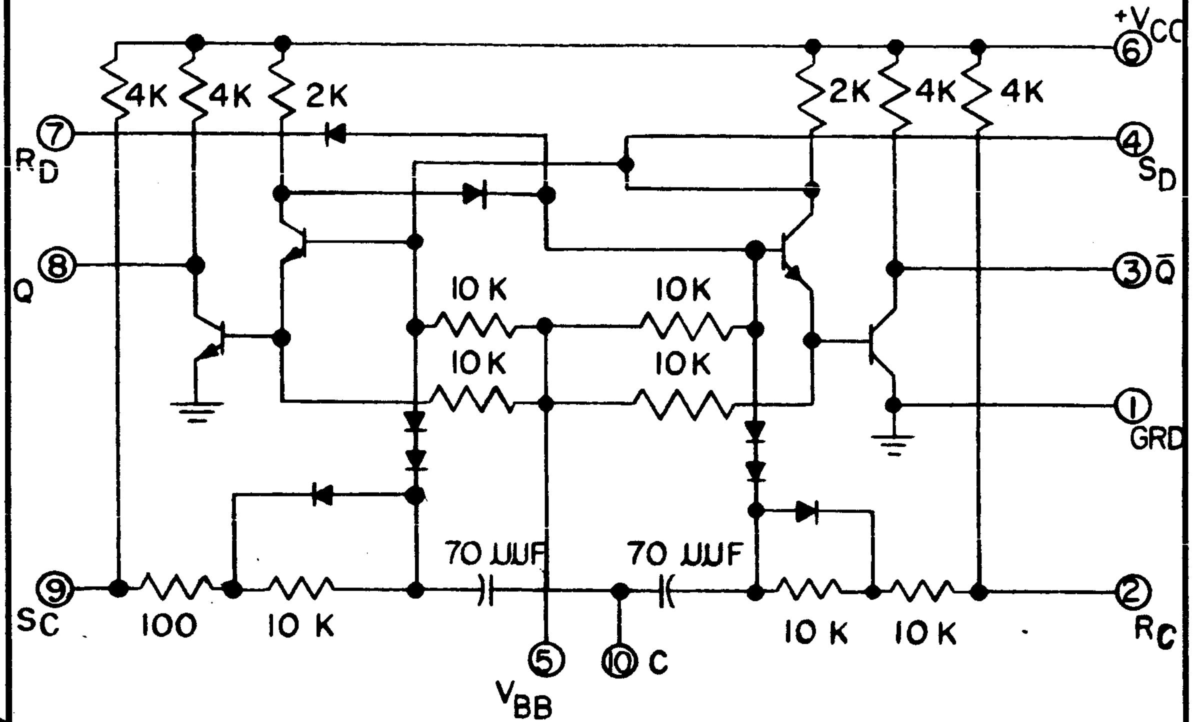
REV	MODEL	VOL	ASSY NO.

DRAWING NO.	SHEET
207-780007	2

REVISED:

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301

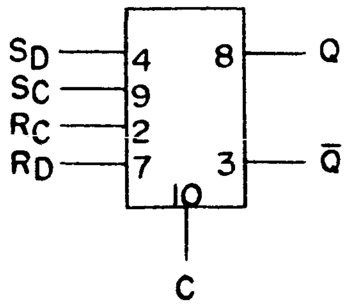


SCHEMATIC DIAGRAM

REVISED:	DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
	CHECK		APPRD							
	APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 3

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301



Logic Diagram

Clocked Set-Reset			Direct Set-Reset		
S_C	R_C	Q	S_D	R_D	Q
0	0	?	0	0	△1
0	1	1	0	1	1
1	0	0	1	0	0
1	1	No Change	1	1	No Change

Truth Table

Positive Logic Definitions: High Voltage = 1
Low Voltage = 0

△1 Both Q and $\overline{Q}$ in 1 state until either S_D or R_D rises

Clocked set-reset Q is the logic state after the first negative going edge of the clock pulse at pin 10 with initial conditions before clock pulse at S_C and R_C as shown.

Table I, Maximum Ratings (25°C)

Characteristic	Min.	Max.	Unit
Input Voltage (Pins 2, 3, 4, 7, 8, 9, 10)	0	+ 8	V
Output Voltage (Pins 3, 8)	0	+ 8	V
Vcc (Pin 6)	0	+8.2	V
Vbb (Pin 5)	0	- 8	V
Input Current (Pins 2, 3, 4, 7, 8, 9, 10)	- 30	+ 30	MA
Output Current (Pins 3, 8)	-100	+100	MA
Operating Temperature	- 55	+125	°C
Storage Temperature	- 65	+175	°C
Power Dissipation	——	150	MW

DRAWN		APPRD		INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD						
APPRD		APPRD		MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 4

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Notes:

1. General

1.1 These parts shall be specified, procured and used under the McDonnell approved part number 207-780007 (any vendor part number is for reference only).

1.2 These parts shall meet all requirements of McDonnell drawing 207-78003 except as noted herein.

1.3 All tests and measurements shall be performed at a temperature of 25 ±2°C unless otherwise specified.

1.4 All symbols and abbreviations shall be as defined in MIL-S-19500.

1.5 All voltage and capacitance measurements are referenced to ground unless noted. Positive current flow is defined as into the pin referenced. Pins not specifically referenced are left open.

2. Requirements

2.1 Electrical

2.1.1 Performance characteristics shall be as specified in Table II (Group A) and Table IV (Group B) inspections.

2.1.2 The maximum electrical ratings shall be as specified in Table I when operated at an ambient temperature of 25°C.

2.2 Mechanical

2.2.1 Each device shall be of the design, construction and physical dimensions specified herein.

2.2.2 Leads shall be in accordance with MIL-STD-1276, Type K.

2.2.3 Devices shall be monolythic, planar passivated construction.

2.3 Environmental

2.3.1 Devices shall meet the end point test limits of Group B, Subgroup 2 before and after the sterilization heat test (6 cycles) per paragraph 3.7.1.1 of 207-780003.

DRAWN			APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK			APPRD				DRAWING NO.			SHEET
APPRD			APPRD			MCDONNELL ST. LOUIS, MO.	207-780007			5

REVISED:

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301

2.3 Environmental (Continued)

2.3.2 Devices shall meet the end point test limits of Group B, Subgroup 2 before and after the ethylene oxide decontamination test (6 cycles) per paragraph 3.7.1.2 of 207-780003.

2.4 Failure Rate

2.4.1 The qualification approval devices shall demonstrate a maximum failure rate of 1.0 percent per 1,000 hours at 90 percent confidence level. Failures are defined as devices which do not meet the Table III (Group A) inspection requirements. During the life test, the devices shall be operated at $T_A = 125 \pm 2^{\circ}C$, dynamic operation at $100KH_z$ in the circuit described in test circuit Figure 3.

2.5 Marking

2.5.1 Each device shall be permanently and legibly marked per McDonnell specification 207-780003, paragraph 3.10 with the following:

- Manufacturer's name or symbol
- Serial number in accordance with McDonnell specification 207-780003, paragraph 3.11
- McDonnell part number.

2.6 Quality Assurance

2.6.1 Qualification inspection shall consist of the examinations and tests specified in Tables II, III and IV in addition to the failure rate inspection of paragraph 2.4.

2.6.2 Acceptance inspection shall consist of the examinations and tests of Table II 100 percent process preconditioning and screening and Table III (Group A) inspections.

DRAWN			APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL / ASSY NO.
CHECK			APPRD				DRAWING NO.		SHEET
APPRD			APPRD			MCDONNELL ST. LOUIS, MO.	207-780007		6

REVISED:

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301

2.6 Quality Assurance (Continued)

2.6.3 Each device shall be photographed at 100X magnification, in color, just prior to final seal. Photographs shall be identified with device part number and serial number and delivered with the devices. Photographs shall have sufficient resolution to show scratches in conductor path, particle inclusions, etc.

2.7 Preparation for Delivery

2.7.1 Devices shall be prepared for delivery in accordance with McDonnell specification 207-780003, paragraph 5.

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 7

REVISED:

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CODE IDENT NO. 76301

Table II 100% Process-Preconditioning and Screening

Examination or Test	MIL-STD-750 Method	MIL-STD-750 Conditions	Limits Min.-Max.	Units
Subgroup 1				
Photograph		Paragraph 2.6.3		
High Temperature Storage	1031	$T_A = 200 {}^{+10}_{-0}$ °C		
Temperature Cycling	1051	Condition C		
Constant Acceleration	2006	30,000 g, Y_1 Axis		
Seal				
Fine Leak		MIL-STD-202, Method 112C Condition C, Procedure IIIa	5×10^{-8}	cc/sec.
Gross Leak		MIL-STD-202, Method 112C Condition A, Ethylene Glycol		
Subgroup 2			PDA-10	
Power Burn In	1026	$T_A = 125 {}^{+10}_{-0}$ °C t = 168 Hours Dynamic Operation at 100Khz (Fig. 3)		
End Points		Per Group A, Subgroup 3		
"1" Output Voltage (V3, V8)			± 20% of Initial Value	
"0" Input Voltage (V4, V7, V10)			± 20% of Initial Value	
"0" Output Voltage (V3, V8)			± 0.1V	
"1" Input Current (I4, I7, I10)			10 Times Initial Value	

REVISED:

DRAWN		APPRD		
CHECK		APPRD		
APPRD		APPRD		

INTEGRATED CIRCUIT
FLIP FLOP, RST

MCDONNELL
ST. LOUIS, MO.

REV	MODEL	VOL	ASSY NO.

DRAWING NO.	SHEET
207-780007	7a

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301

4.2 Qualification Inspection. Qualification tests are those tests performed on devices to verify conformance to all requirements of this specification. Unless otherwise specified the total qualification test sample shall consist of 60 specimens which have not been previously subjected to life testing. The specimens shall be subjected to the 100% Process Preconditioning and Screening, the group A and B tests and the failure rate life test of the detail specification, as follows: All specimens shall be subjected to 100% Process-Preconditioning and Screening, Group A tests and the Failure Rate Life Test. For group B, testing the specimens shall be divided into three groups of 20 specimens each. The first group shall be subjected to the tests specified in Sub-group 1 and 2 of Group B; the second group shall be subjected to the tests specified in sub-group 3 of Group B; the third group shall be subjected to the tests specified in the remaining sub-group of Group B.

4.2.1 Post Qualification Test End Points - The end point tests specified in the individual detail specification shall be performed after the intermittent life test and after each Group B sub-group test where end points are specified. Failure of one device in one or more tests of a given sub-group will be charged as a single failure. Failures in excess of those allowed for each group shall constitute qualification failure. Devices subjected to qualification inspection may be shipped except for destructive tests which include solderability,soldering heat, moisture resistance, terminal strength, salt atmosphere and salt spray. Compliance with these requirements qualifies the manufacturer for the following 12 month period provided design changes are not made during this time.

4.3 Acceptance Inspection. Acceptance Inspection. Acceptance inspection consists of the following inspections:

(a) Dimensional

(b) Visual

(c) 100% Process-Preconditioning and Screening (Burn-in)

(d) Group A Electrical

(e) X-ray (diodes and transistors); Color (Micro-Photographs (Integrated Circuit - see 4.3.7)

(f) Group B Environmental

Electrical measurement methods shall conform to the applicable requirements of MIL-STD-750. The McDonnell Outside Production Quality Assurance Department shall be notified at least one week in advance of the scheduled date for performing acceptance inspection on semiconductors purchased to this

Table III Group A Tests (Continued)

Examination or Test	Test Conditions (V6 = 4.0V, V5 = -2.0V, V1 = Ground unless otherwise noted)	Measurement Terminal	LTPD	Limits Min.	Limits Max.	Units
Subgroup 4	T_A = +125 $^{+10}_{-0}$ °C		1			
"1" Output Voltage						
VQ_1	V4 = .60V	I 8		3.8	-	V
$V\bar{Q}_1$	V7 = .60V	I 3		3.8	-	V
"0" Output Voltage						
VQ_0	V4 = 1.7V, V7 = 0V, I8 = 16mA	I 8		-	.45	V
$V\bar{Q}_0$	V4 = 0V, V7 = 1.7V, I3 = 16mA	I 3		-	.45	V
"1" Input Current						
IS_{D1}	V4 = 5.0V	V 4		-	10.00	uA
IR_{D1}	V7 = 5.0V	V 7		-	10.00	uA
IC_1	V10 = 5.0V, V9 = 0V, V2 = 0			-	10.00	uA
Subgroup 5	T_A = -55 $^{+0}_{-10}$ °C		1			
"1" Output Voltage						
VQ_1	V4 = 0.6V	V 8		3.9	-	V
$V\bar{Q}_1$	V7 = 0.6V	V 3		3.9	-	V
"0" Output Voltage						
VQ_0	V4 = 1.7V, V7 = 0V, I8 = 16mA	V 8		-	0.40	V
$V\bar{Q}_0$	V4 = 0V, V7 = 1.7V, I3 = 16mA	V 3		-	0.40	V
Subgroup 6	T_A = +25 ±2°C		1			
Clocked mode switching level	Test Circuit Figure 1	-		-	1.00	V
Clocked mode holding level	Test Circuit Figure 1	-		3.4	-	V
Clocked mode turn on delay	Test Circuit Figure 2	-		15.0	40.00	ns
Clocked mode turn off delay	Test Circuit Figure 2	-		10.0	40.00	ns

* 100 percent inspection

REVISED:

DRAWN		APPRD		
CHECK		APPRD		
APPRD		APPRD		

INTEGRATED CIRCUIT
FLIP FLOP, RST

MCDONNELL
ST. LOUIS, MO.

REV	MODEL	VOL	ASSY NO.

DRAWING NO. 207-780007. SHEET 9

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301

Table III Group B Tests

Examination or Test	MIL-STD-750 Method	MIL-STD-750 Conditions	LTPD	Limits
Subgroup 1			15	
Physical Dimensions	2066			
Subgroup 2			15	
D.C. Parameters		Per Group A, Subgroup 3		
Solderability	2026	All Terminals		
Temperature Cycling	1052	10 Cycles T Max. = + 175°C		
Thermal Shock	1056	T Min. = - 70°C, T Max. = + 100°C		
Moisture Resistance	1021	Omit Initial Conditioning		
Heat Sterilization		Per Paragraph 2.3.1		
Ethylene Oxide Decontamination		Per Paragraph 2.3.2		
End Points		Ref. Group A, Subgroup 3		
"1" Input Current				10 Times Initial Value
"1" Output Voltage				± 20% Initial Value
"0" Input Current				± 20% Initial Value
"0" Output Voltage				± 0.1V
Subgroup 3			15	
D.C. Parameters		Per Group A, Subgroup 3		
Shock	2016	1500 g, 5 Blows, Each $X_1 \cdot Y_1 \cdot Z_1$ .05ms		
Vibration Fatigue	2046	30 g, Non Operating		
Vibration Variable Frequency	2056	30 g		
Constant Acceleration	2006	30,000 g, 1 Min., Each $X_1 \cdot Y_1 \cdot Z_1$		
End Points				
"1" Input Current				10 Times Initial Value
"1" Output Voltage				± 20% Initial Value
"0" Input Current				± 20% Initial Value
"0" Output Voltage				± 0.1V
Subgroup 4			15	
Terminal Strength	2036	Test Condition E, Weight 4 Oz.		

REVISED:

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 10

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CODE IDENT NO. 76301

Table III Group B Tests (Continued)

Examination or Test	MIL-STD-750 Method	MIL-STD-750 Conditions	LTPD	Limits
<u>Subgroup 5</u>			$\lambda = 5$	
D.C. Parameters		Per Group A, Subgroup 3		
High Temperature Life	1031	Non Operation, 1000 Hours T Min. = 150°C		
End Points				
"1" Input Current				10 Times Initial Value
"1" Output Voltage				± 20% Initial Value
"0" Input Current				± 20% Initial Value
"0" Output Voltage				± 0.1V
<u>Subgroup 6</u>			$\lambda = 5$	
D.C. Parameters		Per Group A, Subgroup 3		
Operating Life	1026	1000 Hours, T Min. = +125°C Dynamic Operation at 100 KC Test Circuit 3		
End Points				
"1" Input Current				10 Times Initial Value
"1" Output Voltage				± 20% Initial Value
"0" Input Current				± 20% Initial Value
"0" Output Voltage				± 0.1V

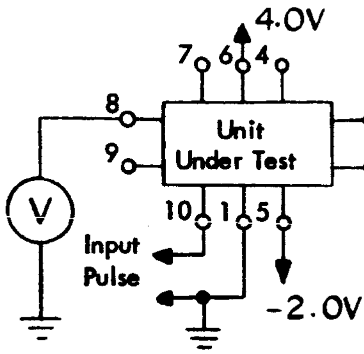
DRAWN		APPRD		INTEGRATED CIRCUIT FLIP FLOP, RST	REV / MODEL / VOL / ASSY NO.
CHECK		APPRD			DRAWING NO. 207-780007 — SHEET 11
APPRD		APPRD		MCDONNELL ST. LOUIS, MO.	

REVISED:

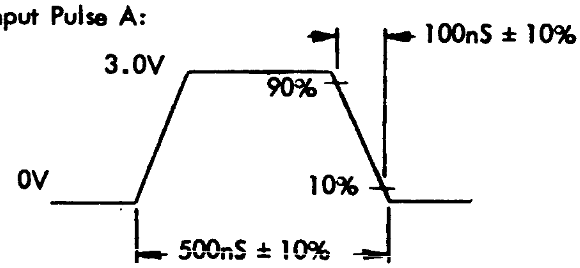
MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301

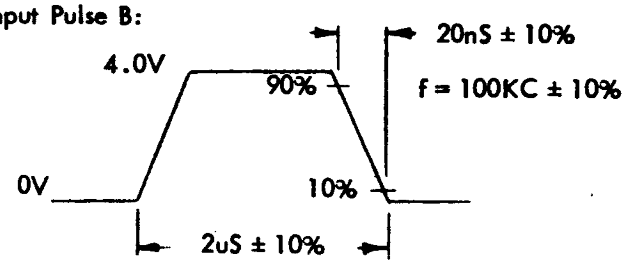
APPENDIX A



Input Pulse A:



Input Pulse B:



CLOCKED MODE SWITCHING LEVEL

Procedure:

a) Set V_9=1.0 Vdc; V_2=4.0 Vdc; momentary contact, V_7 to ground.
b) Apply one input pulse to Pin 10.
c) The device shall be rejected if it does not change state when the single input pulse is applied.
d) Set V_9=4.0 Vdc; V_2=1.0 Vdc; momentary contact, V_4 to ground.
e) Apply one input pulse to Pin 10.
f) The device shall be rejected if it does not change state when the single input pulse is applied.

CLOCKED MODE HOLDING LEVEL

a) Apply input pulses.
b) Set V_2=3.4V, V_9=4.0V.
c) Momentary contact, Pin 4 to Pin 1, V_8 shall be high ($> 3.5V$).
d) The part shall be rejected if V_8 does not remain high when Pin 4 is open.
e) Set V_2=4.0V, V_9=3.4V.
f) Momentary contact, Pin 7 to Pin 1, V_8 shall be low ($< 0.5V$).
g) The part shall be rejected if V_8 does not remain low when Pin 7 is open.

FIGURE 1

REVISED:

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 12

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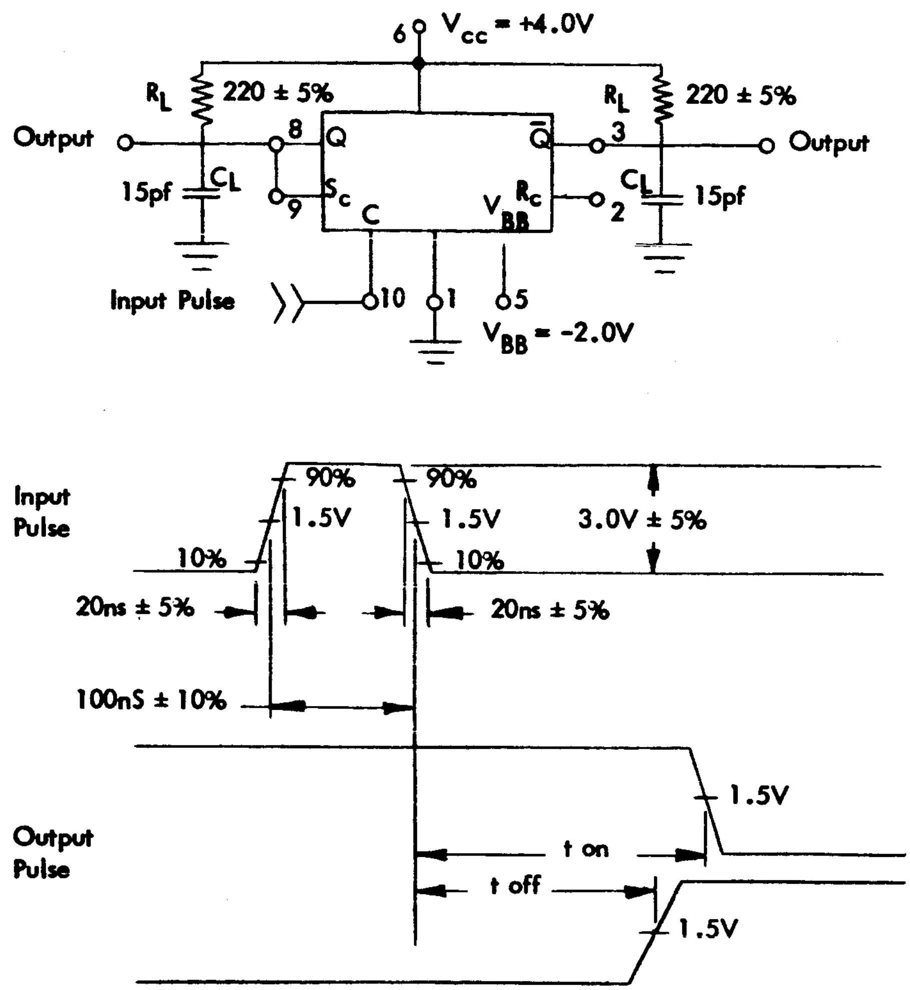
CODE IDENT NO. 76301



Note:

C_L includes jig and probe capacitance

SWITCHING TIME TEST CIRCUIT

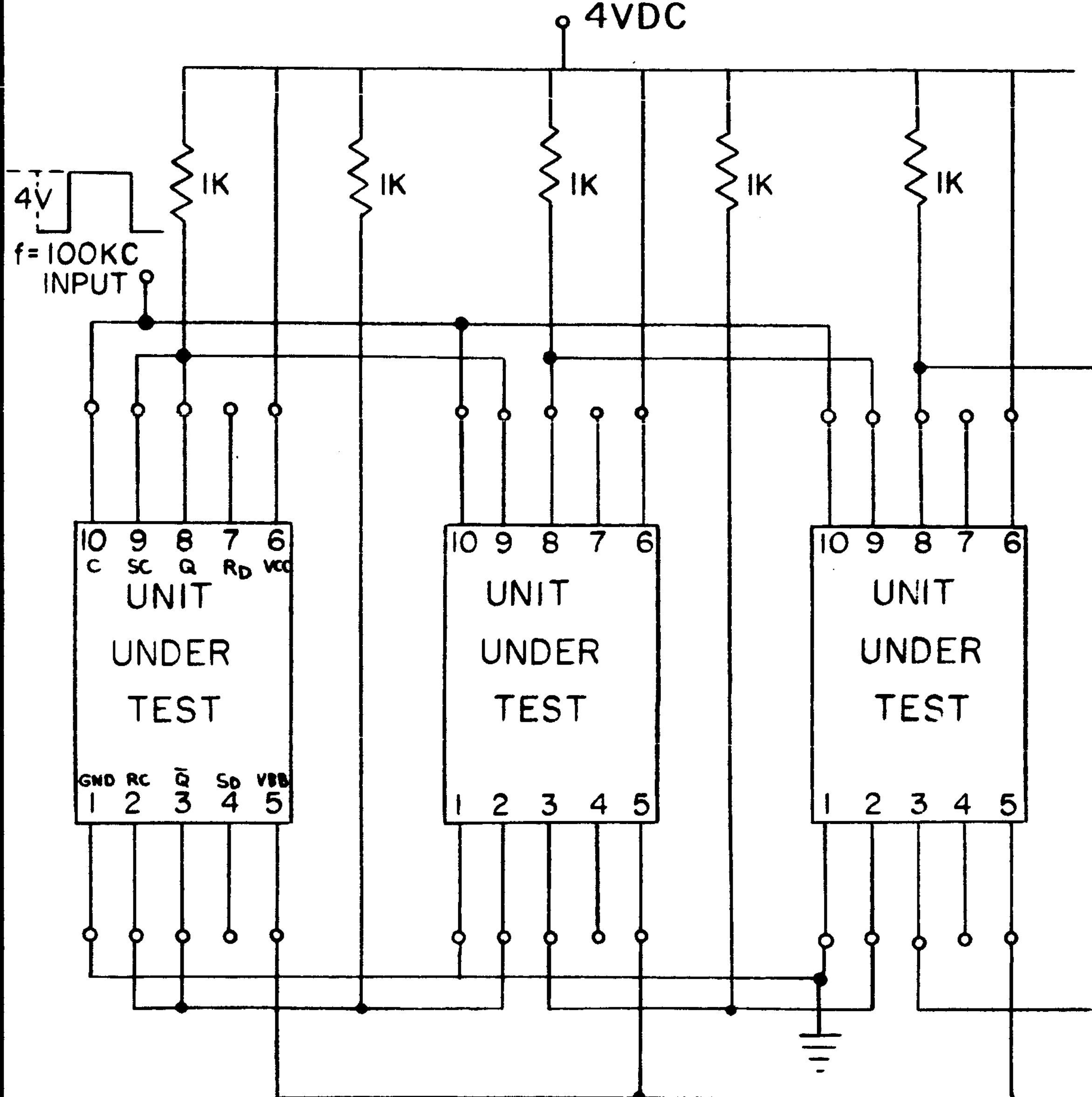
FIGURE 2

DRAWN			APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK			APPRD							
APPRD			APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 13

REVISED:

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301



DYNAMIC OPERATING CIRCUIT
(POWER BURN IN AND OPERATING LIFE)
FIGURE 3

DRAWN		APPRD		INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD						
APPRD		APPRD		MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 14

REVISED:

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301

Parts shall be procured directly from the manufacturers listed under the following approved sources of supply:

Signetics Corporation (18324)
Sunnyvale, California

Part No. SE124G

The above listed vendors and designations are the only items and sources for parts specified herein approved for procurement and/or use on McDonnell products. Vendors of competitive articles may apply to the McDonnell Standards Engineering Department for approval as a source of supply.

DRAWN		APPRD			INTEGRATED CIRCUIT FLIP FLOP, RST	REV	MODEL	VOL	ASSY NO.
CHECK		APPRD							
APPRD		APPRD			MCDONNELL ST. LOUIS, MO.	DRAWING NO. 207-780007			SHEET 15

REVISED:

MAC 1202A (REV 4 AUG 61)

CODE IDENT NO. 76301

APPENDIX A

PART I

PLANETARY QUARANTINE

The quarantine of Mars is being accomplished by limiting the number, the trajectory and the contamination state of the exploratory vehicles approaching the planet. Landers represent the greatest contamination threat and therefore must be sterile when entering the Martian environment. The NASA Planetary Quarantine Plan specifies that the VOYAGER Flight Capsule will be sterilized by dry heat prior to launch and will be contained within a microbiological barrier until ready for Mars atmospheric entry.

This places new requirements on the design, development, and production of the Flight Capsule System equipment. The Entry Science Package contractor must produce a system that can be confidently certified as sterile. During the past study effort we have established and used design guidelines to assure the compatibility of our ESP approach with NASA's heat and decontamination requirements. We have performed Contamination Sensitivity Analyses using a Bio-load Prediction Mathematical Model to isolate the critical events and factors which need to be controled in the ESP's fabrication cycle. In addition, we have developed a Sterilization Plan which formulates the means for implementing the design features and contamination controls during fabrication to assure that the Entry Package and the Landing Capsule are sterile. The sections below deal with the contamination factors and their impositions on the Entry Package. The Sterilization Plan, which integrates the sterilization requirements with manufacturing, testing, and launch site operations, is summarized below and is presented in its entirety in Volume VI.

SECTION I

CONSTRAINTS

Satisfying the VOYAGER Program objectives of Planetary Quarantine depends upon achieving sterility of the Capsule Lander. The ESP as part of the Lander, is therefore constrained by this requirement. It must be sterilized for quarantine and it must function reliably after sterilization for mission success. Figure 1-1 shows the progression of constraints and requirements which make the design for sterility and the contamination control real necessities.

1.1 PLANETARY QUARANTINE REQUIREMENTS - Each landed capsule will have associated with it a requirement for a probability of 10^{-3} of containing a viable earth organism. In addition, the probability that Mars will actually be contaminated from now through 1984, by any organism that is delivered and survives on Mars must be no greater than 10^{-3}. These requirements impose dry heat sterilization on the ESP and all other Lander equipment, since heat is the only acceptable sporicide which sterilizes and also yields the required contamination probability.

1.2 STERILIZATION REQUIREMENTS

1.2.1 <u>ETO Decontamination</u> - Ethylene Oxide, used to reduce surface contamination, constrains the use of certain exposed materials and affects the ESP by demanding that such surfaces be accessible to gaseous diffusion and subsequent purging. ETO poses a particular problem for lubricants, coatings, and encapsulants, and especially for thermal insulation of the ESP.

1.2.2 <u>Heat Cycling</u> - The use of dry heat constrains the use of volatile chemicals and heat sensitive material. Hardware must be designed for effective heat transfer and dimensional stability. Substantial changes in equipment calibration and accuracy will not be allowed.

1.2.3 <u>Final Heat Sterilization</u> - The terminal heating procedure places additional constraints on the insulation system and thermal design of the structure. It affects experiment interfaces, communication and power interfaces, and the Capsule Bus interface.

1.2.4 <u>Bio-Barrier</u> - The bio-barrier or Sterilization Canister constrains repair/replacement and limits calibration, adjustment and system functional checks to remote operations. This, in turn, increases system complexity and development and reliability costs.

FLOW OF PLANETARY QUARANTINE CONSTRAINTS AND REQUIRED CONTAMINATION CONTROLS FOR LANDING CAPSULES

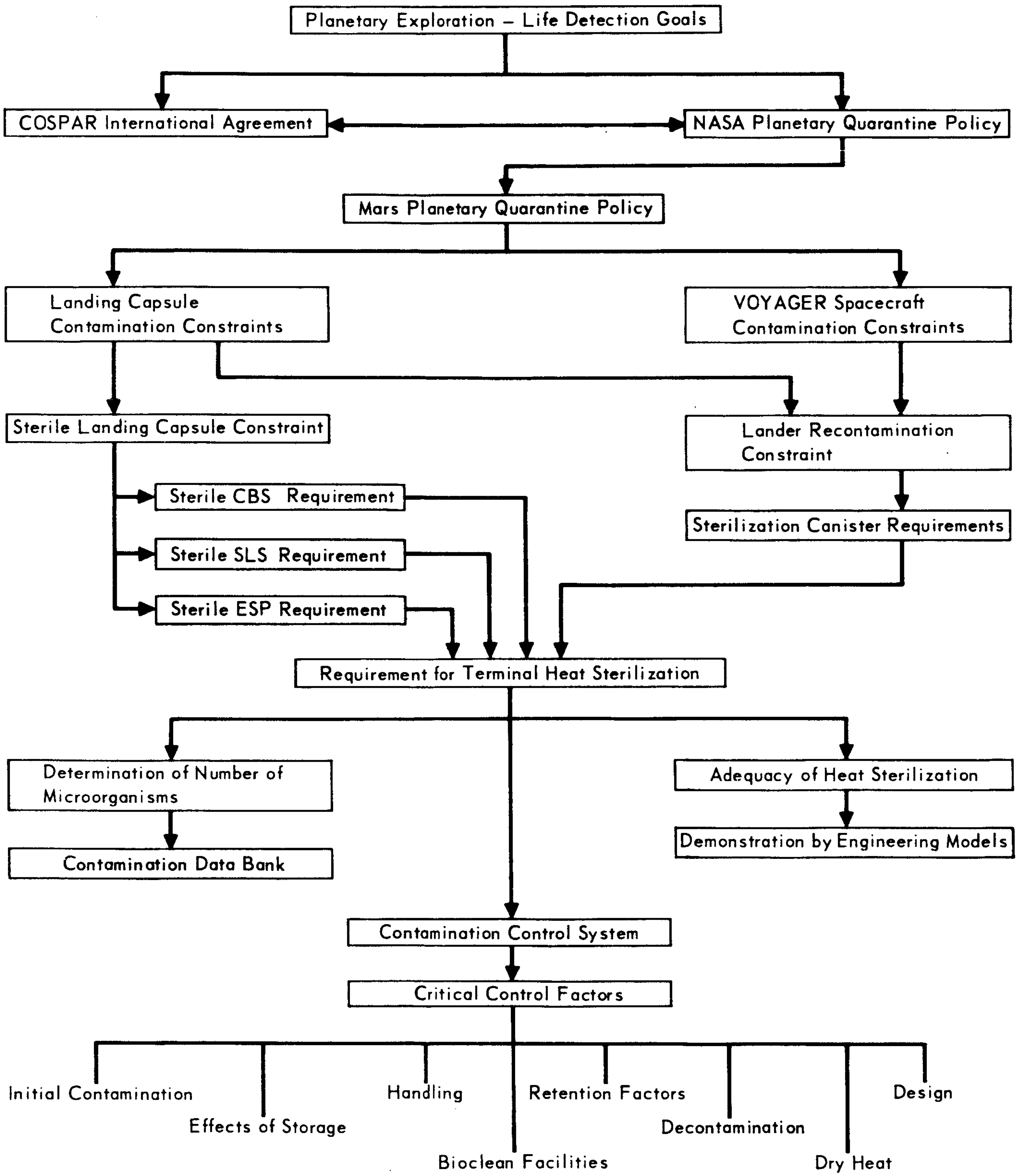


Figure 1-1

SECTION 2

CONTAMINATION FACTORS

The purpose of this section is to examine the sensitive factors in terms of their influence on the Entry Package from design to Martian operation.

2.1 INITIAL CONTAMINATION - The initial internal burden of contamination on piece parts and materials significantly contributes to the total ESP burden, depending on the assembly environment and the timing of the flight acceptance (FA) heat cycle which is used to reduce the accumulated bio-burden during assembly. With assembly in ultra-clean rooms (Class 100 or better), and late FA heat cycling, initial burdens represent the large proportion of contamination possibilities. This is particularly true of the Entry Package, which has a large number of connectors and hand-finished piece parts. Assembly in ordinary clean rooms (Class 100,000 or worse) loads the system quickly and even overshadows the importance of initial burdens. In either case initial burdens must be known (or conservative estimates determined) to make contamination reports as complete and accurate as possible.

2.2 EFFECTS OF STORAGE - Each item used in the ESP will be stored several times as assembly progresses and as work alternates among subsystems. Vegetative cells die in storage at rates estimated as high as 99 percent per year, depending on conditions such as humidity, temperature, and available light. Spores are substantially hardier, dying off a total of perhaps only 10 percent. To provide a conservative estimate of the ESP burden, only die-off of vegetative cells will be considered; that is, all arriving spores plus the surviving vegetative cells will be summed to give the contamination count. McDonnell will take advantage of the low humidity and moderate temperature of the bonded storage areas and double wrapped packaging to reduce vegetative counts.

2.3 HANDLING - Contact by human operators offers the greatest contamination threat to the ESP. Touching parts with the bare hands and arms deposits organisms by the hundreds and thousands per square inch and frequently inoculates nutrient media in the laboratory so profusely that bioassay counting is hopeless. Sterile gloves reduce the contamination hazard to a livable average of about four organisms per square inch per touch. Therefore, regardless of the choice of assembly room conditions and other burden sensitive factors, hand and arm protection is required.

2.4 BIO-CLEAN FACILITIES - Contamination of exposed parts and assemblies by airborne organisms is a hazard second only to handling. Several types of clean facilities can be used to control such contamination, ranging in size from small workbenches to large rooms with sophisticated controls. They vary in effectiveness from adequate particulate control to total biological control, such as with a sterile assembler.

There are two periods during the manufacturing and testing of the ESP in which the effect of clean facilities was evaluated by the McDonnell study. The first of these is the time from piece part acquisition until flight acceptance heat cycling. The study showed that good particulate control is required to produce high quality hardware, but bio-burden determination is less critical. Contamination may be estimated using limited monitoring data coupled with microbiology laboratory and past clean room experience. Class 100,000 facilities are adequate during this period.

After the load reduction by the FA heat cycle, any final assembly, environmental tests and system confidence tests must be carried out within ultra-clean facilities so that contamination is kept within tight bounds. Otherwise, the burden would quickly surpass the maximum allowed (10^5) prior to terminal heat sterilization. A Class 100 facility provides adequate control for this period, however, in effect there are three clean room operation alternatives:

a. Optimizing the level of assembly at which FA heating takes place.
b. Upgrading clean facilities for better contamination control with a resultant allowable reduction in the heating period and,
c. Encapsulating the ESP within its thermal control insulation and sterilizing it prior to integration with the Capsule Bus.

McDonnell's choices were made on the basis of optimizing the ease of assembly and test; reducing the facilities required; and providing adequate contamination control.

In order to optimize ease of assembly and test and to reduce additional facilities, the ESP is preferably assembled to near completion in a "normal" clean environment (Class 100,000). Subsystem checks and system tests are also performed in that facility and mating with the Capsule Bus is completed. The ESP and Capsule Bus is than subjected to the FA heat cycle. Class 100 facilities are then used during the remaining system confidence tests and at all times prior to terminal heat sterilization of the ESP as a part of the Capsule Bus. In addition to reducing the facilities required and making assembly easier, this method allows the ESP contractor to simulate terminal sterilization during the FA cycle and improves reliability by not requiring disassembly.

2.5 RETENTION FACTORS - Entry Science Package materials display a spectrum of electrostatic properties. The native ability of materials to attract and retain airborne particles (both viable and non-viable) is considered during design and clean room assembly of the ESP. It has been demonstrated, for example, that certain plastics retain ten times as many organisms as most metals. Retention factors are approximated from experimental data and combined with the measured arrival rates of airborne organsims.

2.6 DECONTAMINATION - The number of microorganisms which accumulates on the exposed surfaces of the ESP can be reduced by as much as four orders of magnitude by gaseous decontamination. Ethylene Oxide (ETO) is used as a planned control mechanism, as specified in JPL Vol. 50503 ETS, to lower surface burdens prior to the flight acceptance and terminal heat cycles. It may also be used, with considerable discretion, for recovering from accidential contamination control breakdowns. ETO is not freely or indiscriminately used in lieu of limiting the arrival and deposition of microorganisms.

2.7 DRY HEAT CYCLING - Dry heat applied at proper temperatures and times is used twice during the ESP assembly. A flight acceptance heat cycle is planned at an incomplete level of assembly, which effectively reduces the bio-burden to zero and serves as a starting point for biomonitoring and precise contamination control. Prior to launch, a terminal sterilization heat cycle lowers the contamination of the ESP, combined with that of the Flight Capsule, to the level that there will be only one chance in a thousand that a single spore remains viable.

Constrained by the final number of organisms allowed prior to the final cycle, terminal sterilization must meet time and temperature specifications for kill effectiveness. If the accumulated organisms prior to insertion into the sterilization oven can be shown to be fewer than the limit, time for sterilization could be substantially reduced at NASA's discretion. This would improve confidence in the system and make later heat recycles (if post-terminal sterilization breaching of the biobarriers is required) less detrimental.

The flight acceptance heat cycle could be employed at almost any point during the assembly process. However, the earlier it is applied, the sooner problems will begin to be uncovered. Applied later in assembly, it simulates the terminal sterilization cycle more closely and reduces the scheduled time in the Class 100 environment which must follow. As described in 2.4 above, the timing of this heat cycle has been selected to optimize facility schedules, manufacturing efficiency, and contamination control, and to preempt terminal sterilization problems. A flow diagram of the recommended ESP fabrication cycle may be found in Volume VI, Part B, Section 3.2

SECTION 3

DESIGN FOR STERILITY

The ESP design details must be compatible with dry heat and ETO. Not only piece parts and materials must qualify, but subassemblies, assemblies, etc., and the entire system itself must be impervious to damage or change when applying these procedures. In addition, the rate of contamination accumulation, the accessibility of surfaces to gas diffusion, and the efficiency of heat transfer, all influence or create design criteria.

3.1 STRUCTURE - Although it is generally conceded that structure represents the least problem in meeting design criteria, it is nonetheless important that it does so. For example, bioload buildup and decontamination effectiveness is profoundly affected by structural simplicity, by the number of steps or operations required during assembly, and by the areas which are "internalized" during the assembly process. Structure is responsible for the proper transfer of sterilizing heat to mounted experiments and subsystems. During heat cycling, poorly designed structure sometimes imposes severe mechanical stresses on subsystems, resulting in a variety of mechanical and electrical failures. Careful consideration has therefore been given to mechanical devices and to structure in our proposed ESP design.

The ESP contractor is responsible for specifying design requirements which anticipate and preclude such problems. During the Phase B study, the McDonnell VOYAGER Planetary Quarantine Office has developed design practices with this in mind and has issued the design guidelines of Figure 3.1-1 to the system engineering staff. These guidelines will become an integral part of the design review criteria to be employed during the Phase C and D detailed design of the ESP.

GENERAL GUIDELINES - STERILE VOYAGER DESIGN

GUIDELINES - The following general rules for designing sterilizable aerospace vehicle components are applicable to the VOYAGER Systems and Structure and will serve as the basis of design review by the McDonnell Planetary Quarantine Office. The number of assembly contact points at all levels of assembly should be minimized to provide good heat transmission paths for equalizing temperature rates during heat sterilization and to prevent occluding of contaminated surfaces. (Contact points must be sufficient to maintain structural integrity, however.) Specifically, contact points may be reduced as follows:

a. Replace bolts and fasteners with rivets, when possible (without impairing our flexibility of part replaceability).

b. Replace rivets with welds, when possible.

c. Keep surface simple with smooth curvature - avoid compound curves.

The number and volume of voids within the structure should be minimized to provide optimal heat conduction and to reduce the number of occluded organisms. The number of assembly steps required after FA heat cycle should be reduced to a practical minimum to eliminate excess handling and fallout exposure.

Occluded and mated areas should be minimized by good design practice, specific items include:

a. Reducing assembly contact points.

b. Adding gas diffusion holes in containers, covers, and packages, which do not have to be sealed.

The number of electrical and plumbing connectors used should be minimized. These are notorious contamination collectors because of the added handling they receive and the encapsulation of microorganisms when they are "made".

Heat sterilization compatibility should be considered by:

a. Minimizing the number of bi-metallic adjoining surfaces.

b. Designing for efficient heat flow.

c. Designing for dimensional stability by using proper materials, expansion joints, heat sinks, thermal switches, fins, insulation, and symetry.

d. Reviewing heat sensitive components for possible changes in concept, material, and manufacture.

Figure 3.1-1

e. Determinaing expansion/contractions envelopes, especially on all plumbing and electrical lines.

Sterile maintainability should be designed into the end product by:

a. Remote post-sterilization calibration.
b. Remote post-sterilization adjustment.
c. Easy access to critical hardware and to service items, such as batteries and gas bottles.

3.2 SCIENCE SUBSYSTEMS - Fortunately, most science subsystems already exist as working prototypes and their heat qualification requirements have been identified. Impositions created by decontamination are discussed in Part D, Section 2 above; however, an overview will be helpful. Sensitive elements in visual imaging include the vidicon tube; however, the sterilizability of an ASOS vidicon has been demonstrated as discussed in JPL SPS 37/43, Vol. IV, Page 264. The atmospheric sensors are heat insensitive, except for the pressure transducer which changes calibration with each successive heat cycle.

3.3 THERMAL CONTROL SUBSYSTEM - The thermal control subsystem is a very important one, considering its effect on the implementation of FA heat cycling, and on terminal sterilization. The surrounding insulation, one in place, retards heat buildup in the ESP and makes soak periods prohibitively long. The ESP contractor is restricted from using techniques such as sterile assembly to install insulation after the heat cycle. However, active thermal control elements and internal heaters may be used. Therefore, provision for electrical heating of the ESP during heating cycles has been included in the baseline configuation.

3.4 OTHER SUBSYSTEMS - In the power subsystem, sterilizable batteries remain to be developed which are light weight, have long life storage capabilties after changing and do not leak. In the communication subsystem, bulk storage, by means of sterilizable magnetic core memories and tape recorders, is being developed, but is not now state-of-the-art.

SECTION 4

MAINTENANCE OF STERILITY

Following integration with the Surface Laboratory and the Entry Science Package, the Capsule Bus will be enclosed in the sterilization canister and heat sterilized. The canister bars access and impares communication so that the Capsule Lander must be remotely tested to verify that each system has withstood the terminal sterilization heat soak. In-flight tests prior to separation will add to the remote testing burden. Inaccessibility also requires more accurate and reliable systems which do not need adjustment and recalibration. The telecommunication will operate in a special test mode to verify system operation.

SECTION 5

STERILIZATION PLAN SUMMARY

The recommended procedure for producing a sterile Entry Science Package which meets NASA requirements was derived from a thorough analysis of the contamination factors, design requirements, practical manufacturing and testing procedures, and the qualification programs presently in work. That procedure is the preferred Sterilization Plan, which is detailed in Volume VI. Paraphrasing that plan, there is a need to:

a. Control Contamination - by carefully selecting and training clean room personnel; by imposing control procedures on major subcontractors; by designing the ESP for low burden accumulation rates and easy decontamination; by collecting contamination data during receipt, inspection, checking, assembly, and systems testing; by assembling the ESP in a Class 100,000 clean facility; by performing flight acceptance heat cycling after the system is essentially completed, and by monitoring assembly procedures, test procedures, clothing procedures, and personnel cleanliness; by completing assembly and subsystem testing prior to the flight acceptance heat cycle and verifying performance after the FA heat cycle, thereby simulating the anticipated effects of the terminal heat cycle; by decontaminating the ESP at predetermined points; by establishing bioburden limits at progressive stages of manufacture, based on data from development test vehicles; by creating a contamination data system for daily and periodic burden reports; by using a Class 100 facility for continued system tests after flight acceptance heating; by shipping the lightly contaminated Capsule Lander in an environmentally controlled shipping canister, and by using Class 100 facilities at KSC.

b. Sterilize the Capsule Lander - by determining the contamination load using assembly room bioassays and coupon assays and by applying heat as specified by NASA constraints to reduce contamination to the probabilistic level.

c. Maintain Sterility - by designing a sterilization canister which keeps a positive differential pressure inside at all times from sterilization through launch; by employing CBS, SLS, and ESP systems which require no post-sterilization adjustment; by monitoring pressure and seal integrity of the canister continuously; and by using separation techniques which generate no debris to contaminate the planet or Capsule Lander, and which will not allow contamination cross over from the unsterile Spacecraft.

d. Assure Reliability of Sterilizable Components - by conducting qualification tests on all piece parts, materials, subassemblies, assemblies and systems which are candidate types for flight hardware.

SUMMARY

The McDonnell Operational Support Equipment (OSE) concept is based on a systems-oriented analysis of the VOYAGER program requirements and CBS/ESP guidelines and constraints. Operational Support Equipment is considered as a vital element in achieving a successful VOYAGER mission. OSE, flight systems, and test concepts are balanced to provide an ESP Operational Support Equipment design that meets program objectives and requirements.

- <u>Probability of Mission Success</u> - Our approach to Operational Support Equipment for the ESP maximizes the probability of mission success and launch-on-time by using the speed, repeatability, and safety of computer controlled checkout, while retaining man-in-the-loop for critical decision making and contingency action. The repeatability of automated testing provides a high confidence test data bank, with rapid access to diagnostic and trend analysis data during ground test and mission operations.
- <u>Planetary Quarantine</u> - Integration of system test requirements into the design of the flight telemetry and in-flight checkout systems has solved the problem of transmitting system test data through the capsule sterile canister, and has led to the development of a System Test Complex that can conduct system level tests at the CB Contractor's factory and at KSC, with minimum dependence on Subsystem Test Sets.
- <u>ESP Approach</u> - The ESP is treated as an individual system, assembled and tested at an ESP contractor's factory, in a manner consistent with ultimate technical management by the CB or SLS Contractor. ESP test requirements are less in quantity and complexity than the CB or SLS and dictate a simplified equipment approach at the ESP factory. At the Capsule Bus (CB) integration site and at KSC, time sharing selected elements of the CB contractor's System Test Complex is a feasible way of meeting the ESP's relatively limited system test requirements and reducing total program OSE quantity and space requirements.
- <u>Subsystem Test Concept</u> - Subsystem Test Sets (SSTS) are automated on selected subsystems for which automation represents a cost-effective solution: Telemetry and Science. Small automatic processors provide flexibility to accomodate flight system changes and capacity for independent subsystem tests,

and are compatible with future growth to centralized computer control. SSTS and STC feature extensive use of digital displays for high accuracy and reduction of human error. A hard copy printout provides a permanent record of test and acceptance. Major Subsystem Test Equipment groups include Power, TCM, Science, and Thermal.

- System Test Concept - At the ESP factory, Subsystem Test Sets plus selected system level OSE, capsule and SLS simulators, are used for semi-automatic system level tests.

  At the CB contractor's plant and KSC, the ESP shares the CB contractor's Computer Data System to perform automatic test sequencing, response analysis, automatic limit and alarm monitoring, data suppression, and OSE self-check. Additional elements of the ESP System Test Complex include the ESP Command and Display console, Ground Data Transmission System, and Communication, Timing, and Power Distribution Groups. Integration of the ESP OSE with the Spacecraft, Capsule Bus, Mission Operations System, and other VOYAGER System elements is reflected in our selected design interfaces, OSE arrangement, and data link utilization.
- Launch Pad Operations - An ESP Launch Monitor Panel located in the Launch Control Center is hardlined to associated Launch Complex Equipment (LCE) at the Launch pad, for maximum reliability in safeing the SLS if a critical malfunction occurs. Use of the Spacecraft umbilical for the ESP data transmission eliminates the need to use the Capsule OSE umbilical for launch pad operations. The ESP System Test Complex provides automatic monitoring and alarm backup for the LCE.
- Mission Dependent Equipment - ESP Mission Dependent Equipment consists of software and telemetry processing equipment required for decommutation, coding, command encoding, and TV data processing in the Deep Space Instrumentation Facility, and diagnostic displays used in the Space Flight Operations Facility. Identical software is used to perform telemetry decommutation in the System Test Complex, thus reducing hardware requirements.
- OSE - OSE Development risk is minimized by extensive utilization of commercial hardware and standardized computer software. Phased "building-block" software development provides maximum commonality of software packages, and assures early use of the computer for manual mode operation prior to validation of test software. Equipment modules are standardized for commonality of design, spares, and field support.

o <u>Utilization and Human Factors</u> - The ESP OSE is designed and configured for compatibility with the test team approach used successfully on previous interplanetary and McDonnell-Douglas spacecraft programs. A test team composed of cognizant flight subsystem engineers and experienced test, launch, and mission operations personnel is assigned to support a particular ESP/capsule from factory operations through launch and the reentry operations. Major studies conducted as part of OSE concept selection include alternative methods of automation and display techniques, and STC computer utilization. Supporting data includes an analysis of an alternative OSE integration concept, based on maximum sharing of equipment by CB, SLS, and ESP contractors. The selected OSE concept meets the VOYAGER Program growth potential, and is designed for realistic implementation.

SECTION 1

INTRODUCTION AND OBJECTIVES

1.1 INTRODUCTION - This Part of Volume IV contains the functional descriptions and preliminary designs for the recommended Operational Support Equipment (OSE) and Mission Dependent Equipment (MDE) for the Entry Science Package. The approach used to establish the OSE requirements, translation of these requirements into design criteria, identification of alternative design and utilization concepts, and the rationale and criteria employed in selection of the preferred concept are described. Trade studies and supporting data are included. The ESP OSE integration concept and OSE interfaces are defined to provide a foundation for firm Phase C OSE integration ground rules.

OSE for the Entry Science Package includes all ground-based equipment and software required to test, checkout, transport, and handle, align, install, and service the ESP from factory through launch, and the equipment and software (MDE) required to interface the ESP with the existing and planned facilities of the Deep Space Network. Additionally, ESP OSE includes ESP Simulators required at the Spacecraft, ESP, and CB contractor's facility and government furnished equipment required for CB and ESP integration.

1.2 VOYAGER PROGRAM AND MISSION OBJECTIVES - The ultimate goal of ESP OSE is to provide the maximum probability of on-schedule mission accomplishment, and successful acquisition of the mission data. In addition, ESP OSE must provide "The assurance of some measure of success, regardless of circumstances". Recognizing the vital role of Operational Support Equipment in attaining these goals, we have established fundamental objectives for the performance, integration, development, and implementation of ESP Operational Support Equipment, based on VOYAGER program studies and on Mercury/Gemini experience.

1.3 ENTRY SCIENCE PACKAGE OSE OBJECTIVES

1.3.1 Performance and Design Objectives

- Provide the highest practical probability of launch-on-time. Key to attainment of this objective is the realiability, speed, and availability of the OSE use for prelaunch and launch operations at KSC.
- Accurately and repeatably detect and/or isolate all ESP and OSE malfunctions.
- Provide test continuity, elimination of test variables, and a continuous test history as the ESP and its components flow from factory through launch and reentry.

- Protect personnel, flight systems, and OSE from hazard or damage due to OSE failure or human error.
- Achieve maximum commonality of functional modules and unnecessary duplication of equipment.
- Accommodate subsystem changes and provide growth potential and flexibility for future missions with minimum change.

1.3.2 Integration Objectives

- Clearly define the physical and functional interfaces of ESP OSE and provide the minimum duplication of equipment consistent with clearcut contractual responsibility.
- Maximize compatibility with existing facilities at KSC, and with other elements of the VOYAGER System.
- Design and package OSE to conserve space in integrated operations areas.
- Incorporate effective and economical maintainability provisions to insure maximum operational availability of OSE.

1.3.3 Development and Implementation Objectives

- Minimize development risk by maximum use of OSE designs and off-the-shelf components that have proven performance on the Mariner, Lunar Orbiter, Gemini, and other NASA programs. Use existing hardware where consistent with performance requirements.
- Demonstrate OSE and software compatibility with the Capsule, SLS, Spacecraft, and DSIF prior to acceptance test of the first flight vehicle.
- Employ practical cost solutions to optimize the cost-effectiveness ratio of ESP OSE.

SECTION 2

REQUIREMENTS AND CONSTRAINTS

Successful implementation of the VOYAGER Program requires more than compliance with the specified requirements alone. We have analyzed the significant problems presented by Entry Science Package (ESP) configuration, sterilization, and integrated checkout in order to derive the additional requirements that will contribute the extra performance margin necessary to assure VOYAGER mission success.

This section describes the basic Operational Support Equipment (OSE) requirements and constraints, and the McDonnell derived requirements used in developing the Entry Science Package OSE design concept.

2.1 BASIC REQUIREMENTS AND APPLICABLE DOCUMENTS - The ESP OSE requirements and constraints contained in the documents listed below are the basic JPL requirements used in the development of our concepts and in our OSE design.

a. MA003BB002-2A11 File MA3AA7E005 "Guidelines for the VOYAGER Capsule Contractor" dated 18 May 1967 (Revision 1)

b. SE003BB002-2A21, File SE3BC-7E-004, "1973 VOYAGER Capsule Systems Constraints and Requirements Document" dated 18 May 1967 (Revision 1)

c. SE002BB001-1B21, File SE1DC, "Performance and Design Requirements for the 1973 VOYAGER Mission, General Specifications For" dated 1 January 1967

d. RFP V06-4509 Enclosure 2, VOYAGER Capsule Specimen Statement of Work Phase B", modified by JPL TWX 192125Z, dated May 1967

e. Engineering Planning Document #283, Revision 2, "Planned Capabilities of the DSN for VOYAGER 1973" dated 1 January 1967

f. Technical Memorandum #33-255, "Description of the Deep Space Network Operational Capabilities as of January 1, 1966" dated 1 July 1966

2.2 CONSTRAINTS - The most significant customer constraints are:

a. Time-limited launch opportunity, launch window, and launch period.

b. Complex 39 will be used at Kennedy Space Center.

c. Planetary quarantine requirements must not be degraded.

d. Two planetary vehicles will be launched on a single launch vehicle.

2.3 DERIVED REQUIREMENTS - ESP OSE - Using the OSE objectives and the basic JPL requirements and constraints as a foundation, additional OSE requirements have been derived by analysis of the problem areas, ESP subsystems, test requirements, the integrated test plan, and other VOYAGER System's integration requirements. The ESP test requirements are less in quantity and complexity than the CBS or SLS and dictate a simplified approach at the ESP factory. Derived ESP OSE requirements are as follows:

a. Mission critical OSE must be allocated a P_s based on reliability analyses of launch operations and supporting equipment. Mission critical OSE is defined as that equipment or software (including Mission Dependent Equipment) whose failure could delay or abort a launch during the terminal count or cause degradation of the mission after launch.

b. OSE required inside the Class 100 rooms must be designed for minimum contamination of the ESP and Class 100 environment.

c. LCE must provide fault isolation and decision-making capability to the level required for launch commitment.

d. Subsystem OSE must be designed for performance margin testing and provide a historical data base readily correlated with system test data after Flight Capsule encapsulation.

e. Trend analysis and failure mode prediction data must be recorded during tests.

f. Human engineering must be performed on all OSE designs to determine the best method of displaying information and arrangement of controls in order to minimize operator error and provide maximum safety for personnel and equipment.

2.4 DERIVED REQUIREMENTS - CAPSULE BUS (CB) AND SPACECRAFT (SC) CONTRACTOR OSE

a. During Planetary Vehicle (PV) systems test and launch pad operations, the SC Contractor's STC must strip out and reroute Entry Science Package (ESP) TM data to the ESP System Text Complex (STC).

b. The SC Contractor's flyaway umbilical must contain pins for handling critical signals and RF coax-connectors for launch pad operations.

c. The CB Contractor must provide interface simulators that will precisely simulate signals and loads for checking compatibility prior to mate.

2.5 OSE BASELINE INTEGRATION REQUIREMENT - In order to comply with the Statement of Work request to provide separate volumes we have treated the CBS, SLS, and ESP as separate systems, and have identified the requirements and OSE separately for each system. We have identified system level ESP OSE as if a separate contractor assembles and tests the ESP and ships it to the Capsule Bus Contractor's facility.

This approach isolates the support requirements for each system and establishes a point of reference for objective integration of OSE functions when the systems configuration and technical responsibility have been established. However, in order to provide VOYAGER Management further insight into the full potential of sharing common OSE during integrated operations, we have included a study of such an alternative integration concept in Section 10.

2.6 SELECTION CRITERIA - Selection of our design concept has been accomplished by weighing alternative design approaches against selection criteria developed in accordance with VOYAGER program objectives. Major OSE selection criteria are summarized below and are described in detail in Section 10.

a. Probability of Mission Success - (OSE reliability and operational availability)
b. OSE and Flight System Performance - (Test quality, test time, test confidence)
c. Development and Schedule Risk - (Initial OSE availability and contingency potential)
d. Versatility/Flexibility - (OSE growth potential, common usage)
e. Cost - (OSE hardware, maintenance, development and operating costs.

SECTION 3

PREFERRED APPROACH-OPERATIONAL SUPPORT EQUIPMENT (OSE)

This section summarizes the design and operating characteristics for the major OSE systems and the major trade studies and criteria involved in selection of our concept. Complete preliminary designs, functional descriptions, and supporting analyses are provided in Sections 4 through 10, Part J.

3.1 OSE UTILIZATION CONCEPT - Our approach to ESP utilization treats the ESP as a system that is assembled and tested at an ESP contractor's factory, and then transported to the CBS contractor's factory for installation and integration. ESP OSE is designed to support development and flight acceptance testing from factory through launch. After launch, ESP Mission Dependent Equipment is used to support the mission and the Mars entry operations. Because OSE design is so fundamentally dependent upon supporting these operations, a summary of OSE utilization is presented as an orientation and introduction to the design concept.

3.1.1 OSE Categories and Functions - The basic OSE categories and their functions are in accordance with the JPL constraints document, and as further defined below:

a. Subsystem Test Equipment (SSTE) - This is test equipment related primarily to the testing of a particular flight subsystem. For the ESP, SSTE is composed of Subsystem Test Sets and a System Level Test Console. The Subsystem Test Sets (SSTS) are used for pre-delivery acceptance (PDA) tests of modules at principal subsystem vendors, at the ESP contractor's plant for Equipment Function Check (EFC) and subsystem test, and at the CB contractor's factory during module buildup and installation. ESP SSTS is required at KSC on a contingency basis only. The System Level Test Console is used for integrated ESP/CB systems test, as described below:

b. System Test Complex (STC) - This is equipment used for integrated system tests and simulated missions at the CB contractor's factory and KSC. It also is used for Launch Complex Equipment (LCE) functions to reduce quantity of LCE required. STC consists of selected items of SSTE plus OSE system elements. Subsystem Test Equipment (SSTE), used exclusively for integrated ESP system tests, such as the system level test console, will be carried in the STC category to conform with its primary functional OSE system's interface.

c. Launch Complex Equipment (LCE) - This supplements the STC for control and monitor of operations of the launch pad and at the KSC Explosive Safe

Facility (ESF). It provides power, alarm warning, and emergency control of the ESP prior to launch.

d. Mission Dependent Equipment (MDE) - This is used to conduct operations from the Deep Space Network (DSN) and Space Flight Operations Facility (SFOF) during cruise and entry. It is also used in the STC to establish compatibility between ESP telemetry and Deep Space Instrumentation Facility (DSIF) at KSC, and to perform telemetry processing.

e. Spacecraft Mounted ESP Equipment OSE (SCME) - This is used at the Spacecraft contractor's plant for subsystem testing of ESP hardware installed in the spacecraft, and in the STC for integrated tests.

f. Assembly, Handling and Shipping Equipment (AHSE) - This is used for transportation and handling of the ESP and for weight and balance, alignment and rigging of structure and mechanical subsystems.

3.1.2 Test Utilization - An overview of the use of ESP OSE for the major test phases, CB factory integration through mission operations, is illustrated in Figure 3.1-1. The major test arrangements at the factory, KSC industrial area, and the launch pad are depicted in Figures 3.1-2, 3.1-3, and 3.1-4 respectively. A detailed description of the Integrated Test Plan, Flight Acceptance Test Plan, and Mission Support Plan is provided in Volume 6.

3.2 DESIGN CHARACTERISTICS

3.2.1 System Test Complex (STC) - The ESP System Test Complex at the CB contractor's plant and at KSC consists of the following equipment:

a. ESP Command and Monitor Console - A sitdown console with a CRT (or equivalent) for ESP subsystems data display, a keyboard and interface unit for addressing the CBS contractor's Computer Data System (CDS), and critical hardline displays and commands.

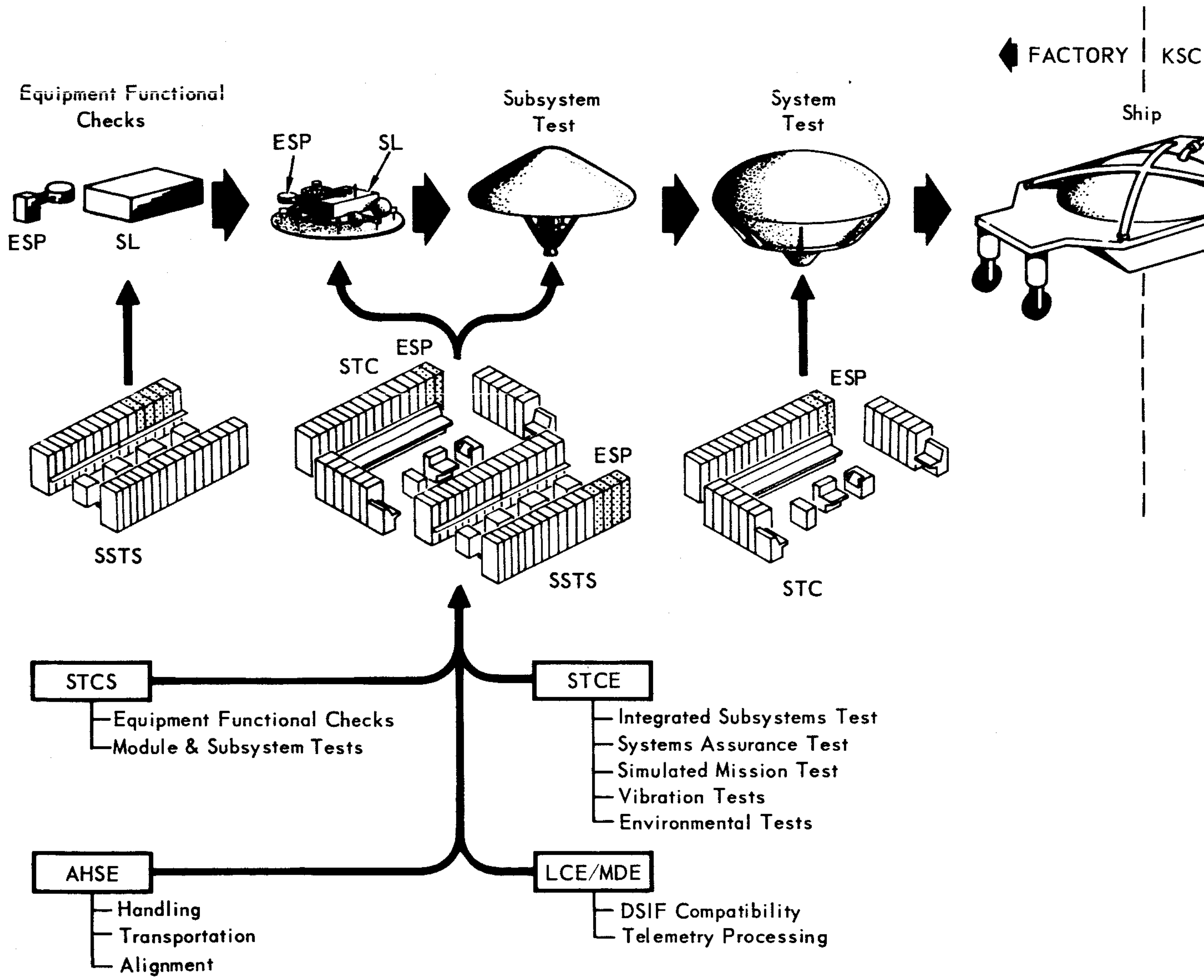
b. STC Required MDE - An exact duplicate of the MDE equipment and software used at the DSIF stations to detect and decode the ESP down-link data, and generate the up-link commands that are required during the mission.

c. STC Required MIE - An exact duplicate of the Telemetry and Command processor and software used at the DSIF's.

d. Ground Data Transmission System (GDTS) - A digital transmission system used for transmission of TCM parameters and ground test data, and commands between the STC and the ESP at remote locations.

e. Simulators - Interface simulation and control equipment required for testing and compatibility demonstration are provided in SSTS.

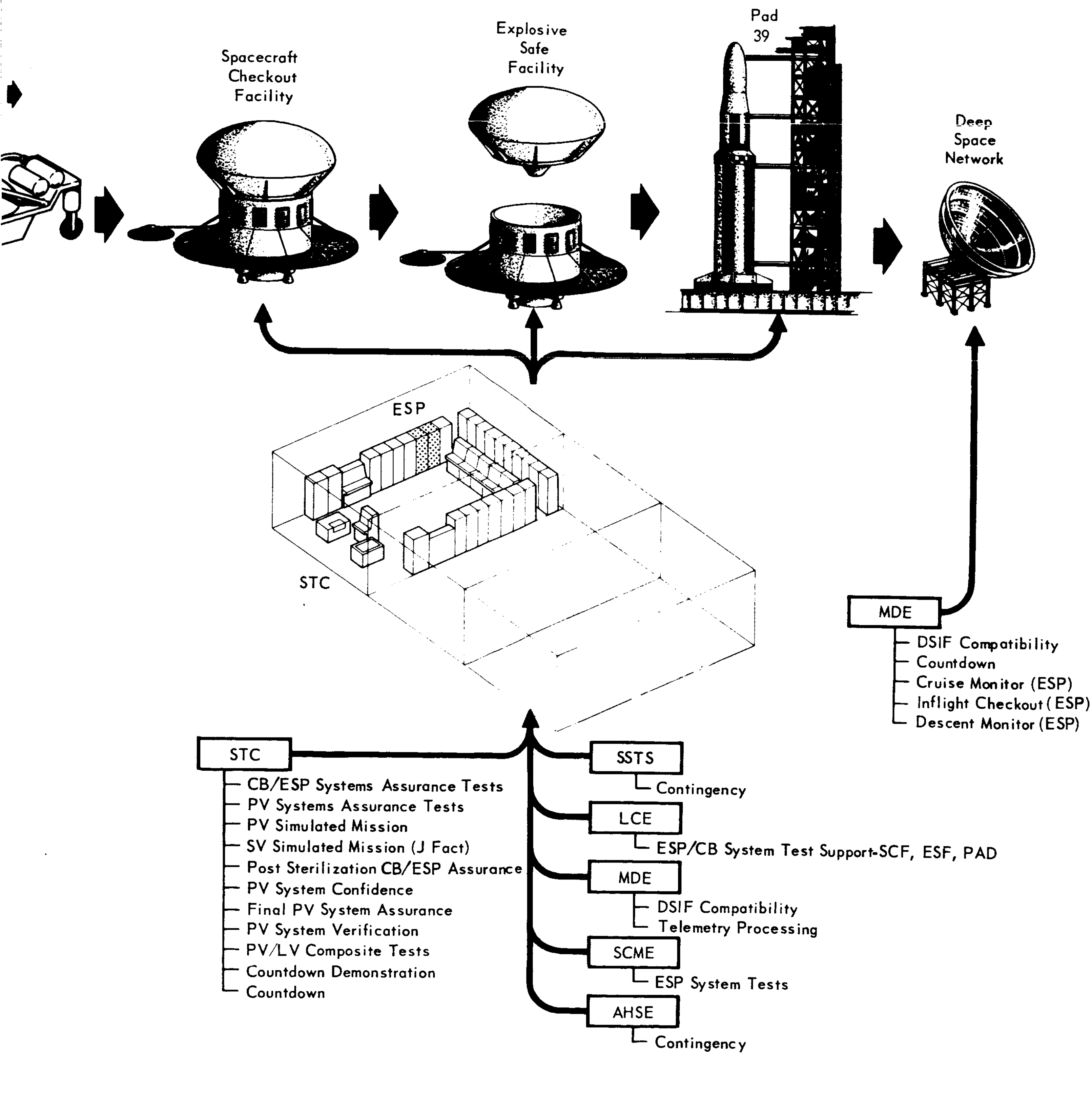
ESP OSE UTILIZATION IN CAPSULE SYSTEMS INTEGRATION



LEGEND

STC – System Test Complex
LCE – Launch Complex Equipment
SSTS – Subsystem Test Sets

Figure 3.1–1


Spacecraft
Checkout
Facility
Explosive
Safe
Facility
Pad
39
Deep
Space
Network
ESP
STC
MDE
DSIF Compatibility
Countdown
Cruise Monitor (ESP)
Inflight Checkout (ESP)
Descent Monitor (ESP)
STC
CB/ESP Systems Assurance Tests
PV Systems Assurance Tests
PV Simulated Mission
SV Simulated Mission (J Fact)
Post Sterilization CB/ESP Assurance
PV System Confidence
Final PV System Assurance
PV System Verification
PV/LV Composite Tests
Countdown Demonstration
Countdown
SSTS
Contingency
LCE
ESP/CB System Test Support-SCF, ESF, PAD
MDE
DSIF Compatibility
Telemetry Processing
SCME
ESP System Tests
AHSE
Contingency

ESP OSE UTILIZATION AT THE CB CONTRACTOR'S FACTORY

TEST PHASE	EQUIPMENT FUNCTIONAL CHECKS (EFC)	PHASE IA MODULE TESTS
USING AREA	CLASS 100,000 CLEAN ROOM	CLASS 100,000 CLEAN ROOM SUBSYSTEM TEST AREA
OSE UTILIZATION	SSTS • Module Performance Verification • Calibration and Adjustments • Failure Analysis	SSTS • Subsystem Tests • Interface Simulation & Verification AHSE • Handling • Installation

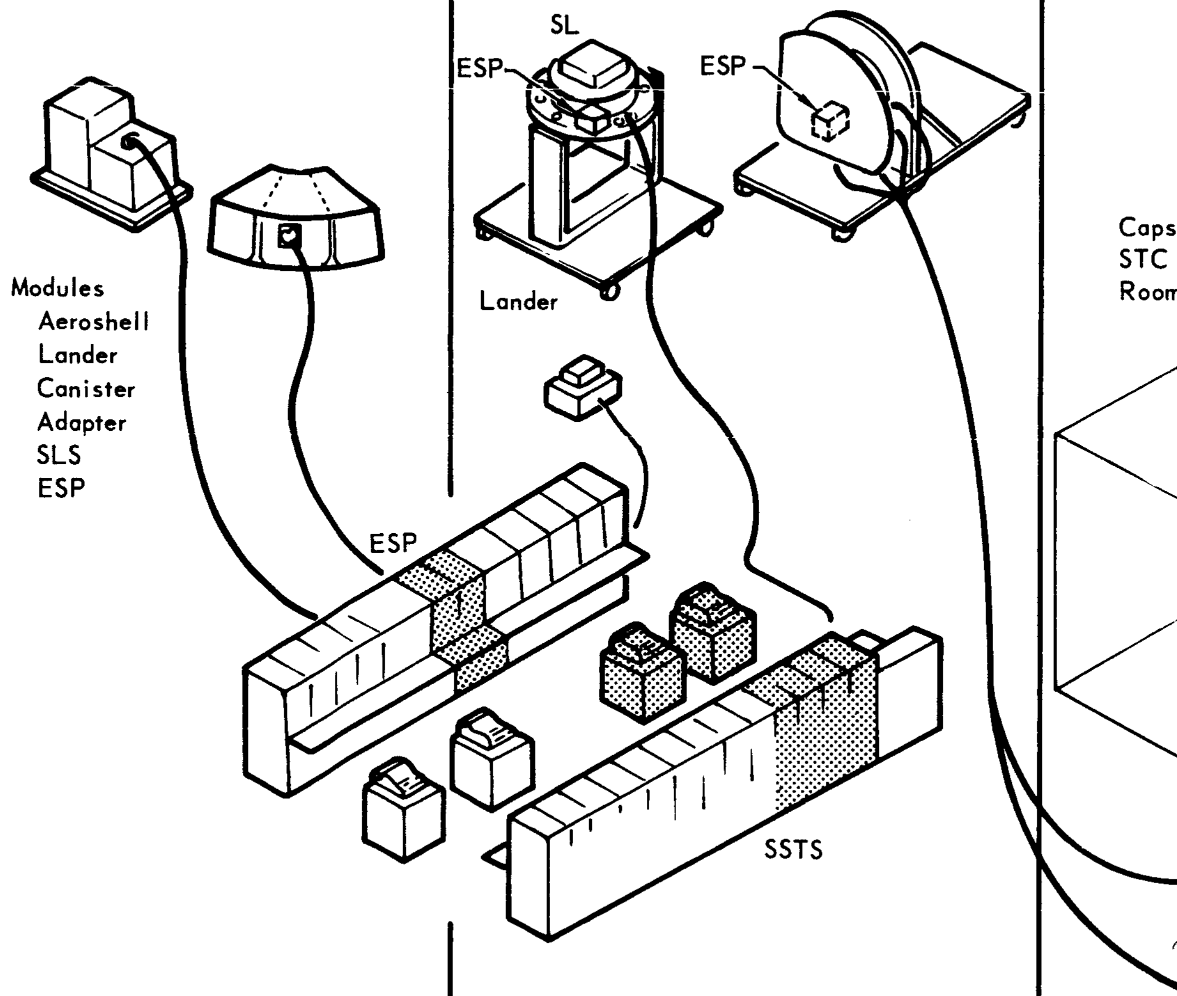
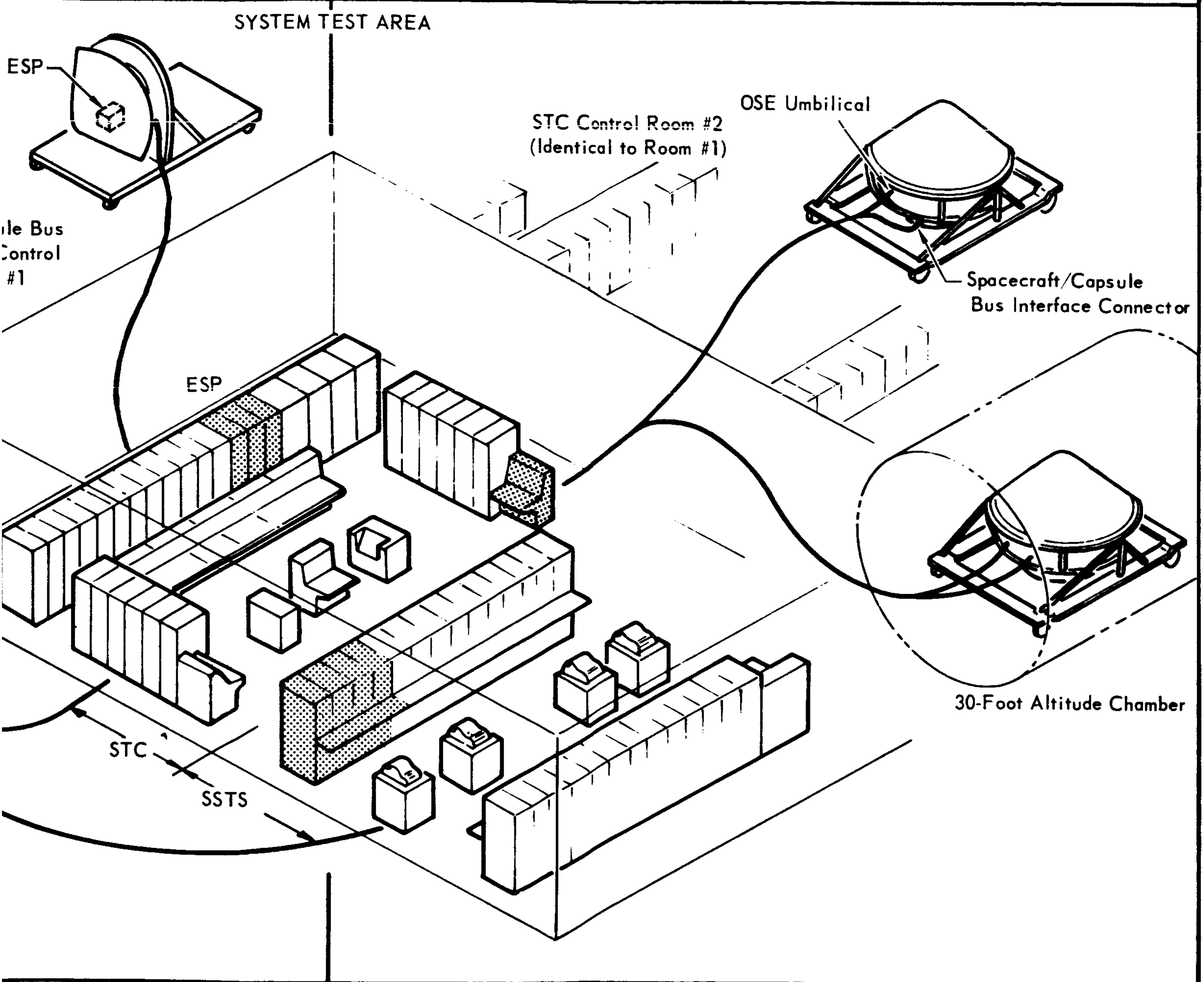


Figure 3.1-2

PHASE IB SUBSYSTEM TESTS	PHASE II INTEGRATED SUBSYSTEMS TEST



TC & SSTS
grated Subsystem Tests

STC
- Systems Assurance Tests
- Simulated Mission
- Vibration Systems Assurance
- Environmental Testing

AHSE
- Handling & Transportation

MDE
- Compatibility Tests and Telemetry Processing

LCE
- ESP/CB Power
- RF Monitor
- ESP/CB Test Stimuli Signals

UTILIZATION OF OPERATIONAL SUPPORT EQUIPMENT AT KENNEDY SPACE CENTER DURING ESP/CB INTEGRATED TESTS

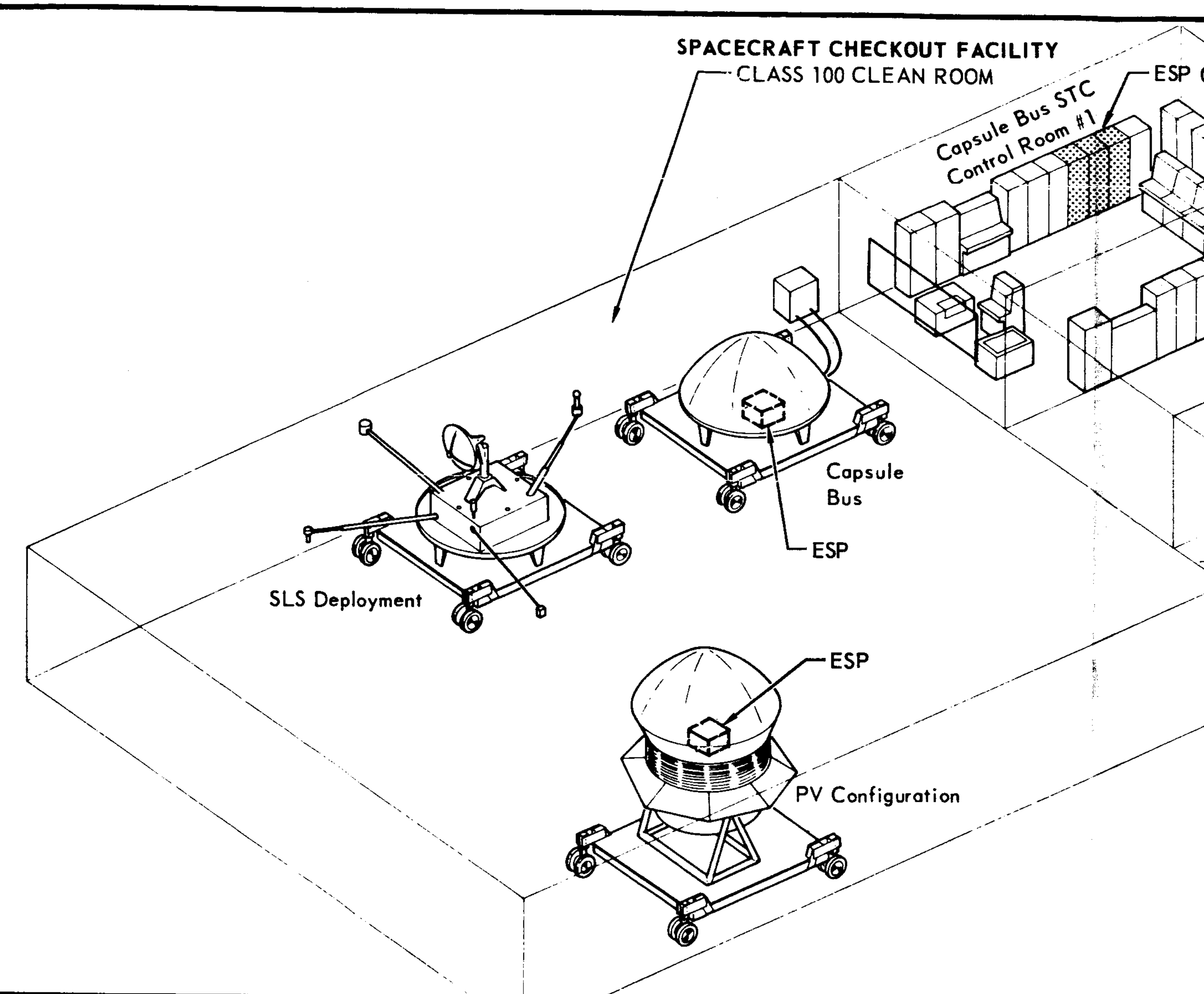
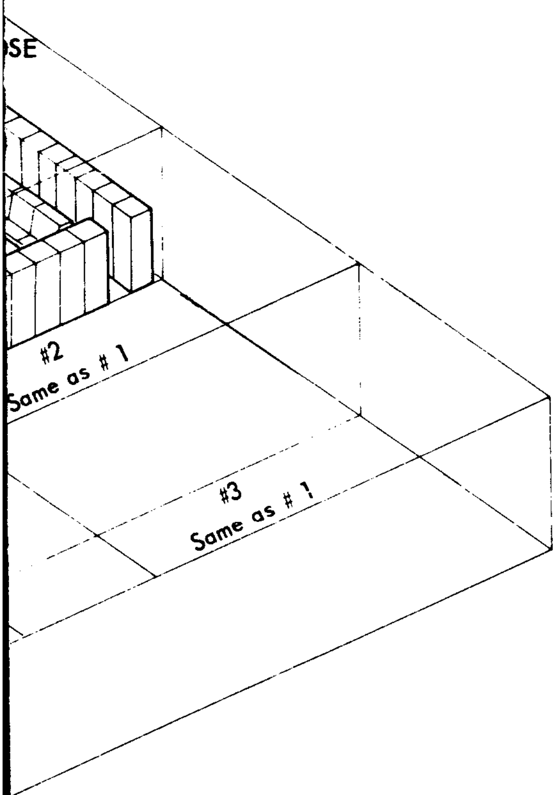
TEST PHASE	PHASE III – CAPSU
USING AREA	
OSE UTILIZATION	STC • Capsule Systems Assurance • Simulated Mission–DSIF 71 Compatibility • Simulated Joint Flight Acceptance Composite Tests SSTS • Contingency Use • T/M D • Comm

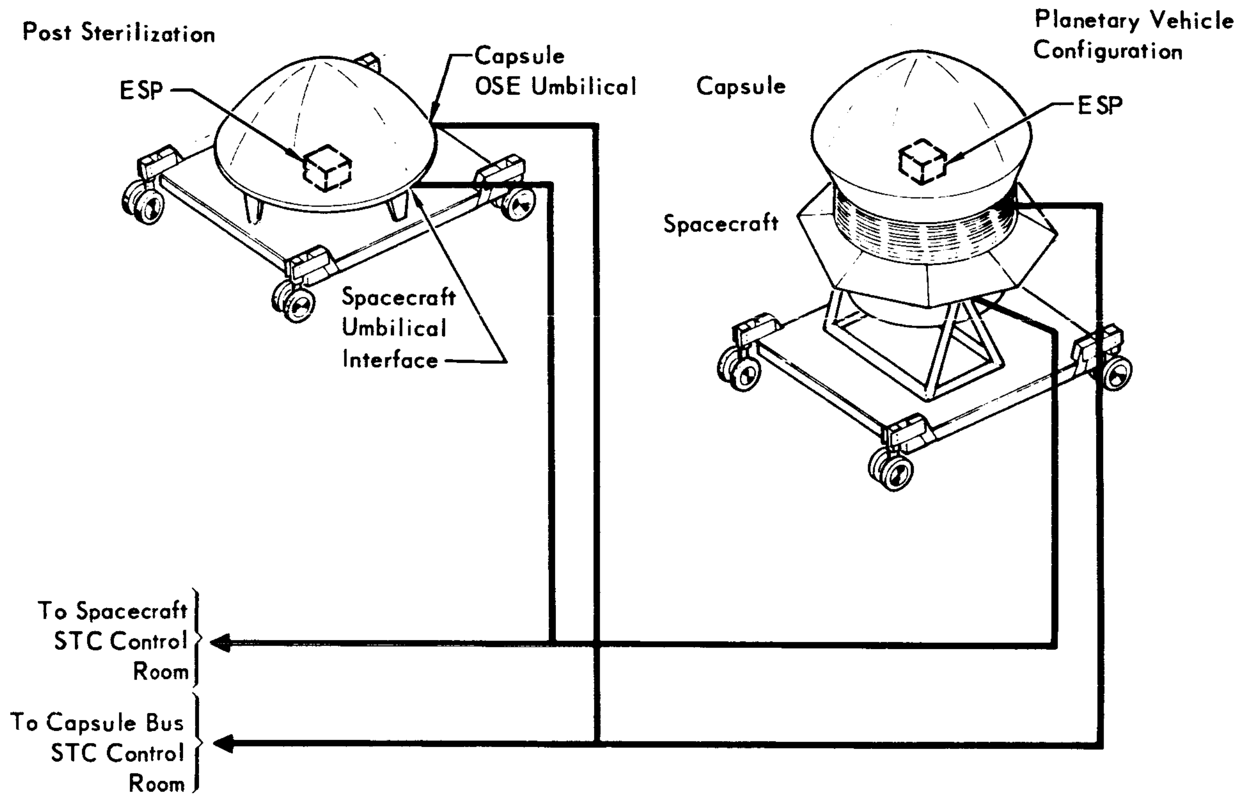
Figure 3.1-3

E & PV SYSTEM TESTS

SE



EXPLOSIVE SAFE FACILITY
CLASS 100 CLEAN ROOM



LCE
- ESP Power
- Remote Stimulation
- UHF Monitor & Test

MDE
ata Aquisition and Processing
nd Pre-processing

AHSE
- Handling, Mating
- Alignment

STC
- ESP Assurance
- Planetary Vehicle Systems Assurance
- Planetary Vehicle Storage Monitoring
- Final Planetary Vehicle Systems Assurance

LCE
- ESP Power
- UHF Monitor & Test
- Remote Simulation

AHSE
- Contingency

UTILIZATION OF OPERATIONAL SUPPORT EQUIPMENT
KENNEDY SPACE CENTER AND DEEP SPACE NETWORK

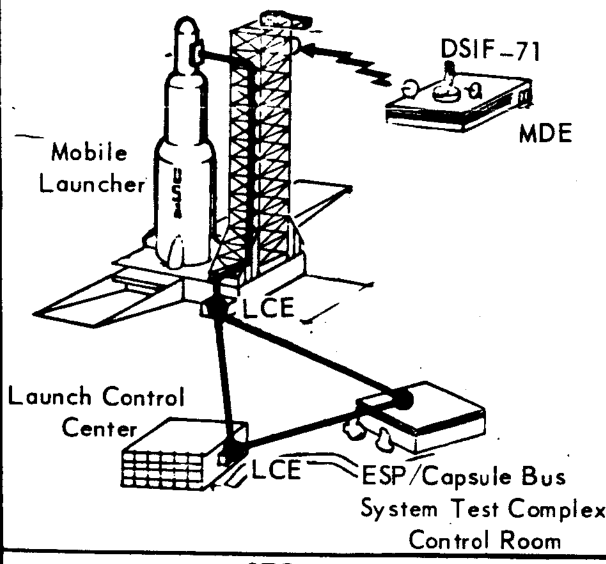
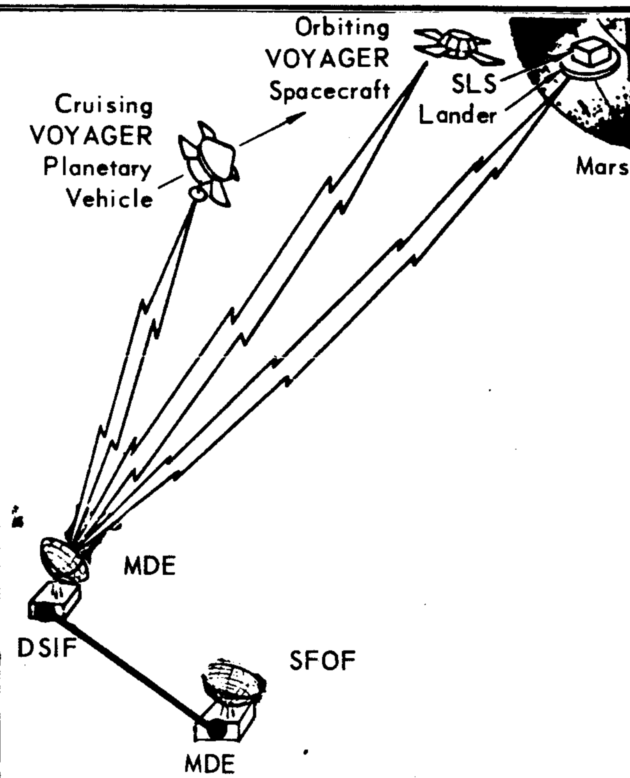
TEST PHASE	PHASE IV LAUNCH CONTROL & MONITOR	MISSION
Using Area	LAUNCH PAD 39  	
OSE Utilization	STC • ESP/CB Systems Verification • Joint Flight Acceptance Composite Tests • Countdown Demonstration • Launch Countdown LCE • Launch Conditioning • Launch Control and monitor MDE • DSIF Compatibility (DSIF-71) • Decomm ESP/CB TM System Test Complex	MDE • Display ESP/CB Analysis Data at SFOF • Decom ESP/CB TM Data in DSIF • Provide Software for DSIF TCP • Preprocess ESP TM Data

Figure 3.1-4

f. Miscellaneous Test Complex Equipment - Timing and distribution, intercomm and complex cabling required to complete the STC complement.

In operation, subsystem test engineers at the System Test Console select automatic test sequences or manual operations on the CRT keyboard. Response data is displayed on a Cathode Ray Tube (or an equivalent display, compatible with the CB contractor's approach) that can display up to 32 lines of parameters or computer outputted information in engineering units or English language. An out-of-limits condition is indicated by a blinking of the affected parameters displayed on the CRT or an equivalent visual indicator, plus a readout of the results of the OSE self-check.

For critical parameters, an audio-visual alarm is also activated. Test operations are enabled by the Capsule Bus test conductor. The high speed line printer at the CB test conductor's console provides a permanent record of all test data required for flight acceptance. The ESP System Test Console is designed to interface with the Computer Data System (CDS) of the responsible contractor's System Test Complex (CB or SLS contractor). Time sharing of the CB or SLS CDS is a feasible way of reducing equipment quantity and is consistent with integration responsibility and the relatively small additional computer load that the ESP system test will generate.

At the ESP contractor's factory, system level test requirements do not justify a duplicate of the Computer Data System used at the SLS or CB contractor's; therefore the STC at the ESP contractor's utilizes the subsystem test sets and semi-automatic operation.

3.2.2 Launch Complex Equipment (LCE) - Launch Complex Equipment (LCE) provides the capability to condition the installed ESP for launch, to control and monitor critical functions on the launch pad, to fault isolate to the OSE or ESP level, and to conduct system assurance and prelaunch checkout on the launch pad. LCE is used at the launch pad, the Explosive Safe Facility (ESF), and the Launch Control Center (LCC). The LCE makes use of selected STC to minimize duplication. LCE consists of the following equipment:

a. Ground Power and Distribution - This equipment provides automatic switching to facility backup power, emergency backup power in case of total facility power failure, and dc power to the ESP. The equipment is located in the base of the Mobile Launcher (ML) and at the ESF.

b. Remote Stimulation Equipment - One cabinet of test signal generation equipment used to provide stimuli for on-pad testing of the ESP. The equipment is located on the Mobile Launcher.

c. UHF Receiving System - A frequency diversity UHF receiver set mounted on the ML that detects the ESP UHF transmitter output (brought out the S/C flyaway umbilical from a parasitic antenna in the canister) and transmitted to the ESP System Test Complex. Spectrum and power-output measurements are made from two cabinets of equipment in the Mobile Launcher base.

d. ESP Launch Monitor Panel - Installed in the CB Launch Monitor console located in the LCC, and has direct hardline access to the ESP through the spacecraft umbilical. CB and SLS subsystem status sent from the STC is also displayed on the console.

e. LCE Required System Test Complex (STC) Equipment - Selected elements of the STC, including the CB or SLS Computer Data System and ESP Mission Dependent Equipment required for on-pad testing of the ESP. Test point access to the TCM is via the Spacecraft flyaway umbilical.

Operation of the LCE is from the ESF and the STC during CB pyrotechnic checkout and sterilization. Control shifts to the CB Launch Monitor Console in the LCC during launch pad operations. The STC Computer Data System provides automatic alarm monitoring, but approximately 10 critical parameters are hardlined to hard-wired logic and displays in the LCC to provide maximum reliability for control of unsafe or potentially catastrophic conditions.

Data Link Utilization - The utilization and allocation of data links is a significant problem associated with VOYAGER System integration. A digital data link, the Ground Data Transmission System (GDTS), is employed between the ESP and the STC during system testing at the Spacecraft Checkout Facility, the ESF, and the launch pad. The GDTS uses the A2A land line system plus unique multiplexing, coding and encoding terminals. (Sharing of the CB contractor's data link is described in Volume II, Part D, Section 10.) The link differs at the launch pad in that OSE umbilical test data is no longer available, and all the data used by the ESP and LCE is routed through the Spacecraft flyaway umbilical to a junction box on the ML. At the junction box on the Mobile Launcher, ESP data (interleaved with CB data) is split into two separate data trains.

a. The ESP/CB interleaved UHF and SLS landed TM is transmitted by A2A landline to the ESP Mission Dependent Equipment. The ESP data is de-interleaved and routed to the Capsule Bus CDS and ESP system console. An alternate RF data path is also provided, using parasitic antennas to radiate to the TCP computer in the DSIF.

b. The ESP critical functions are analog hardlined to the ESP LCE at the Launch Control Center. ESP data link utilization at KSC is illustrated in Figure 3.2-1.

3.2.3 Mission Dependent Equipment (MDE) - The ESP MDE consists of ESP equipment and computer software required to support telemetry processing and provide data interface compatibility in the Deep Space Instrumentation Facility (DSIF) and the Space Flight Operations Facility (SFOF) at Pasadena. The major elements of MDE are summarized below, and their interfaces with the DSIF and SFOF are illustrated in Figure 3.2-2.

a. Data Demultiplexing Equipment - used at the Deep Space Instrumentation Facilities (DSIF's) to process the CB/ESP telemetry data from the S/C Mission Dependent Equipment to a level compatible with the capabilities of the existing DSIF Telemetry and Command Processor (TCP) computer.

b. Command Equipment - used at the DSIF's to encode and verify commands sent from the TCP computer for transmission over the DSIF Spacecraft command link.

c. TV Processing Equipment - used at the DSIF's to synchronize and format TV data for magnetic tape recording and for TV data transmission to the SFOF via the DSN communication links.

d. Engineering Display Equipment - used at the DSIF's and the Space Flight Operations Facility (SFOF) for display of ESP TM data required for analysis of subsystems status.

e. Telemetry Command Processor (TCP) Software - used to program the TCP computer for decommutation of the TM data from the TM preprocessor. This software also programs the computer for acceptance and verification of commands sent from the SFOF, and addresses the commands to the ESP Command Equipment.

f. TCM Simulator - used at the DSIF's (in conjunction with the Capsule Bus simulator) to simulate the ESP TM and command system during pre-mission compatibility testing of the entire DSN.

The MDE design approach is significantly influenced by the capability of the existing TCP computers (SDS 920) in the DSIF. The Data Demultiplexer reduces the load on these computers by demultiplexing and de-interleaving the real time and delayed time ESP data.

3.2.4 Subsystem Level Test Equipment - ESP subsystem level test equipment consists of approximately 6 test sets that provide detail test capability for each of the ESP subsystems, on any individual element of the subsystem. Flight subsystems

OSE DATA LINKS AT KENNEDY SPACE CENTER

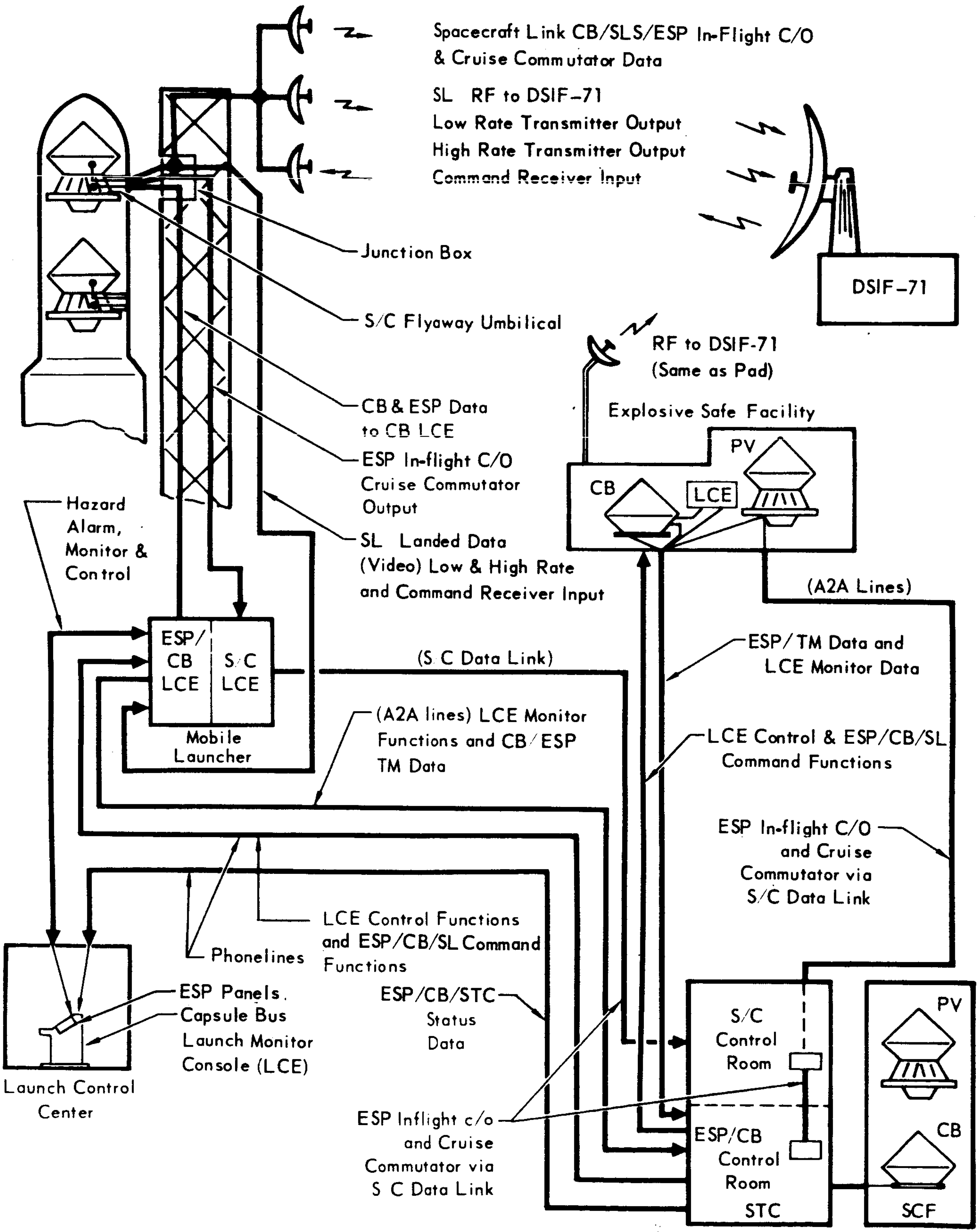
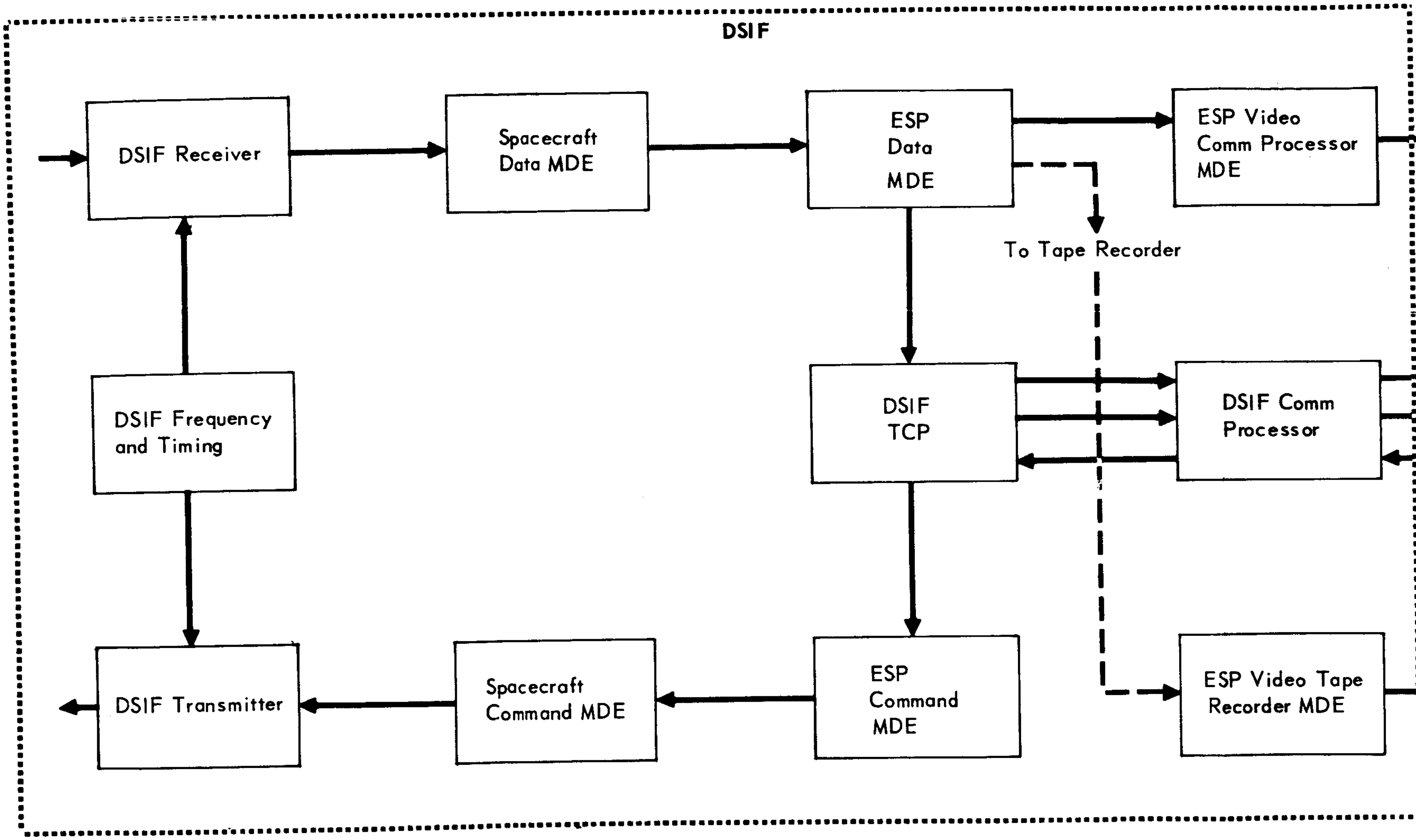


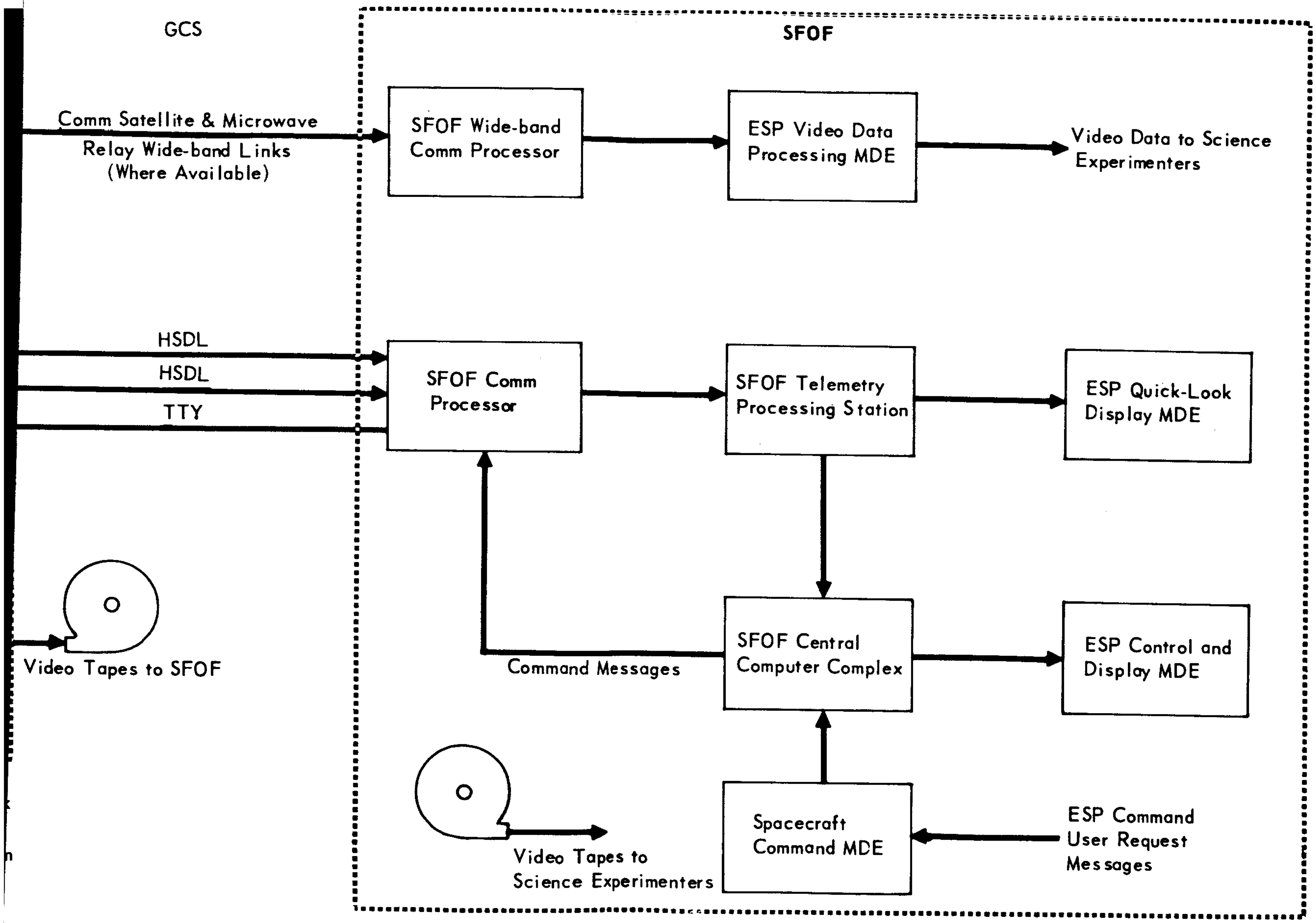
Figure 3.2-1

BLOCK DIAGRAM, ESP DATA FLOW



Note: HSDL – High Speed Data Link
TTY – Teletype Link
GCS – Ground Comm. System

Figure 3.2-2


GCS
SFOF
Comm Satellite & Microwave
Relay Wide-band Links
(Where Available)
SFOF Wide-band
Comm Processor
ESP Video Data
Processing MDE
Video Data to Science
Experimenters
HSDL
HSDL
TTY
SFOF Comm
Processor
SFOF Telemetry
Processing Station
ESP Quick-Look
Display MDE
Video Tapes to SFOF
Command Messages
SFOF Central
Computer Complex
ESP Control and
Display MDE
Spacecraft
Command MDE
ESP Command
User Request
Messages
Video Tapes to
Science Experimenters

functions are grouped to minimize duplication of equipment and to provide the maximum utilization of common designs. For a given subsystem, the same test set can be used for equipment functional check (EFC), subsystem level tests, and subsystem test at the system level, in conjunction with the STC. Further, the same design may be used at those vendors furnishing a complete subsystem. The SSTE groups and the flight systems which they support are listed below:

SSTE Functional Group	Flight Subsystem
Science	Science
Power	Power
Telecommunications	Antenna, Command, Data Storage, Radio, Telemetry
Thermal Control	Thermal Control

For maximum accuracy and simplicity, analog hardlines are used to connect the ESP and its modules to the subsystem test sets. To minimize human error and retain the inherent accuracy of the analog data, extensive use is made of digital displays. The test sets provide stimuli, display, recording, time, loads and alarm monitoring for the subsystem under test. Marginal performance testing is accomplished by programmed variation of the stimuli. Significant analogs or events are recorded on oscillographic recorders.

As subsystems are integrated into the Entry Science Package, subsystem test sets will be used to verify operational compatibility. System Test Complex (STC) equipment will be used with the subsystem test sets during final system test.

On receipt of the assembled ESP at the integration site (CB or SLS Contractor), an equipment functional check (EFC) will be performed, using the SSTE. Thus, test data continuity is established and proper subsystem operation is verified prior to installation of the ESP into the CB. During subsequent testing, direct accessibility by the ESP subsystem test connectors will be restricted as the ESP, CB, and SLS are installed in the Adaptor and Aft Canister. During environmental tests, however, subsystem test sets may be used for monitoring subsystems operation and fault isolation if required.

One complete set of subsystem test sets for the ESP will be located at KSC in the event subsystem -level testing is required for contingencies or fault isolation. The automation concept for subsystem test sets was established after evaluation of manual operation, selective automation, and total automation. Selective automation of Telemetry and Science Subsystems was chosen on the basis of cost effectiveness and inherent compatibility with the high speed, repetitive nature of the flight systems testing. The automated subsystem test sets also contribute significantly to test confidence and the quality of the test history, both of which are important factors in mission success.

3.2.5 Spacecraft-Mounted Entry Science Package Support Equipment OSE (SCME) - Complete subsystem-level test capability for the ESP subsystems that are physically located in the spacecraft is provided by the ESP/SC-Mounted TCM Subsystems test set. The test set consists of six standard cabinets of test equipment that provide stimuli, power, loads, test sequencing control and monitoring for the Antenna, Data Storage and Radio Subsystems.

The test set is used for qualification and compatibility testing on individual units and for subsystems-level tests during systems integration. One set of test equipment is supplied to the spacecraft contractor for use in integration and an additional set is installed at KSC in the event of contingencies.

The test set may be controlled manually or automatically and has provisions for interfacing with the Telemetry and Command Processor (TCP) and the Computer Data System (CDS) in the Systems Test Complex.

3.2.6 Assembly, Handling, Shipping, and Servicing Equipment (AHSE) - No special equipment will be required to assemble, handle, transport, or service the ESP or its components. Shipping requirements (including mechanical and environmental protection) will be met by standard packaging techniques and procedures. Alignment of the installed TV imager at the CB contractor's plant will be accomplished with standard optical tooling (factory equipment). For a final functional and alignment check of the TV imager when installed in the Capsule Bus, a TV Camera Alignment Target Assembly will be supplied.

3.3 OSE EQUIPMENT SUMMARY - A summary of the most significant ESP OSE hardware and using sites is illustrated in Figure 3.3-1. A detailed summary of OSE hardware requirements and using areas is contained in Section 9.0.

ESP OSE EQUIPMENT SUMMARY

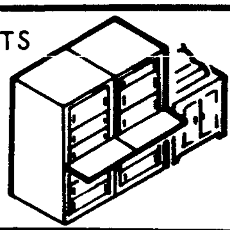
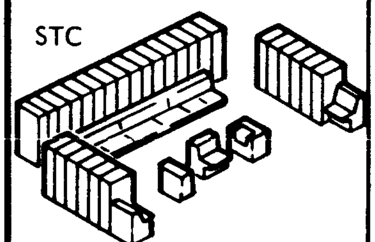
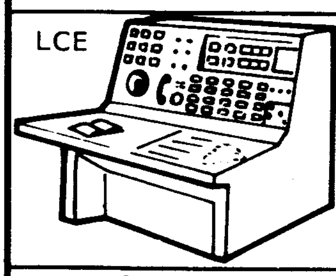
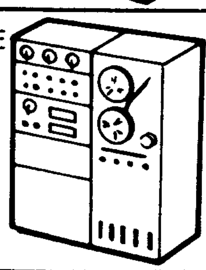
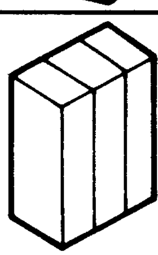
OSE	CB CONTRACTOR'S FACTORY	KSC	DSN
SSTS 	Entry Science Package Subsystem Test Sets	Entry Science Package Subsystem Test Sets	
STC 	ESP Command and Display Console Timing, Intercom and CCTV TCM Equipment TCP Computer CDS Computer (CB/ESP) Ground Data Transmission System Simulators Computer Software	ESP Command and Display Console Timing, Intercom and CCTV TCM Equipment TCP Computer CDS Computer (CB/ESP) Ground Data Transmission System Computer Software	
LCE 	Power Control and Distribution Stimuli and RF Monitor Equipment	Power Control and Distribution Stimuli and RF Monitor Equipment Launch Monitor Panel	
MDE 	TM Pre-processor Equipment Command Verification Equipment Computer Software	TM Pre-processor Equipment Command Verification Equipment Computer Software	Computer Software TCM Pre-processor Equipment Command Verification Equipment SFOF Display Console ESP TCM/Simulator
SCME 	ESP Relay Link Test Equipment (at S/ Contractor Factory)	ESP Relay Link Test Equipment	

Figure 3.3-1

SECTION 4

SYSTEM LEVEL SUPPORT EQUIPMENT

4.1 SUMMARY - System level tests start at integration of the ESP flight subsystems, and end at LV lift-off. System level Support Equipment required for these tests is used at the ESP contractor's plant, the CB contractor's plant, and at KSC. The configuration of these equipments is determined largely by the tests required at these locations, the accessibility of ESP test points, and system level simulation required. Portions of these equipments are used in the Deep Space Network (DSN), and continue in use through mission completion. They control the ESP and interpret data before and after landing on Mars. Hence, System Level Support Equipment will be a significant factor in the success of the mission.

4.2 IDENTIFICATION AND USAGE OF SYSTEM SUPPORT EQUIPMENT - The basic system categories and their usage are described below.

a. System Test Complex (STC) - used to exercise and determine the quality of the integrated ESP subsystems, and identify faulty subsystems to the replaceable provisioned spare level.

b. Launch Complex Equipment (LCE) - used for pad testing to demonstrate the readiness of the ESP to perform the mission, identify faults to the support equipment or ESP, and provide power, safety controls and alarms.

c. Mission Dependent Equipment (MDE) - ESP peculiar equipment and associated software, used in the DSN to implement ESP control and interpretation of the ESP data from lift-off to mission termination. MDE also is used in the STC and LCE to implement testing and demonstrate ESP/MDE compatibility prior to DSN usage.

To delineate ESP requirements and interfaces, we have identified System Level ESP Operational Support Equipment as if a separate contractor is assembling and testing the ESP, and then ships it to the CB integration facility. Many of the ESP OSE requirements can be combined with the SLS or CB contractor when technical responsibility is assigned. We have provided an insight into the effect of CB/SLS arrangement and reduction in equipment requirements in an alternative integration concept described in Volume IV, Part J, Section 10.

4.2.1 Interface Definitions - The STC, LCE, and MDE have two major requirements in common which significantly influence their system interfaces:

a. ESP Command Generation - During flight, but before separation from the

Spacecraft (S/C), the ESP receives commands for in-flight chekcout and cruise monitoring through the S/C command subsystem. The commands are verified however in the ESP MDE at the DSIF's. This command link can also be used for ground systems testing at the launch-pad, at the ESF, and in the STC to partially satisfy the ESP LCE and STC test command requirements.

b. ESP TM Data Retrieval and Processing - Before ESP separation from the S/C and during descent to Mars, the ESP transmits checkout and flight data to the S/C TM subsystem. This data is eventually received in the S/C MDE and routed to the ESP MDE for processing. This data link can also be used during system testing to satisfy the LCE and STC test telemetry requirements.

These common requirements can be satisfied by the sharing of the same equipment. Hence, MDE designed for DSIF usage is also used in the ESP System Test Complex for command and TM data processing, and the STC and MDE are likewise used to accomplish LCE functions. This approach not only provides significant cost savings in design and equipment quantity, but allows early compatibility demonstration of the MDE and LCE with the ESP.

4.3 SYSTEM TEST COMPLEX (STC) - The ESP will be tested at the system level, at the ESP contractors plant, the CB contractor plant, and at KSC. The CB contractor will have a computer-controlled STC, and the selected approach is to integrate the ESP test functions with the CB contractor's STC for ESP system-level testing at the CB and KSC integrated test sites. System testing at the ESP contractor's plant will be accomplished by using Subsystem Test Sets (SSTS), augmented by MDE, and an exact duplicate of the DSIF TCP for TCM processing. The rationale leading to this approach is:

a. Test point accessibility is not limited at the ESP contractor's plant since integration does not occur here. Hence, the OSE test connectors, used by the SSTS for subsystems-level testing, will be fully accessible, and used as required along with data from the ESP UHF TM link, supplemented with hardline analogs brought out through the ESP/CB interface connector.

b. The CB contractor is required to have a computer-controlled STC. The ESP subsystems are fewer in number, and less sophisticated (with the exception of TM) than those in the CB. The additional load imposed by sharing the CB STC should not be excessive since the ESP telemetry load is preprocessed by the ESP Telemetry and Command Processor (TCP) computer.

Software for the CB STC computer includes modules for ESP system testing. The ESP contractor will supply test procedures and parameters to the CB contractor, who will establish the integrated test software requirements.

4.3.1 Requirements and Constraints - The ESP STC has the following requirements and constraints:

a. Acquiring, processing, distributing, and displaying of ESP, OSE and test facility data for real-time and non-real time analysis.
b. Providing capability to vary parameters, or externally supplied signals, for required performance testing.
c. Isolating trouble to the provisioned spare replacement level.
d. Centrally controlling or directing the ESP or any of its subsystems, individually or in combination, through a complete or selected portion of a system test by the use of a general purpose computer system. (CB contractor's and KSC sites).
e. Manually controlling the ESP or any combination of its subsystems, to any operating mode, and in any operating mode, and in any sequence, provided for by the normal ESP test circuitry.
f. Providing external power and simulating flight battery power. Providing battery charge capability to the ESP flight and test batteries.
g. Provide growth capability to accept the anticipated requirements of an ESP for the 1975 launch opportunity.
h. Providing safeguards to prevent the occurrence of damage to any ESP or any of the subsystems due to improper sequencing of test steps, or due to STC element malfunction or failure.

In addition, the sterilization requirements, and resulting canisterization at the CB contractor's plant and at KSC, imposes a test point inaccessibility constraint unique to the VOYAGER Program. We have provided the STC with access to the ESP for test command and data points by maximum utilization of flight TM and the in-flight checkout system, and by establishing the following requirements:

a. S/C Flyaway Umbilical - provide approximately ten (10) wires and one coax cable for ESP testing and monitoring. These will be available up to Space Vehicle lift-off.
b. CB Canister Umbilical - provide approximately fifty (50) wires through the sealed canister for ESP subsystem exercising. These will be used for ESP testing prior to installation of the PV shroud.

4.3.2 Equipment Identification List - The ESP System Test Complex equipment at the ESP contractor differs from that at the CB contractor and KSC, in accordance with Section 4.3.

4.3.2.1 ESP Contractor's STC - This configuration will contain:

- o Selected SSTS, accessing the ESP subsystem through the UHF TM link of the CB/ESP interface connector, and individual subsystem OSE connectors.
- o STC-required MDE - An exact duplicate of the MDE equipment used at the DSIF stations to decode the ESP down-link data, and generate the uplink commands that are required during the mission.
- o STC-required MIE - An exact duplication of the Telemetry and Command Processor, and software, used at the DSIF's.
- o Simulators - Interface simulation and control equipment required for testing and compatibility demonstration are provided in SSTS.
- o Special Purpose STC Equipment - Timing and distribution, CCTV, intercom, and complex cabling required to complete the STC complement.

4.3.2.2 STC at CB Contractor's Plant and KSC - This configuration will contain:

- o The CB contractor's STC
- o An ESP Command and Display Console - used for ESP control and parameter monitoring, which will have displays and digital command generation devices similar to those used in the CB STC and will interface with his STC computer. Critical ESP hardline analog displays and commands will also be available at this console.
- o Ground Data Transmission System (GDTS) - A two way, very low error probability system used to transmit TCM parameters between the STC and ESP and transmit other non-TCM ground test data and commands between the STC and remotely located OSE.
- o STC-required MDE, MIE, and simulators.

4.3.3 Physical Characteristics - Figures 4.3-1 and 4.3-2 show the proposed layouts of the STC configurations with the various equipment identified.

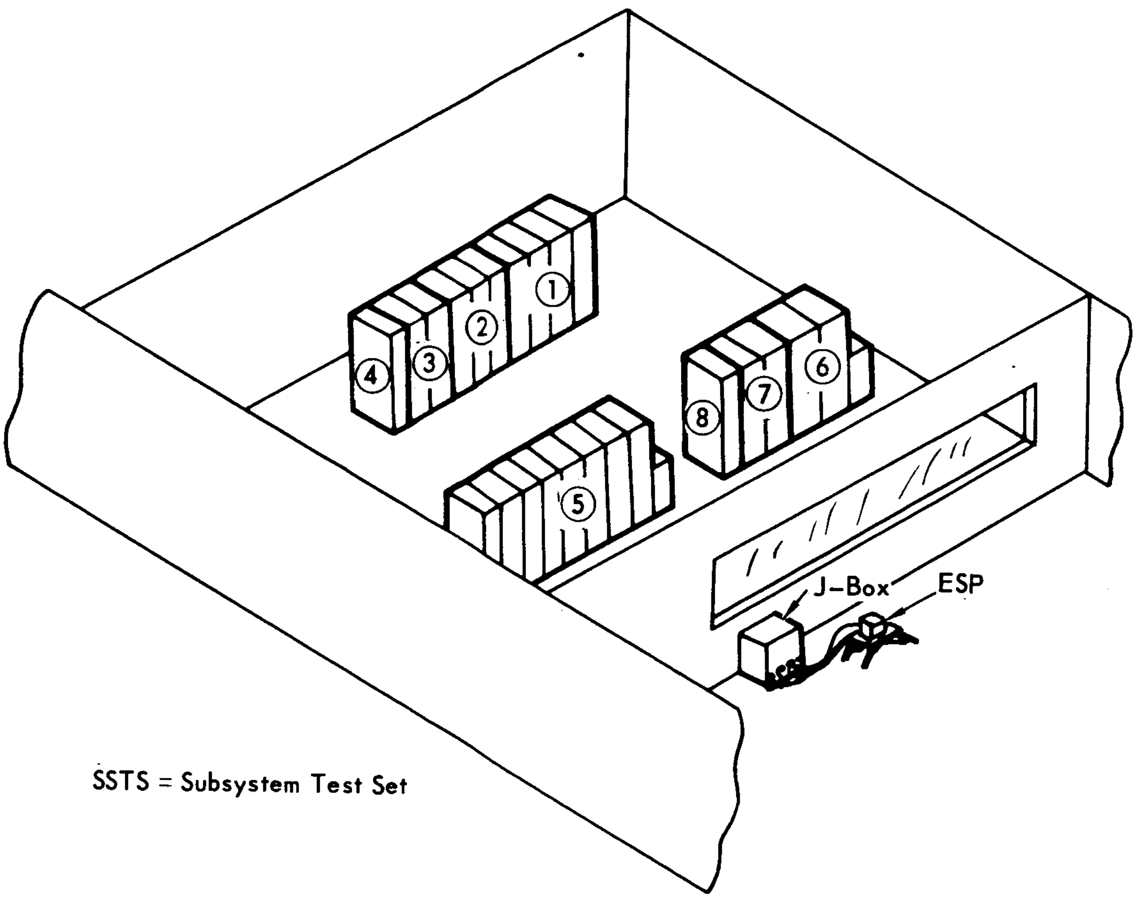
4.3.4 Operational Description - The two ESP STC configurations have these salient operational features:

4.3.4.1 ESP Contractors System Test Complex - (shown in block diagram on Figure 4.3-3)

- o Automatic alarm and monitoring for immediate execution of safety sequences for critical ESP or emergency conditions.

ESP SYSTEM TEST COMPLEX
FACTORY

ITEM	TITLE
1	TCP Computer
2	TCP Computer Peripheral Equipment
3	MDE Set
4	TCP/SSTS Interface Unit
5	Telecommunications SSTS
6	Science SSTS
7	Power SSTS
8	Thermal SSTS



SSTS = Subsystem Test Set

Figure 4.3-1

ESP SYSTEM TEST COMPLEX EQUIPMENT
(AT CAPSULE BUS CONTRACTOR'S PLANT)

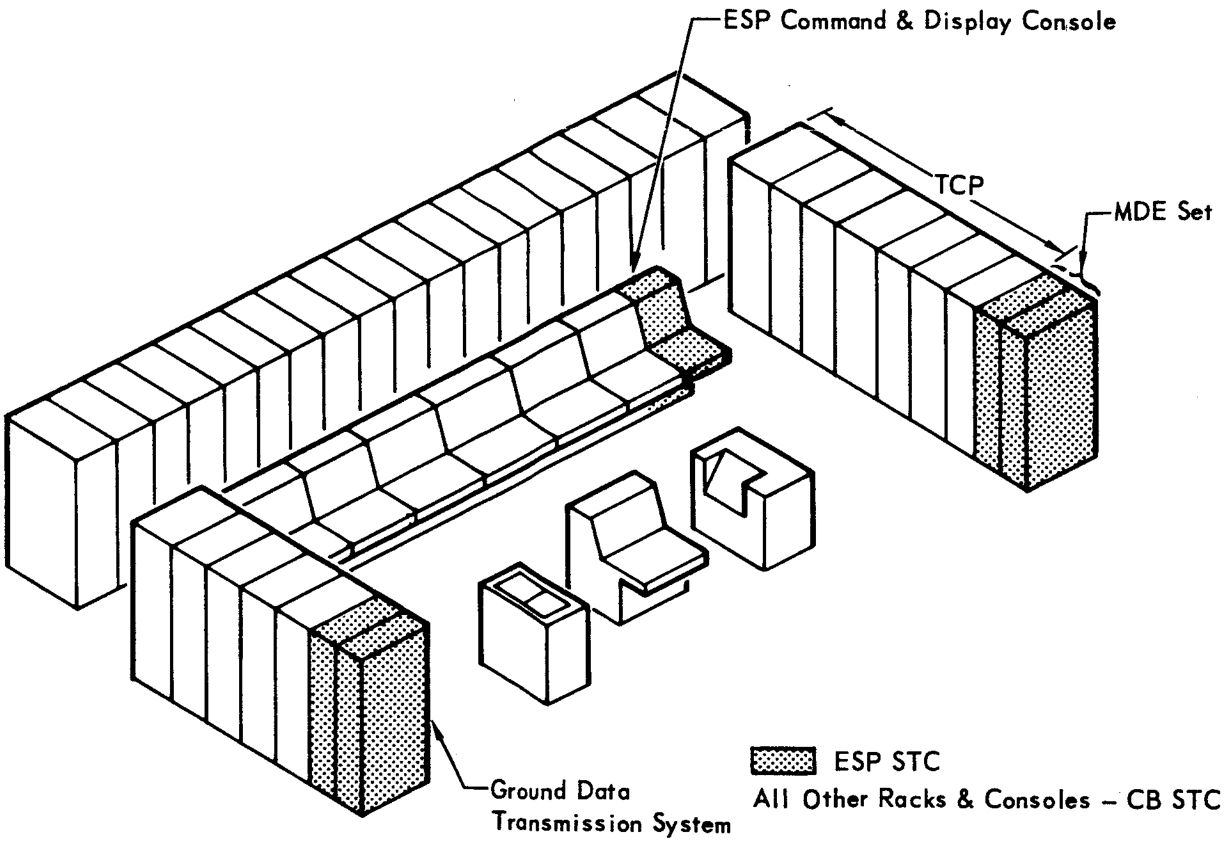


Figure 4.3–2

ENTRY SCIENCE PACKAGE SYSTEMS TEST COMPLEX (STC)
(AT ESP CONTRACTOR FACILITY)

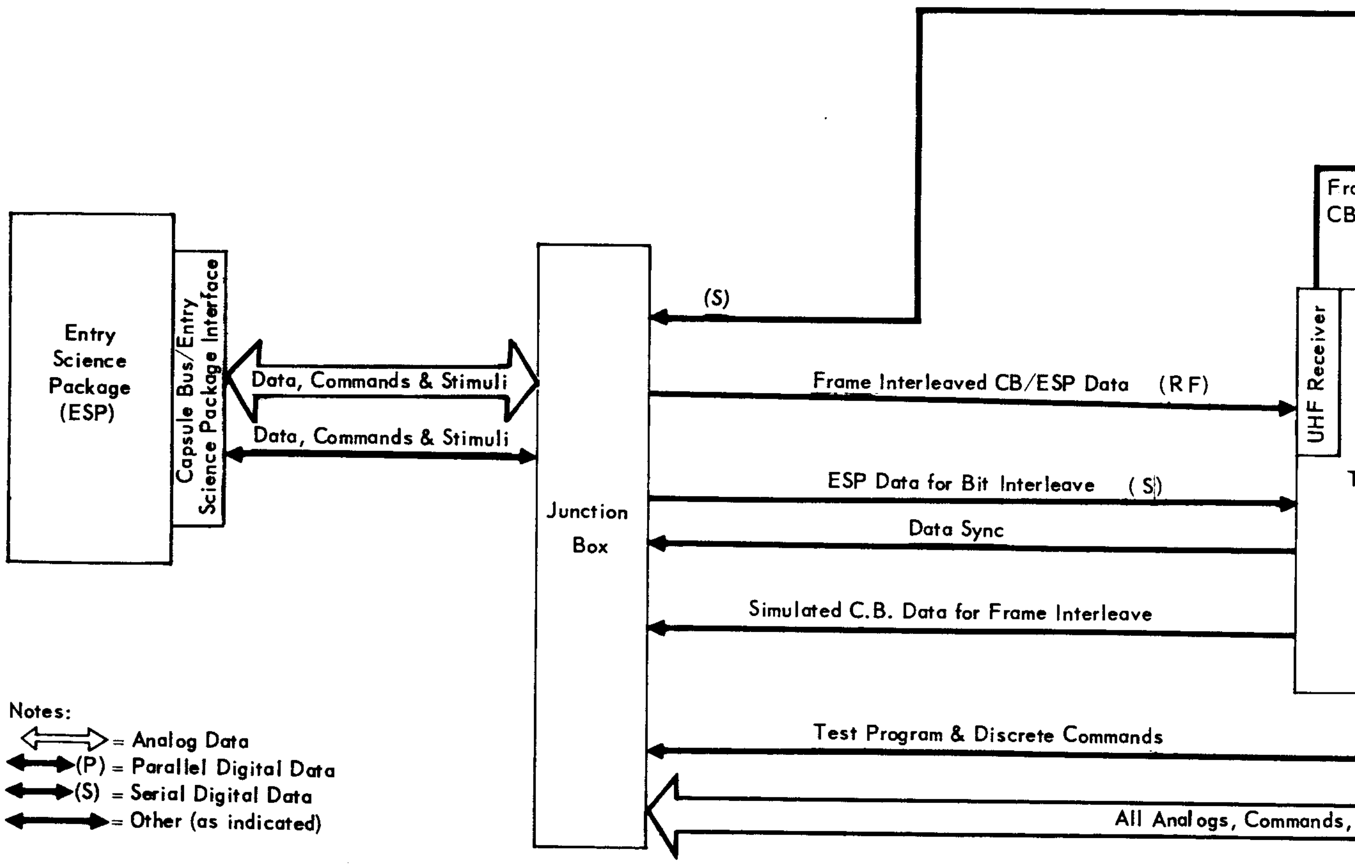
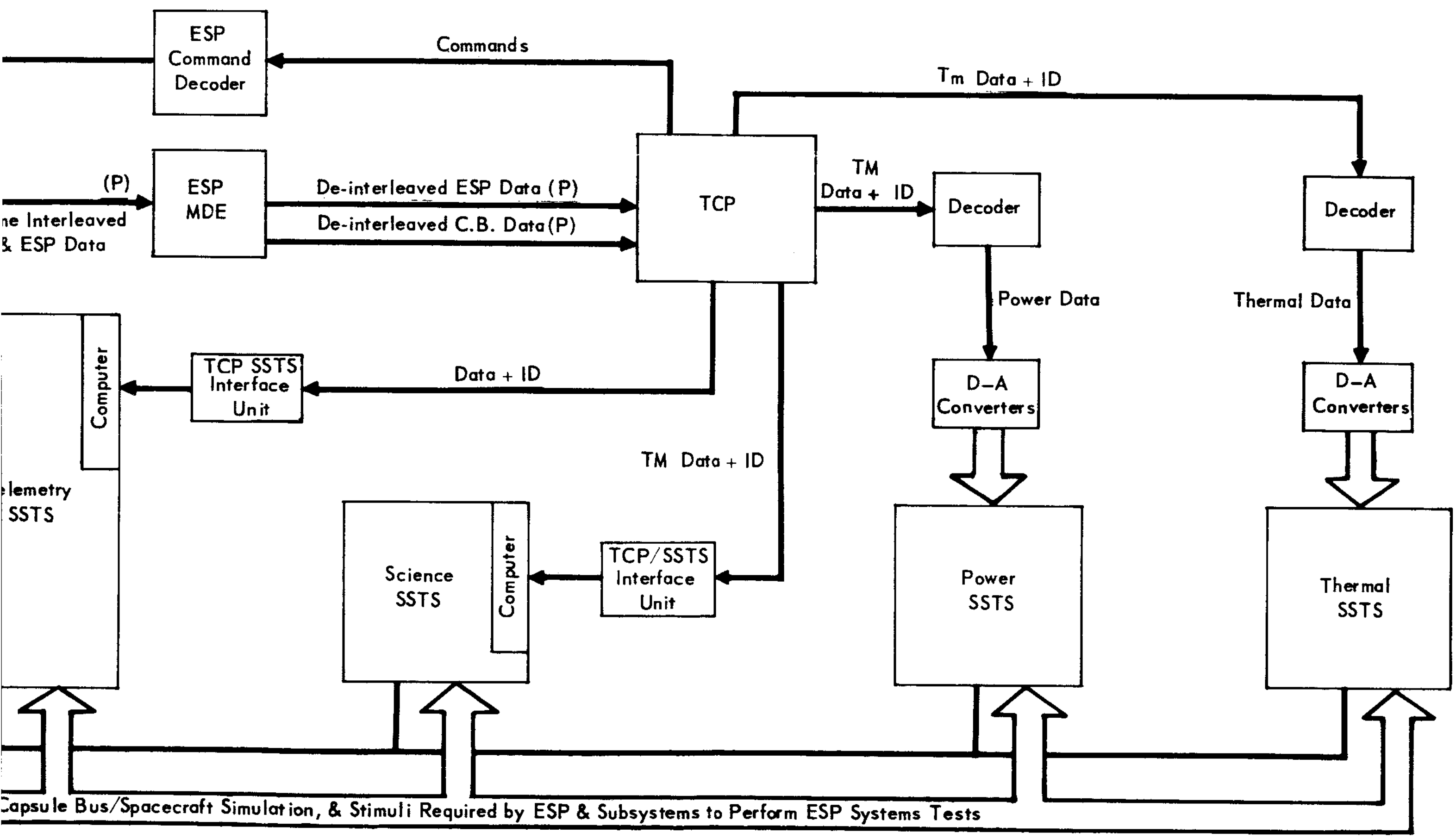


Figure 4.3-3


ESP Command Decoder
Commands
Tm Data + ID
(P)
ESP MDE
ne Interleaved
& ESP Data
De-interleaved ESP Data (P)
De-interleaved C.B. Data(P)
TCP
TM Data + ID
Decoder
Decoder
Power Data
Thermal Data
Computer
TCP SSTS Interface Unit
Data + ID
D–A Converters
D–A Converters
lemetry SSTS
TM Data + ID
Science SSTS
Computer
TCP/SSTS Interface Unit
Power SSTS
Thermal SSTS
Capsule Bus/Spacecraft Simulation, & Stimuli Required by ESP & Subsystems to Perform ESP Systems Tests

- o Use of MDE and the Mission Independent Telemetry and Command Processor (TCP) for TM processing.
- o Demodulation and decommutation of the ESP-to-S/C UHF Data Link, independent of the S/C S-band transmission link.

4.3.4.2 CB Contractor and KSC System Test Complex - (shown in block diagram on Figure 4.3-4).

- o Closed-loop computer controlled test sequence control (by test routine blocks) for CB and ESP automatic testing.
- o Manual test sequence control by the use of key-board access to the computer from each subsystem console and the Test Director's Console.
- o AN/CRT displays for maximum flexibility.
- o Suppressed data print-out, using fixed and floating aperture techniques.
- o Automatic limits comparison of all data.
- o Priority interrupt techniques for immediate execution of safety sequences for critical CB and ESP, or other emergency conditions.
- o Use of MDE, and the Mission Independent Telemetry and Command Processor (TCP).
- o Demodulation and decommutation of the ESP-to-S/C UHF data link independent of the S/C S-band transmission link.

The automatic features are provided largely by the CB computer-controlled STC.

4.3.5 Interface Definition - Figure 4.3-5 shows the interface at the ESP contractor's plant of the STC with the MDE and TCP computer. Figure 4.3-6 illustrates the interface of the ESP contractor supplied Command and Display Console, MDE and TCP, with the Capsule Bus contractor's STC.

4.3.6 Reliability and Safety - Section 4.4 will show usage of STC to implement a large portion of the LCE requirements. Those STC elements used in the launch phase must meet the reliability requirements of Section 4.4.4.

4.3.7 Development Status - Equipment used in the STC configurations will require minimum development. The significant development visualized is ESP software for the computer used in the CB Computer Data System (CDS), which controls the CB and ESP. The risk can be minimized in this area by separating the software program into two areas:

a. (Support Software) - Limits comparison, engineering units conversion, and data suppression.

b. (Operational Software) - Automatic test sequence control and test program routines - The development and packaging of test software is described in

ENTRY SCIENCE PACKAGE SYSTEMS TEST COMPLEX (STC)

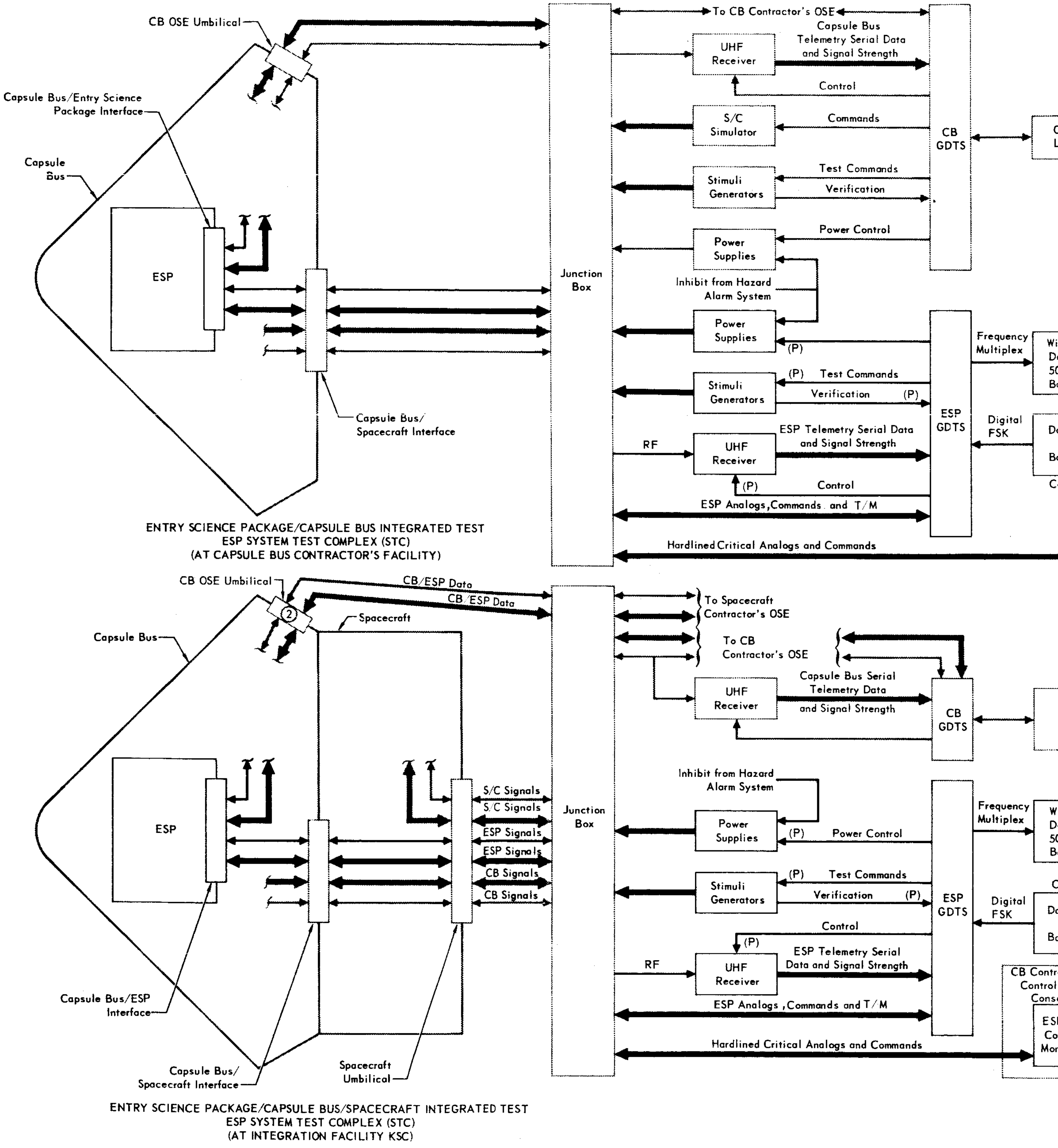
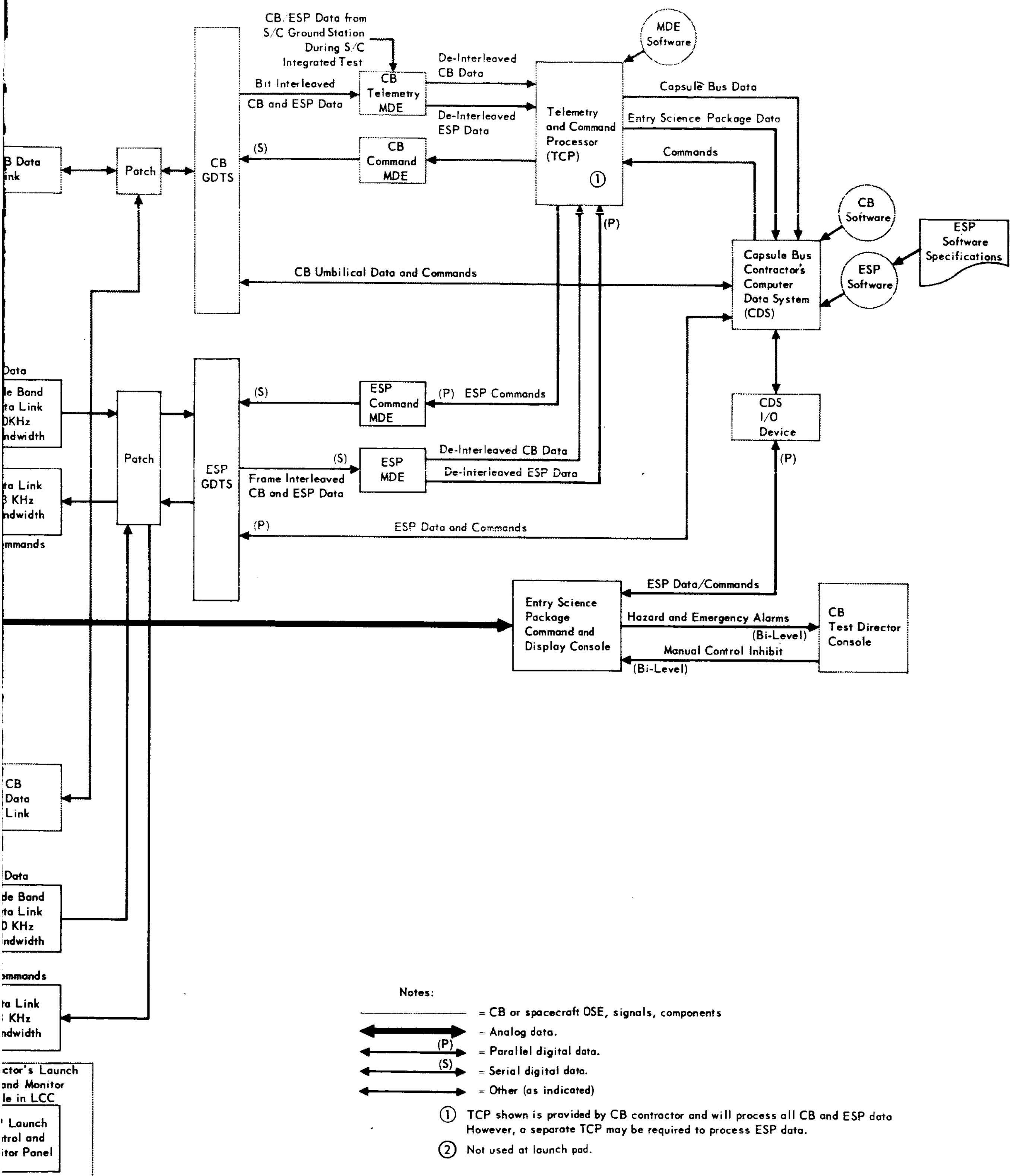


Figure 4.3–4


CB/ESP Data from S/C Ground Station During S/C Integrated Test
MDE Software
De-Interleaved CB Data
Bit Interleaved
CB and ESP Data
CB Telemetry MDE
Capsule Bus Data
De-Interleaved ESP Data
Telemetry and Command Processor (TCP) ①
Entry Science Package Data
B Data
ink
Patch
CB GDTS
(S)
CB Command MDE
Commands
(P)
CB Software
ESP Software Specifications
Capsule Bus Contractor's Computer Data System (CDS)
ESP Software
CB Umbilical Data and Commands
Data
le Band
ta Link
0KHz
ndwidth
(S)
ESP Command MDE
(P) ESP Commands
CDS I/O Device
Patch
ESP GDTS
(S)
ESP MDE
De-Interleaved CB Data
De-interleaved ESP Data
Frame Interleaved CB and ESP Data
(P)
ta Link
3 KHz
ndwidth
mmands
(P)
ESP Data and Commands
ESP Data/Commands
Entry Science Package Command and Display Console
Hazard and Emergency Alarms
(Bi-Level)
CB Test Director Console
Manual Control Inhibit
(Bi-Level)
CB Data Link
Data
de Band
ta Link
0 KHz
ndwidth
mmands
ta Link
KHz
ndwidth
ctor's Launch
and Monitor
le in LCC
' Launch
trol and
itor Panel
Notes:
= CB or spacecraft OSE, signals, components
= Analog data.
(P) = Parallel digital data.
(S) = Serial digital data.
= Other (as indicated)
① TCP shown is provided by CB contractor and will process all CB and ESP data However, a separate TCP may be required to process ESP data.
② Not used at launch pad.

ENTRY SCIENCE PACKAGE
STC/MDE/TCP INTERFACES
(AT ESP CONTRACTOR'S FACILITY)

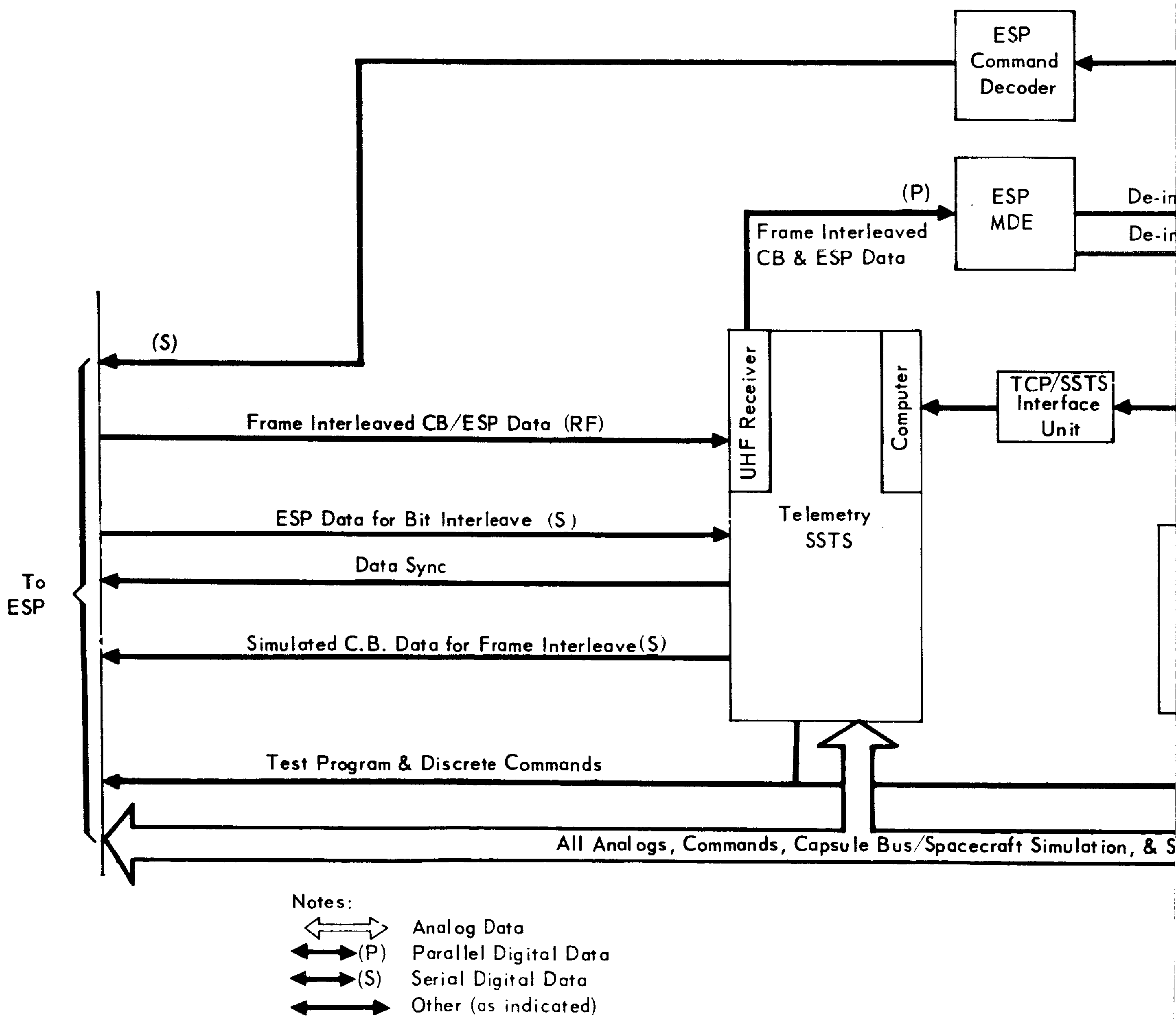
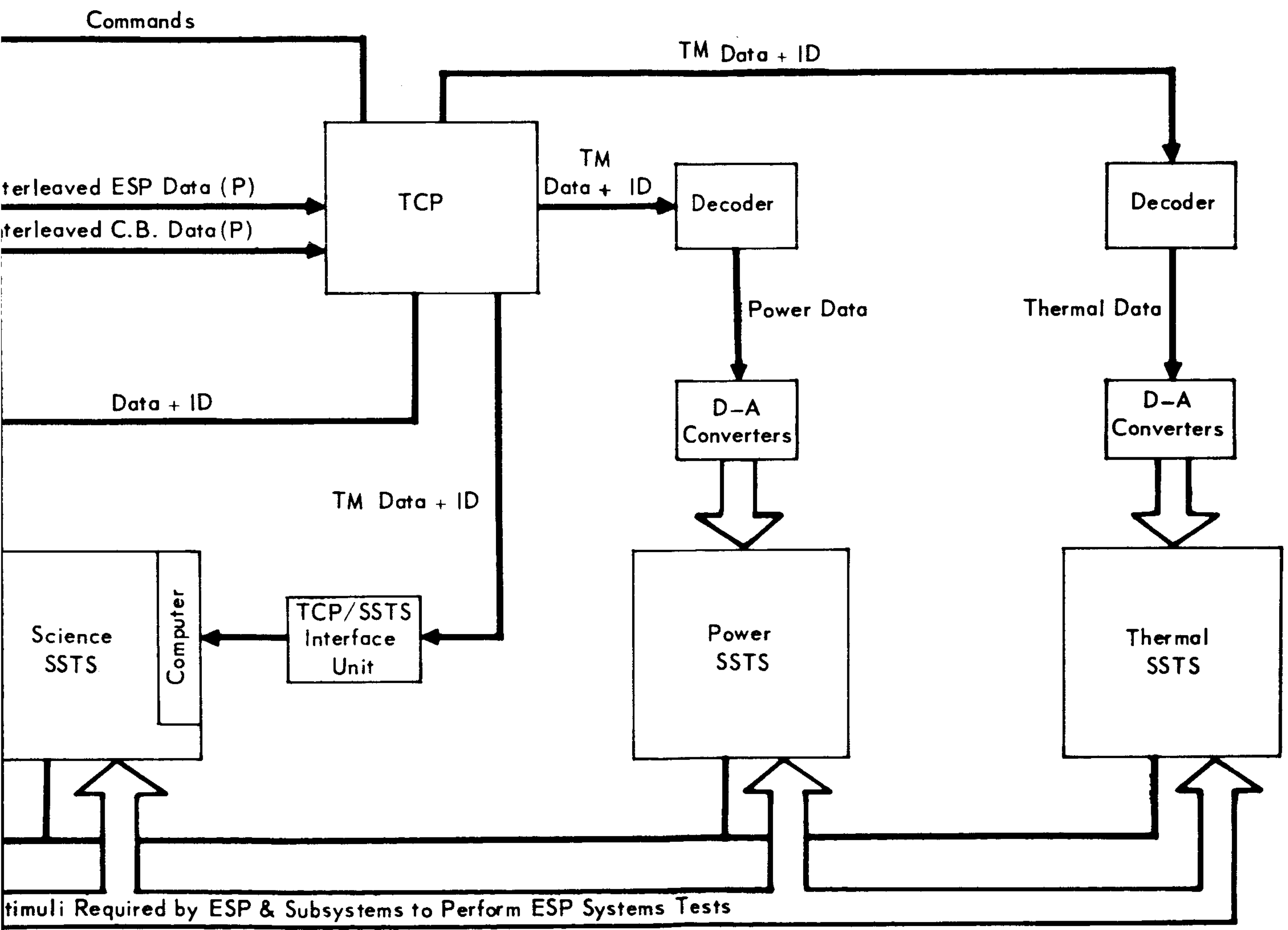


Figure 4.3-5


Commands
TM Data + ID
terleaved ESP Data (P)
terleaved C.B. Data (P)
TCP
TM
Data + ID
Decoder
Decoder
Power Data
Thermal Data
Data + ID
D-A
Converters
D-A
Converters
TM Data + ID
Science
SSTS
Computer
TCP/SSTS
Interface
Unit
Power
SSTS
Thermal
SSTS
timuli Required by ESP & Subsystems to Perform ESP Systems Tests

ESP STC/MDE/TCP INTERFACES WITH CB CONTRACTORS STC

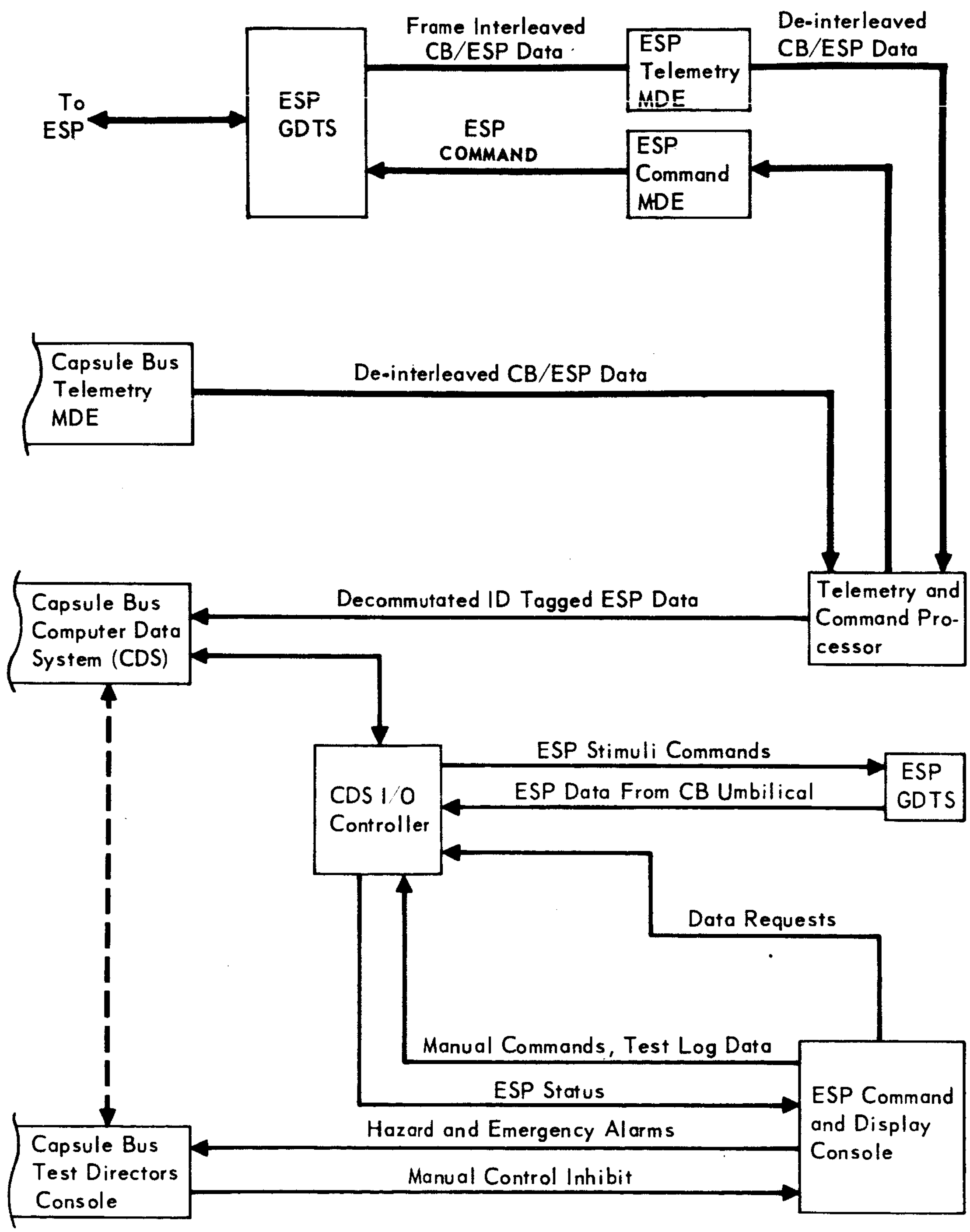


Figure 4.3–6

detail in Part J, Section 8.0 of this volume.

4.3.8 Growth Capability - The SSTS used at the ESP contractor's plant for STC equipment provides growth capability to meet the test requirements of a more sophisticated mission at the 1975 launch opportunity.

4.3.9 Equipment Functional Description - The equipment groups identified above are functionally described in detail as follows:

4.3.9.1 ESP System Test Complex of ESP Contractor's Facility - The ESP System Test Complex at the ESP contractors facility consists of the ESP Subsystem Test Sets, Mission Dependent Equipment, Mission Independent Equipment, Simulators, and special purpose system test complex equipment required to perform complete ESP systems tests. These tests verify the operational readiness of the ESP prior to shipment, (Pre-delivery Acceptance) to the Capsule Bus contractor's facility for integration with the Capsule Bus.

Functional descriptions of the ESP System Test Complex elements required at the ESP contractor's facility are as follows:

4.3.9.1.1 STC Required Test Equipment - System testing at the ESP contractor's plant is conducted using the same SSTS used during module and subsystem test. In the STC configuration, the Power, Thermal, Science and Telemetry SSTS are interconnected with the ESP TCP and MDE. Differences in data signal characteristics require the insertion of decoders and digital-to-analog converters between the TCP and the Power and Thermal SSTS and the use of interface units between the TCP and Telemetry and Science SSTS for digital format compatibility. Section 5.0 discusses SSTS functional characteristics. The STC block diagram in Figure 4.3-3 shows the functional relationships of the SSTS to the TCP and the ESP. The decoders, digital-to-analog (D/A) converters, and digital interface units are briefly described below.

- Decoder - The decoder performs ID word decoding to enable each D/A converter to recognize its input data from the TCP. The parallel ID bits are stored in the decoder on command from the TCP. The ID bits determine which D/A converter is to receive the data bits, and a transfer pulse is sent to read the data into that D/A converter.
- Digital to Analog (D/A) Converters - The D/A converters receive digital inputs from the TCP and decoder, and supply an analog output voltage which is compatible with the using SSTS. Each D/A converter contains a storage register. These registers accept TCP parallel digital information upon receipt of a transfer pulse from the decoder. In addition, the registers

provide digital storage until the next "update" from the TCP and decoder. A D/A converter is required for each analog signal used by the SSTS.

- Digital Interface Unit - The Digital Interface Unit provides format conversion to make the TCP parallel data and ID output compatible with the automatic processors in the Telecommunications and Science SSTS. The data and ID from the TCP are stored in a register on command from the TCP. The Unit then sends a data ready signal to the SSTS automatic processor and waits for an answering transfer request. When the request is received, the data and ID are transferred to the automatic processor at the correct bit rate, logic level, ID format, and word length.

4.3.9.1.2 Mission Independent Equipment (MIE) Required at ESP Factory STC - The Systems Test Complex (STC) required MIE is an exact duplicate of the Telemetry and Command Processor (TCP) computer and peripherals used at the Deep Space Instrumentation Facility (DSIF).

Telemetry and Command Processor (TCP) - The TCP is a high speed general purpose computer system that normally is used in the DSIF to provide flight commands and decommutated Entry Scinece Package (ESP) telemetry data. It also is used in the STC to support all systems tests.

- Physical Characteristics - The TCP presently consists of an SDS 920 Computer System, a magnetic tape recorder group, I/O typewriter, tape punch, and tape reader. Because the SDS 920 computer is a standard SDS product covered in the manufacturer's literature, physical and operational characteristics are not repeated here.
- Functional Description - The TCP translates ESP commands to the required format for ESP testing, and provide on-site data processing of telemetry signals (See Figure 4.3-7) for TCP functional block diagram). The TCP acquires the de-interleaved ESP telemetry signals from the telemetry MDE. An interrupt line is used to indicate the presence of data in an associated buffer. Data is read into memory through the parallel input. On program request, the data is transferred to a buffer area of memory where it is assembled into a word that includes a single character code associated with each individual data word. The decommutated, ID-tagged data is then ready for I/O transfer to peripheral equipment and the ESP system test complex (during ESP factory system tests).

All ESP commands input to the TCP are translated to the required formats, stored in memory, and output to the command MDE.

TELEMETRY AND COMMAND PROCESSOR (TCP) FUNCTIONAL BLOCK DIAGRAM AND INTERFACES (ESP FACTORY STC)

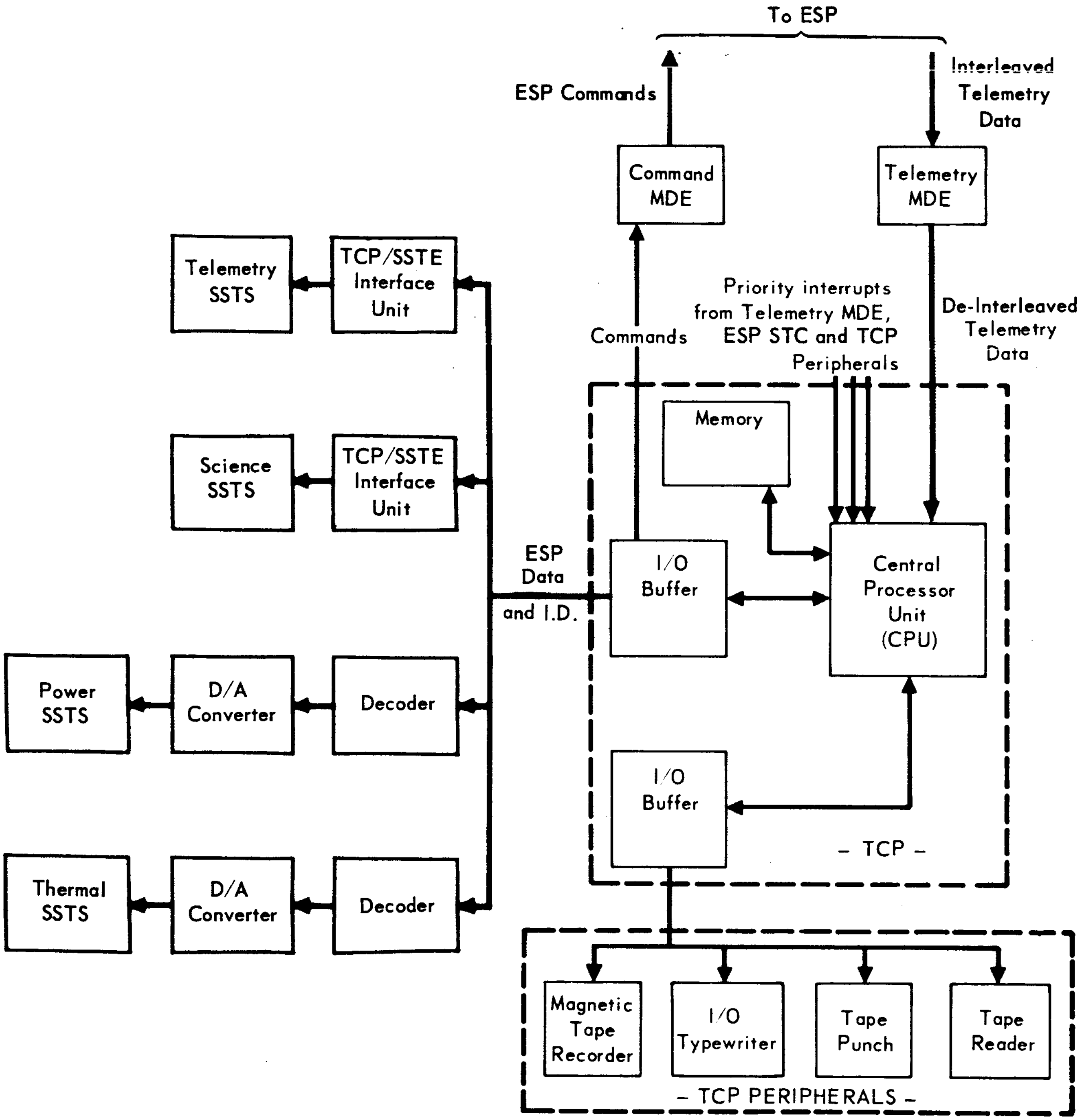


Figure 4.3–7

- o Interfaces - The TCP interfaces with the following components. (See Figure 4.3-7 for TCP interfaces).
  - (1) Telemetry MDE
  - (2) Command MDE
  - (3) ESP System Test Complex Subsystem Test Equipment during ESP factory system tests.
  - (4) TCP Peripherals

TCP Peripherals - The TCP peripherals include the following equipment:

- o Magnetic Tape Recorder - the recorder is used to store TCP-processed telemetry and command signals for playback and future use.
- o Tape Punch and Tape Reader - the punched tape equipment is used for assembling new programs, altering existing programs, and loading the TCP memory.
- o I/O typewriter - The I/O typewriter is used for operation control, error and status message reporting, and simulation of Space Flight Operations Facility/Site Communications Processor communications with the TCP.

TCP Software - The TCP software used in the STC is identical to that Mission Dependent Equipment software package developed for DSIF usage. The software will be developed early in Phase D, and will be used during the ESP telemetry and system testing at the ESP contractor's facility to ensure early compatibility between the ESP and DSIF. The MDE software package for TCP is described in Part J, Section 4.5.4 of this volume. Further details of software management, development, package, and test language are described in Part J, Section 8 of this volume.

4.3.9.1.3 Mission Dependent Equipment (MDE) Required at ESP Factory STC- The MDE required for Entry Science Package (ESP) system test at the ESP contractor's facility is an exact duplicate of the ESP MDE used at the Deep Space Instrumentation Facility (DSIF). The STC MDE processes ESP telemetry data and outputs it to the Telemetry and Command Processor during all ESP systems tests thereby ensuring early compatibility between the ESP and the MDE used at the DSIF's.

- o Physical Description - For a more detailed description of the MDE, see Part J, Section 4.5, of this volume.
- o Functional Description - The ESP MDE receives the frame-interleaved ESP/CB data from the ESP Telemetry Subsystem Test Set (SSTS). The ESP data is de-interleaved from the simulated Capsule Bus data. The de-interleaved data is then processed in the ESP Telemetry and Command Processor and

transferred to the ESP System Test Complex for display, evaluation, and recording as required.

- Interface Definition - The ESP System Test Complex-required MDE for usage at ESP contractor's facility interfaces with the Telemetry and Command Processor as shown in Figure 4.3-8.

4.3.9.1.4 Simulators

Equipment Identification and Usage - The Simulation of Capsule Bus (CB), Spacecraft, and Surface Lab (SL) electrical flight systems is provided by the ESP Subsystem Test Sets during ESP module buildup and systems testing. A CB thermal simulator is used for ESP factory environmental testing. The SL or CB contractors will require an ESP simulator that duplicates the interfacing ESP signals and loads for system testing prior to ESP availability. The simulators and their usage are:

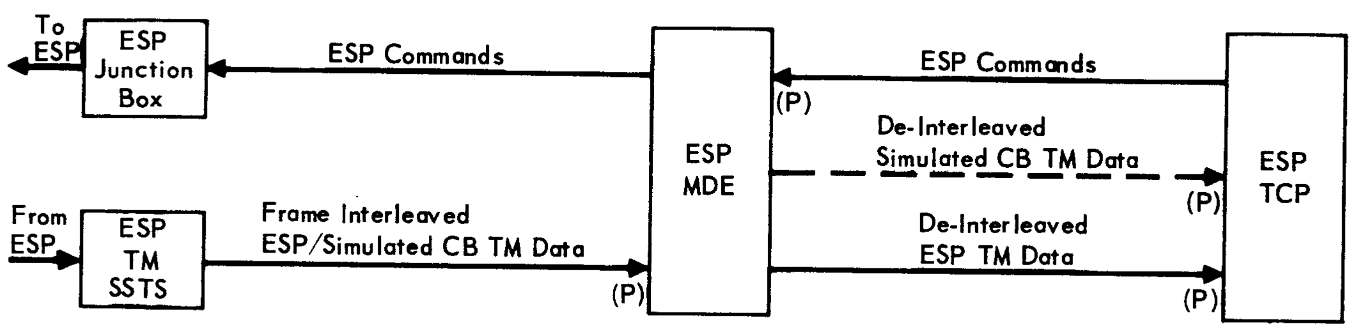
SIMULATOR	USAGE
o Capsule Bus Thermal/ Simulator (GFE)	ESP factory environmental testing
o ESP-to-CB (or SLS) Electrical Simulator	Required by Capsule Bus (or SLS) contractor; used in system tests
o ESP-to-CB (or SLS) Thermal/ Simulator	Required by Capsule Bus (or SLS) contractor for environmental testing

Physical Characteristics - The electrical simulators are installed in standard equipment cabinets and grouped by using location. Power and cooling for the simulators are integral to each cabinet.

Functional Description - Each simulator is described briefly according to its functions:

- Capsule Bus Thermal Simulator (GFE) - is used during thermal vacuum factory testing of the ESP. The simulator provides a thermal interface that represents the radiative and conductive heat transfer characteristic of the Capsule Bus to the ESP.
- ESP-to-Spacecraft Simulator - is furnished to the Spacecraft contractor to simulate ESP electrical functions prior to the Spacecraft-Flight Capsule integration at KSC. A functional block diagram of the simulator is shown in Figure 4.3-9. The simulator is connected to the Spacecraft through a Capsule Bus simulator, or a Spacecraft contractor-supplied junction box. The simulator provides loading and display for Spacecraft-to-ESP commands and Telecommunications Subsystem synchronization signals. Pulse Code Modulation (PCM) Data Simulator supplies ESP in-flight checkout data to

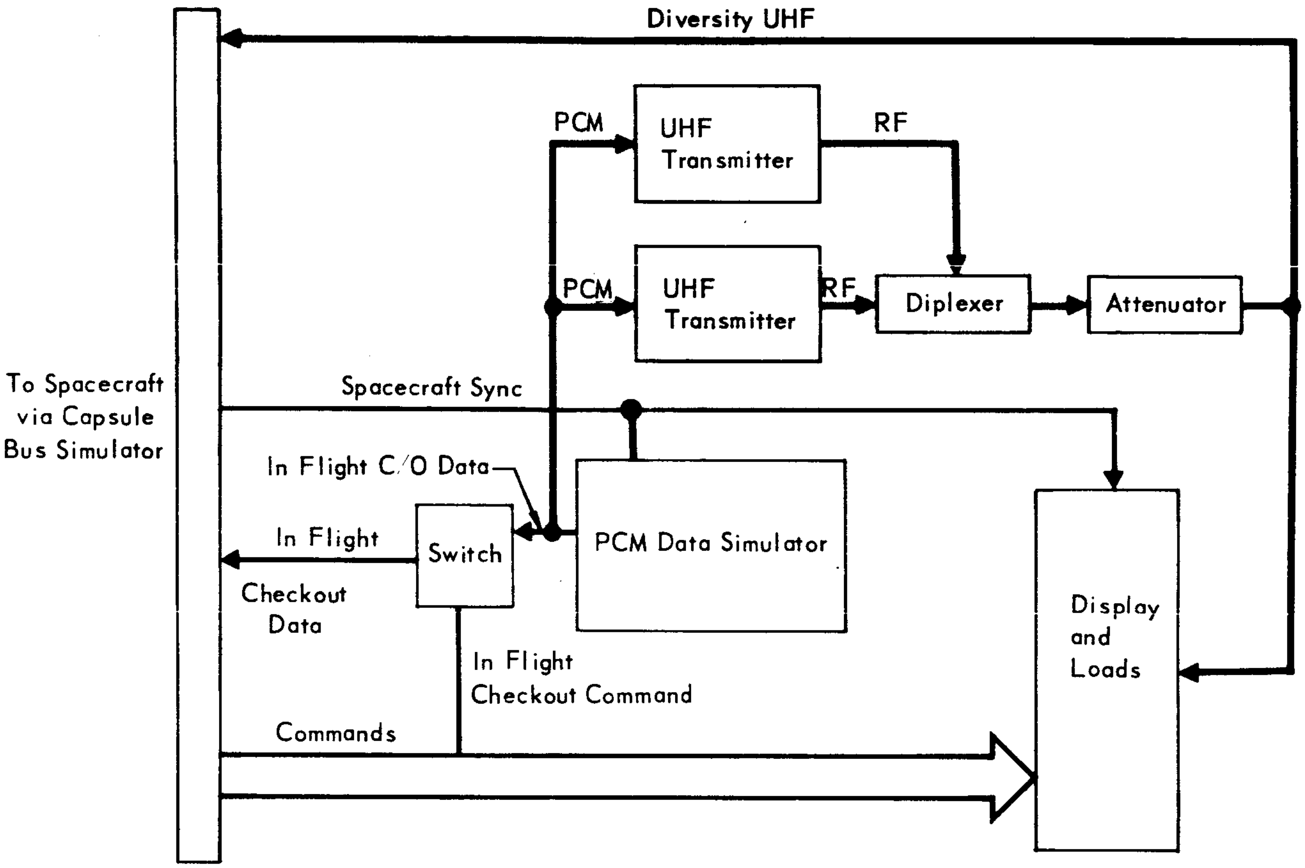
ESP MISSION DEPENDENT EQUIPMENT
AND INTERFACES



ESP CONTRACTOR'S FACILITY

Figure 4.3-8

FUNCTIONAL BLOCK DIAGRAM ESP TO SPACECRAFT ELECTRICAL SIMULATOR



FUNCTIONAL BLOCK DIAGRAM ESP TO CAPSULE BUS ELECTRICAL SIMULATOR

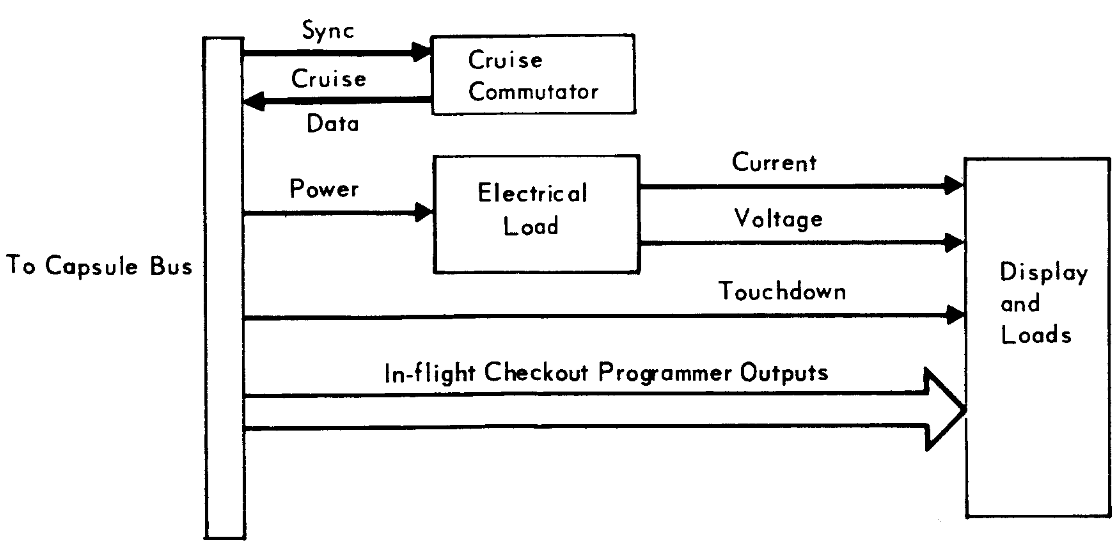


Figure 4.3-9

the Spacecraft upon receipt of the in-flight checkout command.

- ESP-to-CB (or SLS) Electrical Simulator - is furnished to the Capsule Bus (or SLS) contractor for CB testing prior to integration with the flight ESP. A functional block diagram of the simulator is shown in Figure 4.3-9. A power load with display of load voltage and current is provided. Receipt of the touchdown signal from the CB is also displayed. CB in-flight checkout programmer outputs to the ESP are correctly loaded and their status is displayed. Cruise commutator data is also supplied.
- ESP-to-CB (or SLS) Thermal Simulator - is supplied to the Capsule Bus (or SLS) contractor for factory thermal vacuum testing. The simulator provides a thermal interface that represents the conductive and radiative characteristics of the ESP.

4.3.9.1.5 Special Purpose STC Equipment

Equipment Identification and Usage - The special purpose STC equipment completes the operational functions of the STC by providing three end items: the voice communication panel, the complex cabling, and the ESP junction box. The special purpose STC equipment is used in various configurations depending upon the ESP location. The locations and configurations are given in the descriptions that follow.

- Voice Communication Panel

(1) Design Requirements and Constraints - Voice communications is required among elements of the System Test Complex (STC). The communication system must interface with the Capsule Bus System Test Complex (CB STC) communications net for integrated CB/ESP testing.

(2) Physical Characteristics - The Voice Communication Panel contains head set jacks, telephone dials, and access pushbuttons for servicing two headsets. The panels are located in the Subsystem Test Sets, System Test Complex consoles, and other operational locations as required.

(3) Operational Description - At the ESP contractor's factory, the intercom panels are connected to provide three communication networks for use during ESP system testing. Any of the three nets is accessible from any panel. Two headsets may be operated individually from each panel. Internal amplifiers are used for net amplification.

At the CB contractors System Test Complex (STC), the voice communication panels are wired to the CB contractor's voice communications system control cabinet. CB STC communication networks are accessible from the panels via the control cabinet. The CB STC public address system is also accessible from each panel. A backup network is included.

(4) Interfaces - The panels are mounted in appropriate consoles and cabinets, and interface electrically only with each other at the ESP contractor's plant. For CB STC locations the electrical interface is with the CB voice communications control cabinet.

o Complex Cabling -

(1) Equipment Identification and Usage - Cabling is required to interconnect ESP OSE, connect OSE to other interfacing systems, and connect OSE to the ESP flight subsystem. Three cabling configurations are used: ESP factory system test, CB factory integrated system test, and KSC operations.

(2) Cabling Descriptions - For ESP factory system tests the ESP Subsystem Test Sets (SSTS) used for system testing are interconnected with the additional STC elements and connected to the ESP flight subsystems via a junction box. AC power distribution is also supplied.

Flight Capsule integrated testing at the Capsule Bus contractor's facility requires cabling to interconnect the ESP STC cabinets, connect the ESP STC to the CB STC and to supply AC power. The cabling is easily disassembled and transported to KSC for installation in the control room prior to arrival of the STC.

Additional cabling is required at KSC for use on the pad, at the ESF, and at Planetary Vehicle (PV) integration. Standard leased phone lines between the ESP STC console and the Launch Control Center (LCC) ESP panel are required for transmission of data related to ESP status. Use of an A2A wideband data link and a standard phone line between the STC and pad, and between the STC and ESF are required for test data and command transmission.

Because the cabling is moved periodically, particular attention has been given to the cabling approach to prevent incorrect connector mating, control grounding paths, insure single point shield grounds, and size conductors appropriately for all STC configurations. Sufficient spare conductors are included for a 10% growth. Computerized techniques are used for control of cable configuration and changes. Automatic cabling ringout equipment is used to insure rapid, accurate checkout prior to STC connection at all locations.

- ESP Junction Box

  (1) Equipment Identification and Usage - The ESP junction box is used during ESP factory system test to interface the SSTS with the ESP. It is located near the ESP and provides required signal amplification or isolation.

4.3.9.2 ESP System Test Complex at Capsule Bus Contractor's Facility and KSC - The ESP system test complex at the Capsule Bus contractor's facility and KSC consists of the following three major groups:

- ESP contractor-supplied command and display console; Ground Data Transmission System; Mission Dependent Equipment; Mission Independent Equipment; special purpose ESP System Test Complex equipment; and ESP software specifications for the Capsule Bus contractor's computer data system.
- ESP contractor-supplied Ground Power and Distribution System, remote stimulation equipment, and UHF receiving system as described in Part D, Section 4.4.8 of this volume.
- The Capsule Bus contractor's Computer Data System with peripherals; an additional input/output controller for the Capsule Bus contractor's Computer Data System, and the required ESP software for the Capsule Bus Computer Data System (prepared from the ESP contractor supplied specifications).

Functional descriptions of the ESP System Test Complex elements required at the Capsule Bus contractor's facility and KSC are as follows:

4.3.9.2.1 ESP Required Use of Capsule Bus Contractor's System Test Complex (STC) - The Capsule Bus contractor's STC equipment required to support ESP checkout, integration, and test at the CB contractor's facility includes:

- Capsule Bus contractor's Computer Data System (CDS) - In addition to performing the Capsule Bus system test, control, and evaluation functions, the CB CDS is required to support the integration and systems tests of the ESP at the Capsule Bus contractor's facility. The CB CDS, in conjunction with the ESP Command and Display Console will:

  (1) Control the ESP or any of its subsystems through a complete or selected portion of a system test.

  (2) Acquire, process, evaluate, store and distribute all ESP and ESP STC elements data required for real-time and non-real-time analysis of ESP

tests performed at the CB/ESP integrated test facility.

(3) In conjunction with STC elements, provide a means to manually control the ESP test to any mode, in any mode, and in any sequence.

- ESP software for the CB Computer Data System will be required. This software will be developed by the CB contractor, from specifications provided by the ESP contractor and integrated into the total CB/ESP software package. The development and packaging of ESP software is described in Part J, Section 8 of this Volume. ESP software includes:

(1) Support Software - ESP support software provides for all off-line ESP data processing and ESP STC diagnostics.

(2) Operational Software - ESP operational software includes ESP Executive program, ESP I/O Processor, ESP Time Program Interpreter, ESP Alarm Processor, ESP On-Line Input Processor, ESP Display Processor and other miscellaneous processors as required.

(3) CB CDS Input/Output Device Controller (I/O Controller) - The CB CDS requires an additional I/O controller to interface with the ESP Command and Display Console and ESP Ground Data Transmission System (GDTS). This I/O controller is used to accept manual commands, test log data, control functions, status requests, display requests and hazard and emergency alarms from the ESP Command and Display Console. The I/O Controller also outputs ESP data to the ESP Command and Display Console for status monitor, test, and sequence number display, and other displays as required by the ESP STC.

Functional Operation - The CB CDS acquires the decommutated, ID-tagged, ESP data from the Telemetry and Command Processor and the ESP GDTS. Data is limit-checked, compressed, evaluated, and output to the CB CDS peripheral equipment and ESP Command and Display Console for display, recording, mass storage, or status monitoring. The CB Test Director receives ESP hazard and emergency alarms from the ESP Command and Display Console. The Capsule Bus Test Director also has the capability of inhibiting ESP manual control by the ESP Command and Display Console operator during critical real-time CB/ESP integrated test programs.

Interface Definition - The Capsule Bus contractor's STC interfaces with the ESP STC components as shown in Figure 4.3-10.

4.3.9.2.2 ESP Command and Display Console

Identification and Usage - The ESP Command and Display console is provided by the ESP contractor and integrated with the CB STC control room equipment to conduct ESP system tests after integration into the Capsule Bus at the CB contractor's

ENTRY SCIENCE PACKAGE STC INTERFACES WITH CAPSULE BUS CONTRACTORS STC

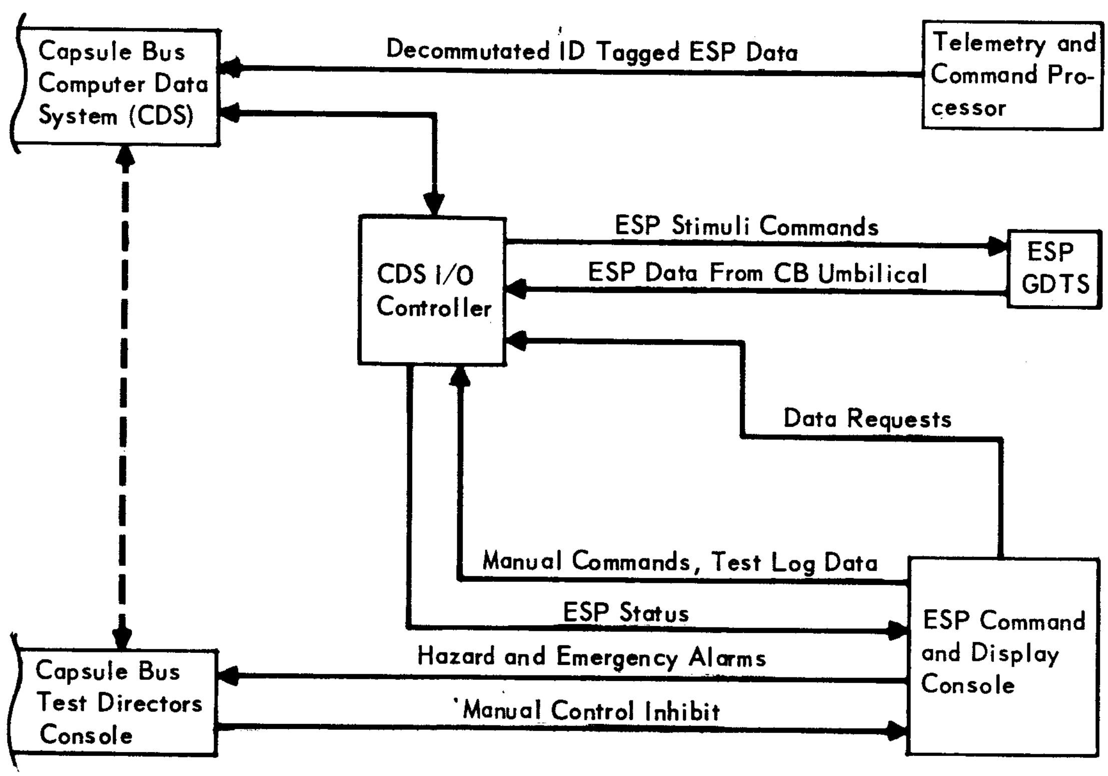


Figure 4.3–10

factory. The console will have a digital interface compatible with the CB computer-controlled STC.

Physical Characteristics - Consists of a two-bay sitdown console with slanted display and control panels for test control and monitor functions, writing surface and under shelf components such as control and display electronics, dc power supply, ac power panel, blower and storage drawer. The console layout, shape and STC electrical interfaces are coordinated with the CB contractor to insure compatibility. Figure 4.3-11 illustrates a typical example of the ESP Console required for ESP testing in the CB STC.

Operational Description - The ESP console combines the functions of an ESP subsystem console and an ESP Test Director's console. In both manual and automatic modes the console provides the ESP engineer/Test Conductor with the capability to monitor the Entry Science Package subsystem, Telemetry and Data Storage, Subsystem and Power and Thermal Control Subsystems. The ESP console operator uses the manual panel controls to conduct specific ESP subsystems tests individually as required. Data display is by CRT or equivalent, compatible with the Capsule Bus contractor's STC computer system.

Interface Definition - The interfaces of the ESP are shown in Figure 4.3-12.

4.3.9.2.3 Ground Data Transmission System

Equipment Identification and Usage - The Ground Data Transmission system (GDTS) is used to send commands from the Capsule Bus (CB) System Test Complex (STC) to the remotely-located Entry Science Package (ESP) and OSE used at CB contractor's integration site and KSC. This system also collects, formats, and transmits data from the remotely-located equipment and ESP to the Capsule Bus STC. One standard A2A line and one voicegrade telephone line are used to connect each remote site with the CB STC. A virtually error-free command transmission technique is used to prevent undesired commands from reaching the ESP.

Design Requirements and Constraints - The GDTS is required to perform the following functions:

- Digitize analog signals and multiplex them with bilevel and digital data at the ESP.
- Transmit the data with parity to the STC.
- Format the received data for interface with the Capsule Bus STC and the ESP console.
- Format STC commands and transmit them to the ESP vicinity, using error control techniques.

ESP COMMAND AND DISPLAY CONSOLE

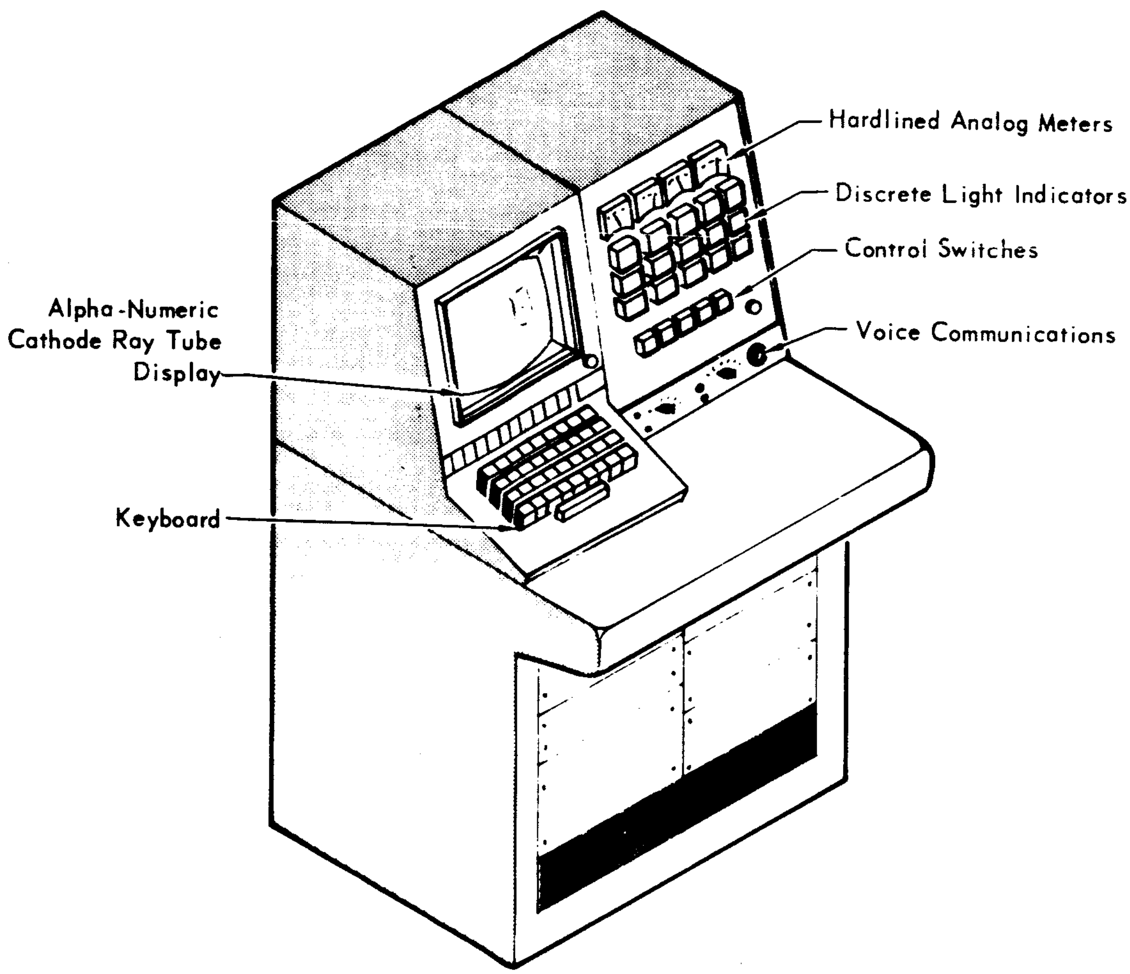


Figure 4.3-11

ENTRY SCIENCE PACKAGE STC CONSOLE
INTERFACE DIAGRAM

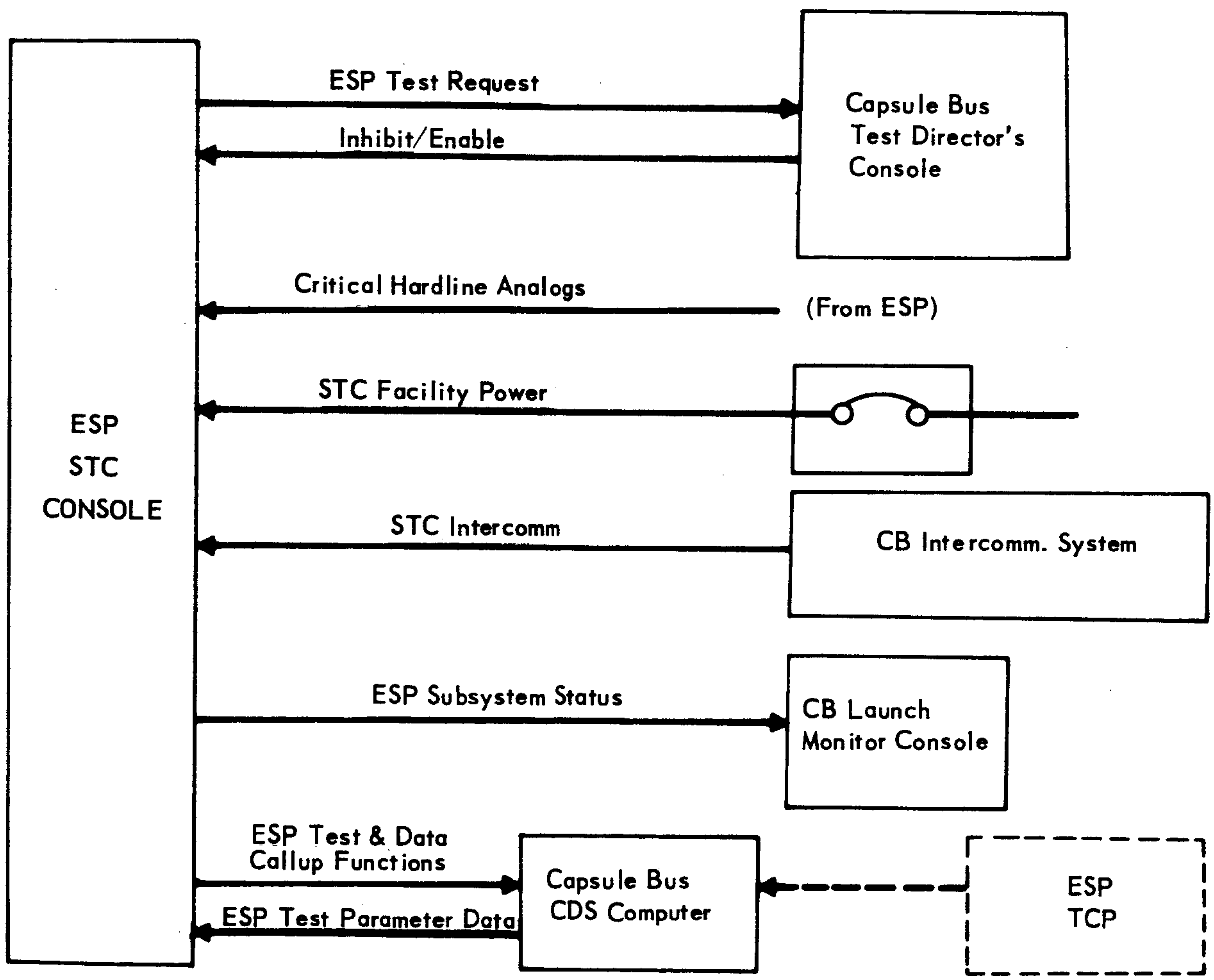


Figure 4.3-12

- o Receive the commands at the ESP and route them to the ESP and vicinity OSE.

Physical Characteristics - The GDTS is contained in two standard cabinets as shown in Figure 4.3-13. The ESP terminal unit is located in the test area adjacent to the ESP. The STC terminal unit is located in the CB contractor's control room. At KSC, the terminals are connected by an existing A2A line and a voice grade telephone line. For CB factory testing the terminals are connected by coaxial cables.

Operational Description - The operation of the GDTS will be described in three parts:

- o The Entry Science Package and vicinity OSE to System Test Complex data flow (downlink)
- o the STC to ESP and OSE command flow (uplink)
- o command verification and self-test.

The GDTS downlink functional block diagram is shown in Figure 4.3-14. ESP and OSE test parameters are routed to the ESP terminal unit for signal conditioning, multiplexing, digitizing, and transmission over the A2A link.

Analog dc voltage inputs are applied to a variable gain multiplexer. Conversion of other analogs (e.g. ac, phase, or resistance) to dc voltages is accomplished in the signal conditioner prior to multiplexing. Storage is provided for bi-level and digital word inputs. The timing generator provides clock signals to control the analog to digital converter, provide channel identification, control the data transfer from the inputs, and perform output formatting control. The formatter serializes the data, supplies synchronization patterns, and adds parity bits. The serial Pulse Code Modulated (PCM) time multiplex output is applied to a voltage controlled oscillator (VCO). The VCO output is a frequency shift keyed signal that is summed with VCO outputs from the following sources:

- o radio frequency UHF-link data (demodulated in the OSE UHF Receiving System)
- o the in-flight checkout PCM hardline output
- o the premodulated (UHF link) PCM hardline output
- o the error control decoder retransmit signal.

The summed VCO outputs produce a 500 KHz bandwidth frequency modulation (FM) multiplex that is compatible with the A2A transmission line.

At the STC terminal unit, the FM multiplex is demodulated and routed as follows. The telecommunications subsystem PCM signals are sent to the STC-located Mission Dependent Equipment (MDE). The error control retransmit signal is sent to the uplink error control encoder. The demodulated time multiplex output is decoded by re-

GROUND DATA TRANSMISSION SYSTEM, UPLINK
FUNCTIONAL BLOCK DIAGRAM

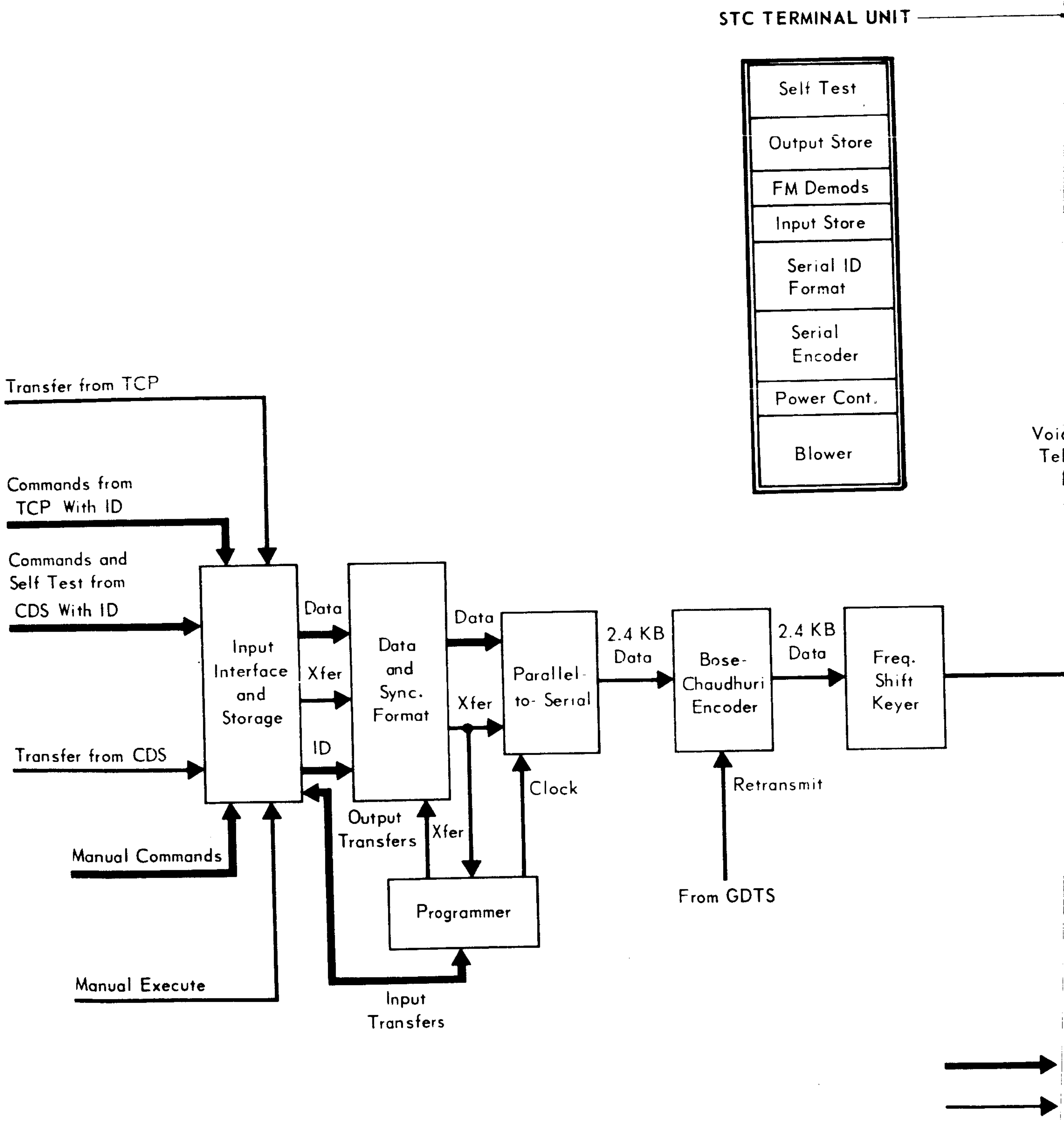
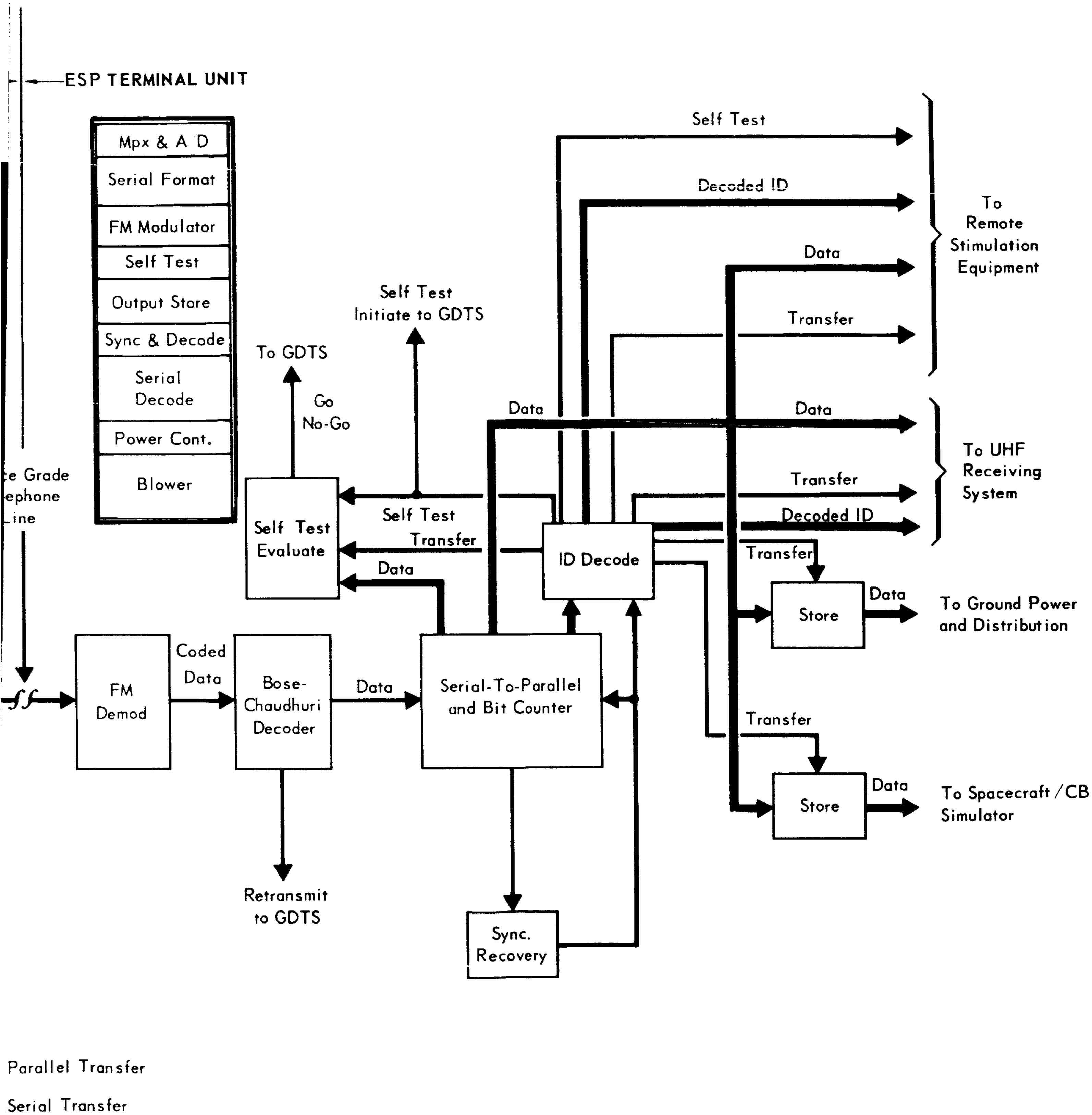


Figure 4.3-13


ESP TERMINAL UNIT
Mpx & A D
Serial Format
FM Modulator
Self Test
Output Store
Sync & Decode
Serial Decode
Power Cont.
Blower
e Grade
ephone
ine
FM Demod
Coded Data
Bose-Chaudhuri Decoder
Data
Retransmit to GDTS
Serial-To-Parallel and Bit Counter
Sync. Recovery
Self Test Evaluate
To GDTS
Go No-Go
Self Test Initiate to GDTS
Self Test
Transfer
Data
ID Decode
Self Test
Decoded ID
Data
Transfer
To Remote Stimulation Equipment
Data
Transfer
Decoded ID
To UHF Receiving System
Transfer
Store
Data
To Ground Power and Distribution
Transfer
Store
Data
To Spacecraft/CB Simulator
Parallel Transfer
Serial Transfer

4-28-2

GROUND DATA TRANSMISSION SYSTEM, DOWNLINK FUNCTIONAL BLOCK DIAGRAM

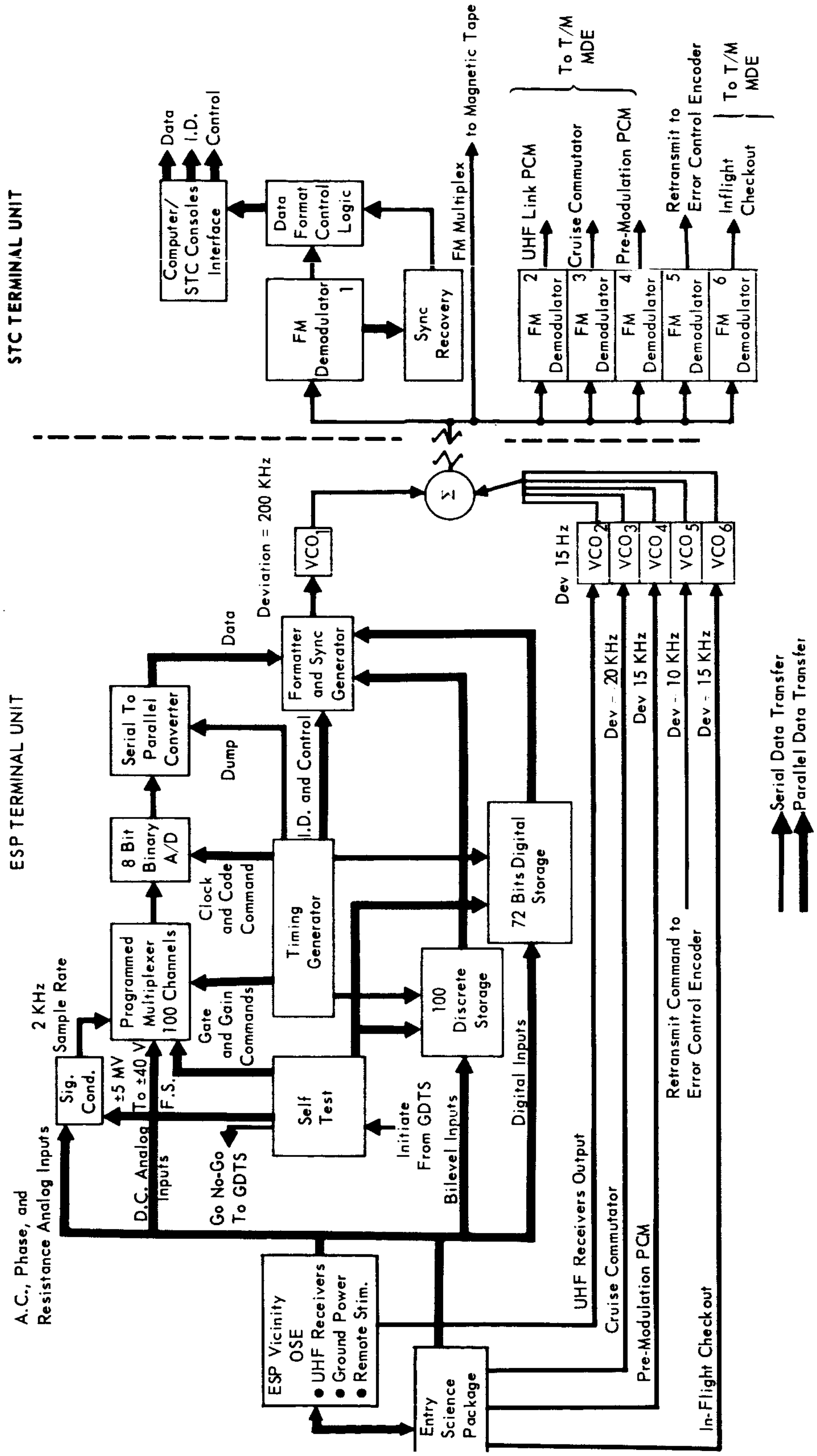


Figure 4.3–14

covering synchronization checking parity converting the data from serial to parallel. The data with ID bits is presented to the Capsule Bus Computer Data System and the ESP Console by use of an output storage buffer.

The GDTS uplink functional block diagram is shown in Figure 4.3-13. Test commands and execute signals are accepted from the Computer Data System, the Telemetry and Command Processor, and the ESP Console Manual Input Panels. The data is ID-tagged and serialized with synchronization bits. The serial output is Bose-Chaudhuri error-control encoded and sent to a frequency shift keyer. The output bandwidth is 2400 Hz, which is compatible with standard voice grade telephone lines. The CB Terminal Unit decodes the Bose-Chaudhuri coding and if an error is detected, requests a retransmission via the downlink while inhibiting output of the erroneous command. The decoder output is converted to parallel and synchronization is acquired. The ID decoder determines the data address, and an individual line from the decoder indicates each received address.

Parallel output is sent with decoded ID lines for remote control of the UHF Receiving System and the Remote Stimulation Equipment. Storage registers are provided for remote control of the Ground Power and Distribution Equipment, and the Spacecraft Simulator.

Command Verification and Self Test - The requirement to prevent inadvertent test sequences or commands from being applied to the ESP imposes stringent limits upon the performance of the GDTS and requires a means of command verification.

The use of the Bose-Chaudhuri encoding technique provides virtually error-free command transmission. This cyclic coding method uses error detection and data re-transmission to achieve a bit error probability of 1.5×10^{-15}, based on a transmission line bit error probability of 10^{-5}. The technique is effective for single bit errors, multiple consecutive (burst) errors, and complete signal loss. In this approach, error control takes place prior to test stimuli application. In addition, stimuli relay positions (received commands) are monitored and automatically compared with the transmitted command by the Computer Data System. This approach meets the requirement for low error command transmission in a manner that permits the use of existing landlines, with commercially available, field proven hardware, and is selected as our preferred concept. Other command verification concepts studied during Phase B included techniques such as the "echo check" technique employed by the McDonnell Douglas Saturn IVB ACS and the double command transmission method used by Apollo ACE.

Self test is performed on both the uplink and downlink of the GDTS. For the uplink, the Computer Data System sends self test data words via the GDTS STC Terminal to the ESP Terminal Unit. These data words are compared bit-by-bit in the self-test evaluator. The ESP Terminal data register inputs are inhibited so that the ESP and vicinity using elements retain their previous inputs during self test.

For the downlink, the ESP Terminal Unit applies self-test signals to all its data inputs, and the resulting output is transmitted to the Computer Data System via the STC Terminal Unit for evaluation.

After one complete data cycle, the test-inputs to both terminal units are removed and the system is again operational. In this manner, self test of the entire GDTS is performed in 250 milliseconds, with minimum impact on the test in progress.

The interface of the GDTS with the Entry Science Package, Capsule Bus STC, and other OSE during ESP/CB integrated systems level tests is shown in Figures 4.3-13 (uplink) and 4.3-14 (downlink). During PV integration, the interfaces are similar except that the OSE umbilical is not used after the PV shroud is installed.

4.3.9.2.4 Mission Independent Equipment (MIE) Required at Capsule Bus Contractor's Facility and KSC

The System Test Complex (STC) required MIE is an exact duplicate of the Telemetry and Command Processor (TCP) Computer and Peripherals used at the Deep Space Instrumentation Facility (DSIF).

Telemetry and Command Processor (TCP) - The TCP is a high speed general purpose computer system that is normally used in the DSIF to provide flight commands and decommutated Entry Science Package (ESP) telemetry data. It is used in the STC to support all systems tests.

- Physical Characteristics - The TCP presently consists of an SDS 920 Computer System, a magnetic tape recorder group, I/O typewriter, tape punch, and tape reader. Because the SDS 920 computer is a standard SDS product covered in the manufacturer's literature, physical and operational characteristics are not repeated herein.
- Functional Description - The TCP translates ESP commands to the required format for ESP testing, and provides on-site data processing of telemetry signals (See Figure 4.3-15 for TCP functional block diagram). The TCP acquires the de-interleaved ESP telemetry signals from the telemetry MDE. An interrupt line is used to indicate the presence of data in an associated buffer. Data is read into memory through the parallel input. On executive

TELEMETRY AND COMMAND PROCESSOR (TCP) FUNCTIONAL BLOCK DIAGRAM AND INTERFACES

(AT CB CONTRACTOR'S FACILITY AND KSC)

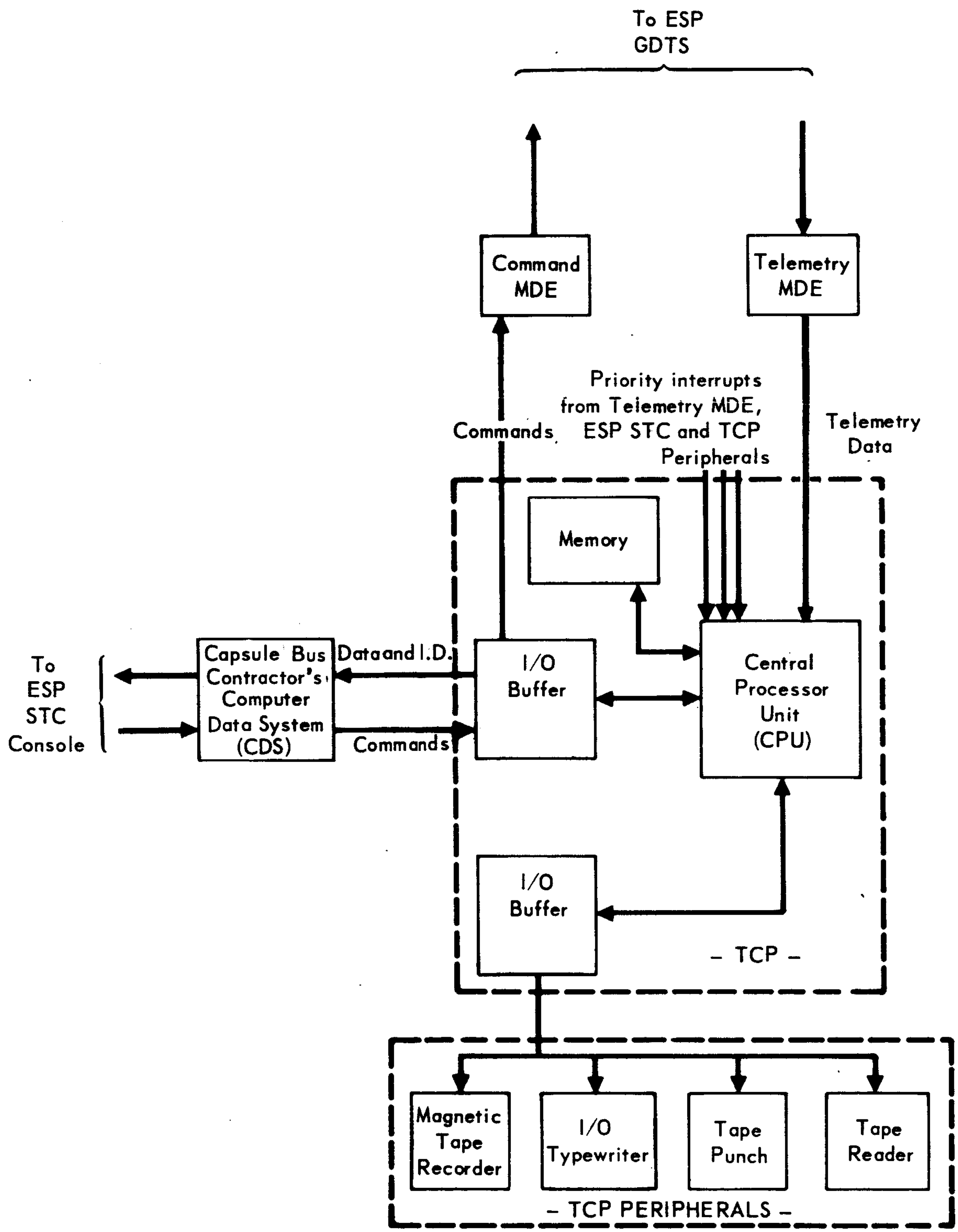


Figure 4.3–15

program request, the data is transferred to a buffer area of memory where it is assembled into a word that includes a single character code associated with each individual data word. The decommutated, ID-tagged data is then ready for I/O transfer to peripheral equipment and the Capsule Bus System Test Complex Computer Data System (during ESP/CB and ESP/CB/Spacecraft integrated tests).

All ESP commands input to the TCP are translated to the required formats, stored in memory, and output to the command MDE.

- Interfaces - The TCP interfaces with the following components. (See Figure 4.3-15 for TCP interfaces).
  (1) Telemetry MDE
  (2) Command MDE
  (3) ESP System Test Complex Computer Data System during ESP/CB or ESP/CB/Spacecraft integrated tests.
  (4) TCP Peripherals

TCP Peripherals - The TCP peripherals include the following equipment:

- Magnetic Tape Recorder - The recorder is used to store TCP processed telemetry and command signals for playback and future use.
- Tape Punch and Tape Reader - the punched tape equipment is used for assembling new programs, altering existing programs, and loading the TCP memory.
- I/O Typewriter - The I/O typewriter is used for operation control, error and status message reporting, and simulation of SFOF/SCP communications with the TCP.

TCP Software - The TCP software used in the STC is identical to that Mission Dependent Equipment software package developed for DSIF usage. This software will be developed early in Phase D, and will be used during the first ESP system tests to ensure early compatibility between the ESP and DSIF. The MDE software package for TCP is described in Part J, Section 4.5.4 of this volume. For further details of software management, development, package, test language, philosophy and commonalities, see Part J, Section 8 of this volume.

4.3.9.2.5 Mission Dependent Equipment (MDE) Required at Capsule Bus Contractor's Facility and KSC - The MDE required to support the Entry Science Package (ESP) at the Capsule Bus contractor's facility and KSC is an exact duplicate of the ESP MDE used at the Deep Space Instrumentation Facility (DSIF). The STC MDE processes ESP Telemetry data and outputs it to the Telemetry and Command

Processor during all ESP systems tests thereby ensuring early compatibility between the ESP and the MDE used at the DSIF's.

- o Physical Description - For a more detailed description of the MDE, see Part J, Section 4.5, of this volume.
- o Functional Description - The ESP MDE receives the frame interleaved ESP/CB data from the ESP Ground Data Transmission System. The ESP data is de-interleaved from the Capsule Bus data. The de-interleaved data is then processed in the Telemetry and Command Processor and transferred to the CB contractor's CDS for evaluation, recording, and output to the ESP Command and Display Console for display.
- o Interface Definition - The ESP System Test Complex required MDE for usage at the Capsule Bus contractor's facility and at KSC interfaces with the Capsule Bus System Test Complex, Telemetry and Command Processor, and ESP System Test Complex as shown in Figure 4.3-16.

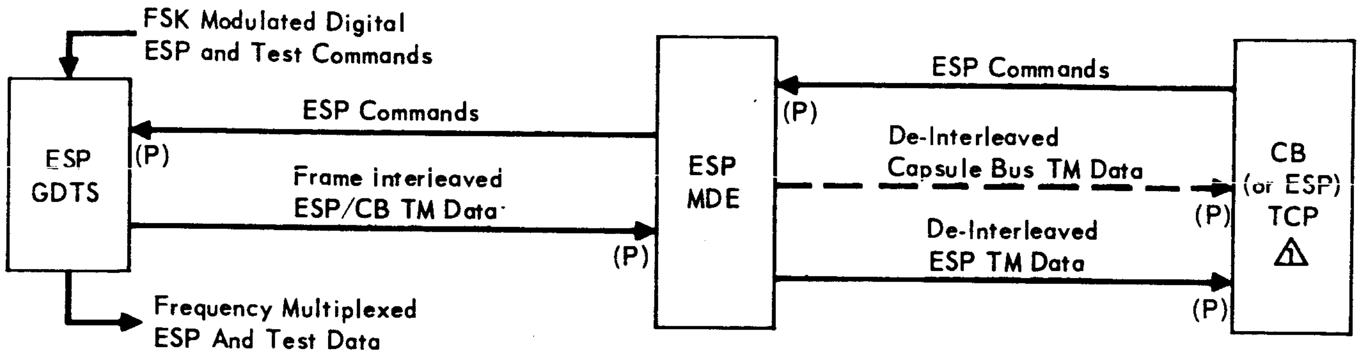
4.3.9.2.6 Special Purpose STC Equipment - Special purpose STC Equipment is described and its functions at the CB contractor's factory are delineated in Section 4.3.9.1.5.

4.4 LAUNCH COMPLEX EQUIPMENT (LCE) - The LCE is required to expeditiously test the ESP on-pad and determine its readiness to meet the mission requirements. These requirements are satisfied by using the ESP TCM link, supplemented by a limited number of hardlines from the S/C flyaway umbilical, and using the corresponding portion of the STC and Mission Dependent Equipment for the LCE function. The ESP in-flight checkout mode, and the System Test Complex and Launch Complex Equipment with their automated test and self-check capabilities will rapidly identify the nature of a malfunction within the ESP or OSE. This ability is essential in deciding to commit to launch or recycle.

LCE must also reliably perform during the critical launch operation. The LCE, including those STC elements used in the LCE, must demonstrate the reliability goals to be assigned. The MDE used will have reliability equal to or greater than the LCE requirements. The choice of critical ESP and OSE launch parameters to be monitored by the LCE will be made during Phase C. This is being implemented by failure mode and reliability analyses and a computerized math model of the ESP and Launch Complex Equipment (LCE) and pad operations. This investigation will provide these results:

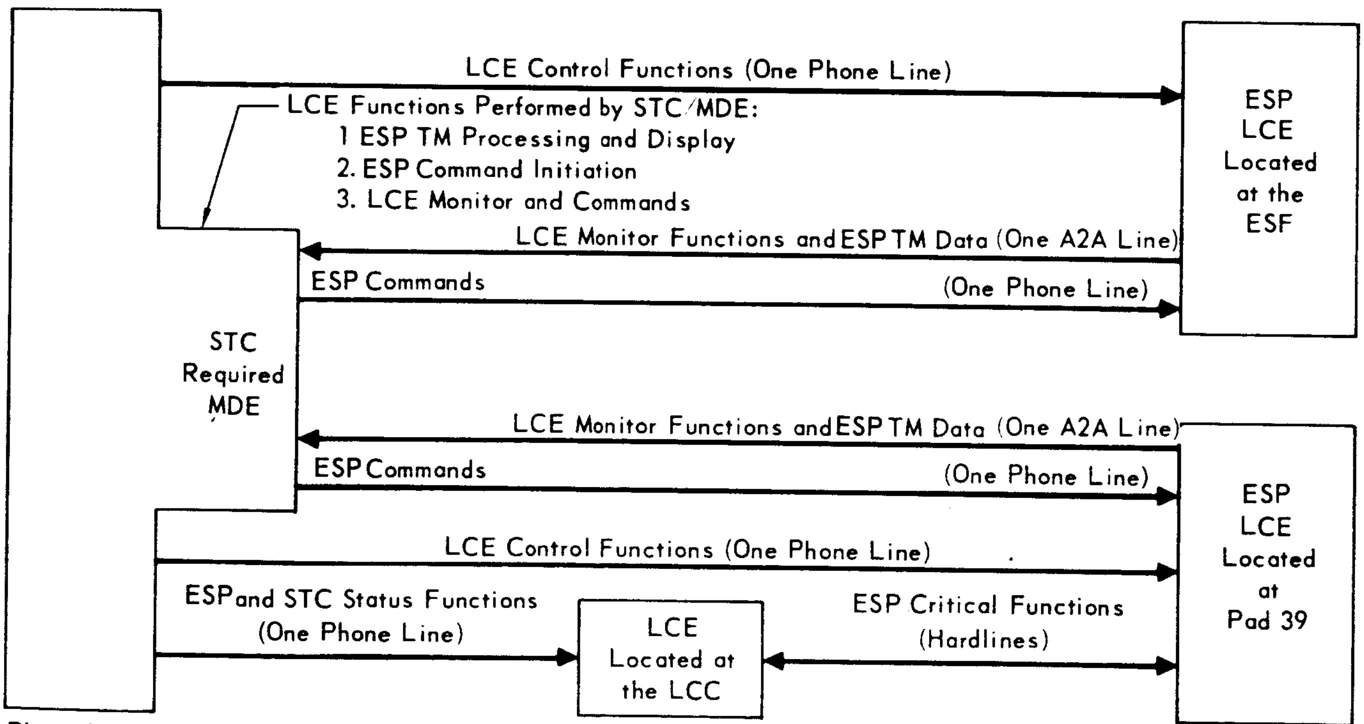
a. Determination of the critical ESP parameters to be brought out of the S/C flyaway umbilical

ESP MDE AND INTERFACES
(AT CAPSULE BUS CONTRACTORS FACILITY)



⚠ ESP TCP required if CB Contractors TCP will not Accommodate Processing Task

ESP MDE AND INTERFACES
(AT INTEGRATION FACILITY KSC)



Phone Line – Standard 3KHZ Telephone line
A2A Line – Standard Wide Band Line

Figure 4.3–16

b. Critical LCE parameters to be monitored by the STC, and by hardlined analog to the Launch Control Center (LCC).

c. The required MTBF for LCE (including those STC elements used for the LCE function)

d. Identification of those LCE elements requiring redundance to meet the VOYAGER P_s of on-time launch;

4.4.1 Requirements and Constraints - The LCE has both ESP contractor and customer derived requirements and constraints which must be met. These having major impact on LCE design are listed below:

a. Complete testing of the ESP, as provided by the Capsule umbilical and RF test circuitry

b. Provide for limited ESP testing during radio frequency (RF) silence

c. Manually control the ESP by the provided test circuitry

d. Isolate trouble to the ESP

e. Automatically control the ESP in the terminal portion of a simulated or real countdown with manual hold and reset capability

f. Supply external ESP power and power switching control

g. Provide the necessary power distribution to minimize the main power distribution requirements in the Launch Control Center

h. Provide for controlled transfer to emergency main power sources

i. Provide for main power isolation from launch facility loads

j. Provide for conditioning the ESP to a safe mode in event of failure and subsequent resumption of facility power

k. Provide continuous indications, controls and alarms, with or without ESP or facility power on, of all ESP or ground functions related to ESP or personnel safety.

l. Provide sufficient safeguards to prevent the occurrence of damage attributed to improper sequencing because of test stops and LCE element failure

m. Provide a communication system between the Launch Control Center, launch pad, and the Planetary Operations Control Center

n. Self-test without interruptions of ESP operation

o. Provide an operational reliability consistent with the launch probability of success

p. Decoding, recording, time-tagging, and displaying independent of other data control centers of:

- o All ESP inputs supplied by the LCE
- o All ESP data available at the launch complex
- o All facility-supplied power to the LCE
- o All signals supplied to or from all other interconnecting equipment, e.g., interfacing functions to or from the Launch Vehicle System
- o All external instrumentation data; e.g., outside temperatures or air conditioning inlet functions to or from the Launch Vehicle System
- o Synchronizing signals from facility and ETR time codes

The LCE which satisfies these constraints is described in the following paragraphs.

4.4.2 Equipment Identification List - LCE can be divided into these functional groups:

a. Ground Power and Distribution - a two-bay rack providing automatic switching to facility back-up power, emergency back-up power in case of total facility power failure and dc power to the ESP. This equipment is located in the base of the Mobile Launcher (ML) and at the ESF.

b. Remote Stimulation Equipment - Test signal generation equipment used to provide stimuli required for on-pad testing of the ESP.

c. UHF Receiving System - Provides UHF receiving equipment on the ML which demodulates the ESP UHF transmitter output (brought out the S/C flyaway umbilical from parasitic antennas in the canister) for transmission of the ESP/TM data to the STC over the Ground Data Transmission System (GDTS). Spectrum and power-output measurements are made from equipment on the Mobile Launcher.

d. LCC Equipment - A panel for displaying ESP Subsystem status, sent from the CB/ESP STC, and critical ESP analogs hardlined from the pad. This panel is installed in the CB Launch Monitor Console.

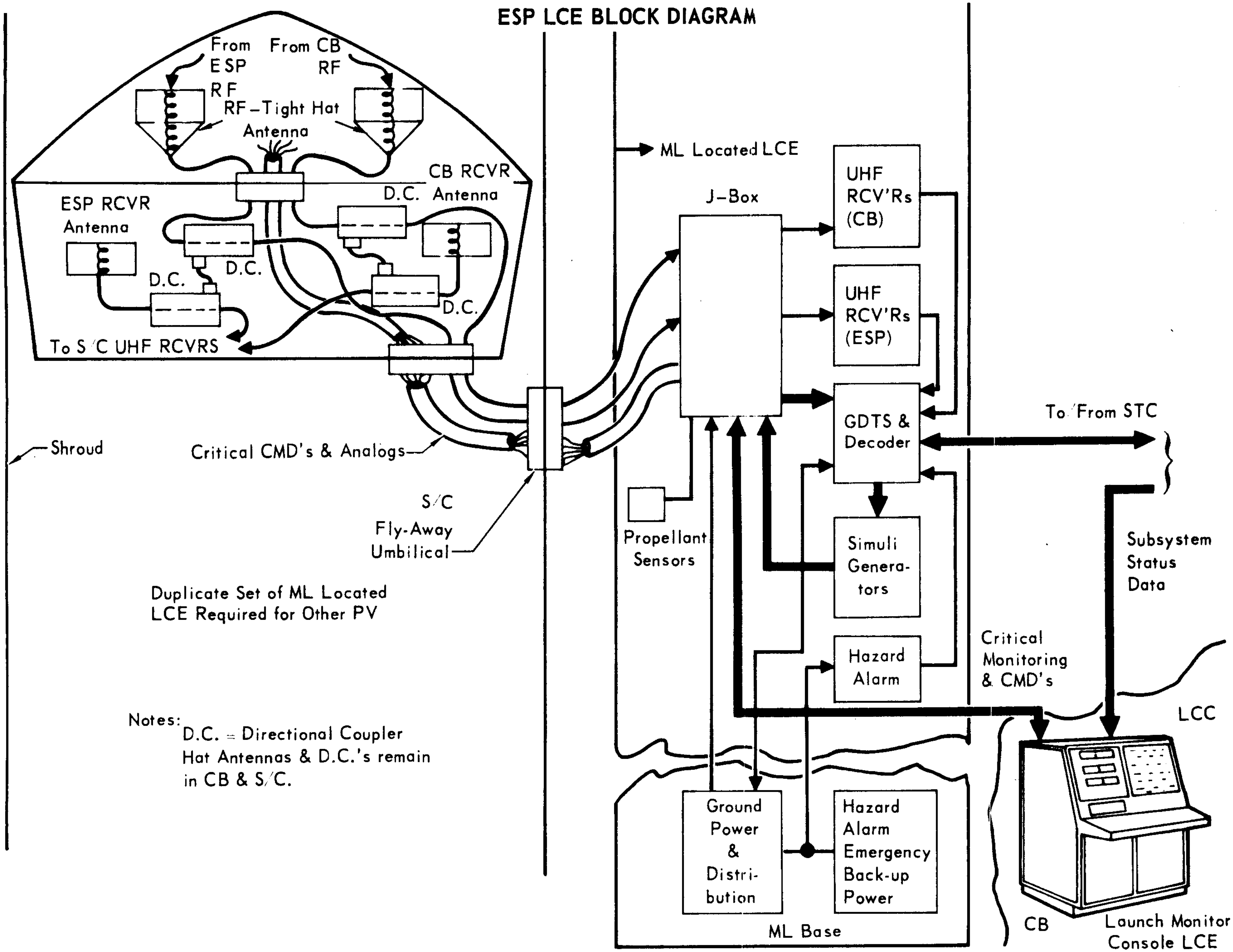
e. LCE Required STC Equipment - the CB/ESP/STC, and associated supplemental ESP Control and Display console, and MDE, required for on-pad testing. Test point access to the TCM is via the Spacecraft flyaway umbilical.

4.4.3 Operational Description - The LCE shown in the block diagram of Figure 4.4-1 provides these operational features:

a. Use of the CB/ESP STC and MDE (refer to Paragraph 4.3.2 for descriptions) analyze data from the ESP.

b. Transmission of the ESP data and commands between the ESP and the STC using the Ground Data Transmission System.

ESP LCE BLOCK DIAGRAM



Duplicate Set of ML Located LCE Required for Other PV

Notes: D.C. = Directional Coupler
Hat Antennas & D.C.'s remain in CB & S/C.

Figure 4.4-1

c. Provides critical data and commands on individual hardlines for monitoring and controlling critical parameters, such as power and temperatures, at the Launch Control Center.

Use of the STC in the LCE function provides a continuation of the test data log started in early STC testing at the CB Contractor's plant and provides test continuity in equipment, procedures, and operating personnel.

4.4.4 Reliability and Safety - Besides those reliability and safety features provided by the STC, additional requirements imposed by pad operations are met by the LCE. These are:

a. Back-up facility power - To prevent test interruption in case of primary power failure.

b. Emergency back-up power - For monitoring critical CB parameters, and sequencing the CB subsystem to a safe condition in event of total facility power failure.

LCE reliability is an important factor in meeting launch-on-time and in providing the highest practical probability of mission success. The various elements of LCE will be examined analytically early in the design phase; and the LCE will be tested on a system basis to demonstrate the assigned P_s, as previously discussed in Section 4.4.

4.4.5 Interface Definition - Figure 4.4-2 shows the Interface of LCE with Pad 39 complex and facilities.

4.4.6 Physical Characteristics - Figure 4.4-3 shows the proposed layout of the LCE, at Pad 39 and at the Launch Control Center (LCC), with the various equipments identified.

4.4.7 Development Status - No major problems are anticipated in LCE development. Software developed for use in the CB STC CDS computer will be essentially identical to that required for LCE use. Compatibility of LCE/STC with ESP and facilities will be demonstrated with the ESP proof test model.

4.4.8 Equipment Functional Description - The LCE equipment groups identified above are functionally described in detail below, along with preliminary design.

4.4.8.1 Ground Power and Distribution

- Identification and Usage - The Ground Power and Distribution equipment is a two-bay cabinet-mounted assembly providing dc ground power to the ESP during systems testing at the ESP test facilities including ESF and Launch Pad. It also provides ac facility power control and distribution for OSE located at the above sites.

ESP LCE/PAD INTERFACE DIAGRAM

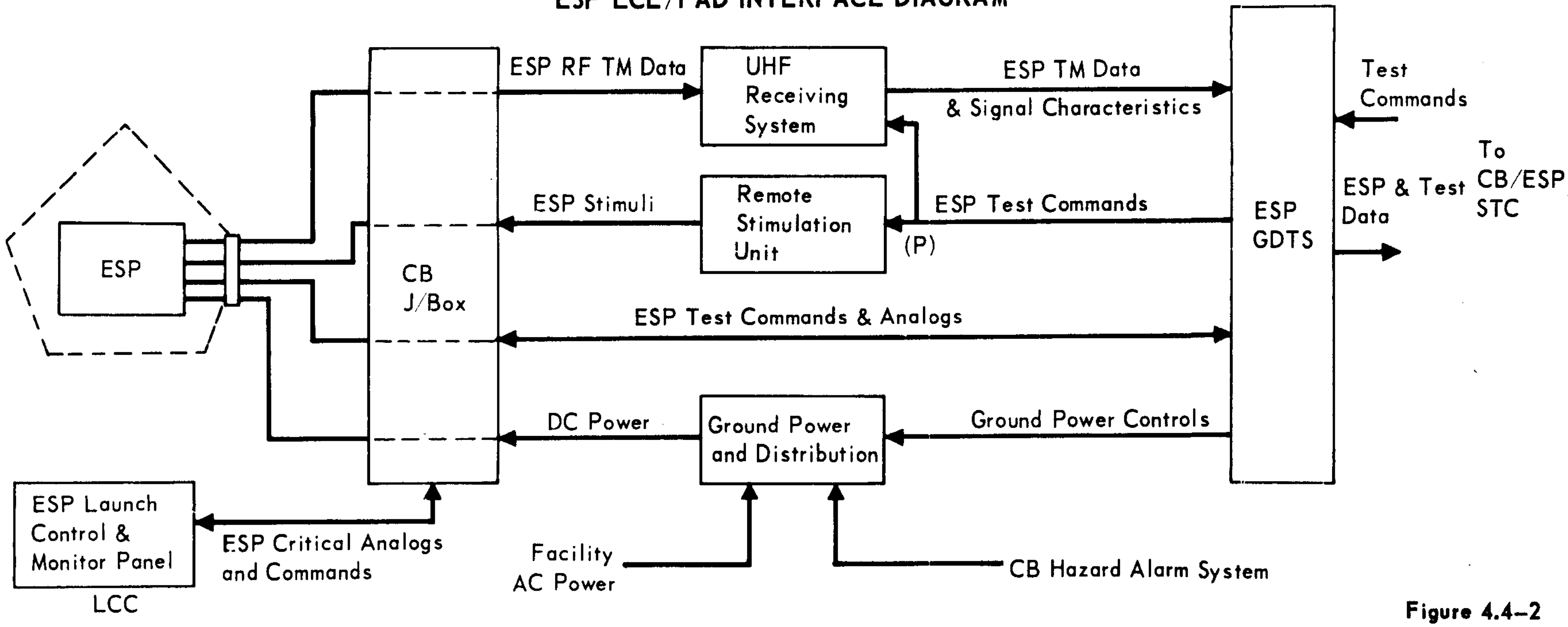


Figure 4.4–2

LCE EQUIPMENT LAYOUT

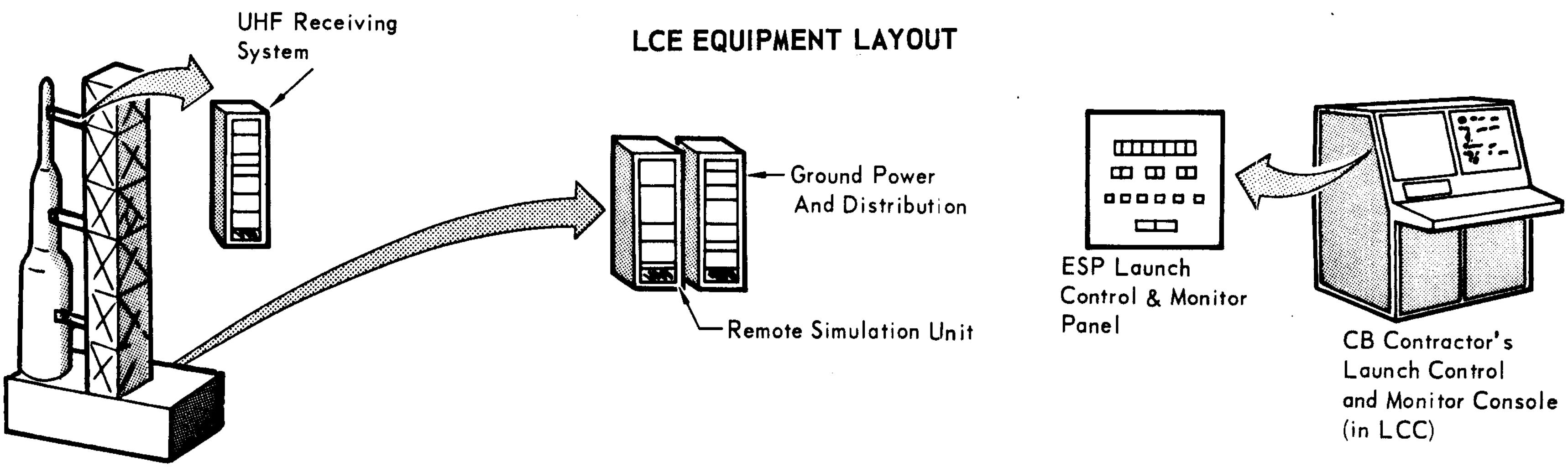


Figure 4.4–3

Figures 4.4–2, 4.4–3

- <u>Design Requirements (dc power)</u> - The Ground Power and Distribution equipment is designed to include the following provisions:
  (1) Convert ac power to 27.5 ± 1 volt dc for the ESP during ground test operations.
  (2) Provide power to charge flight batteries and provide simulated loads to the batteries for charge/discharge cycling.
  (3) Simulate flight battery power including controlled voltage discharge based on watt-hour consumption.
  (4) Provide battery backup power to sequence the ESP to a safe condition in the event of facility power failure.
- <u>Design Requirements - (ac power)</u> - The ground power and distribution equipment is designed with the following ac power provisions:
  (1) Distribute facility ac power to OSE used at all support areas including remote test areas at KSC pad, ESF and SCF sites.
  (2) Provide instrument (regulated) ac power to OSE as required.
  (3) Monitor and provide alarms for out-of-tolerance conditions of main KSC facility power and launch complex power with automatic transfer to emergency main power.
  (4) Isolate the ESP OSE loads at the pad from other facility loads by use of separate circuit breakers and distribution transformers as required.
  (5) Operate in conjunction with the CB, SL and Planetary Vehicle hazard alarm and monitor systems at the ESF and pad during emergency conditions requiring power shutdown.
  (6) Operate under STC control.
- <u>Physical Characteristics</u> - The ground power and distribution equipment is mounted in standard electronic equipment cabinets and includes control and display panels, programmable dc power supplies, switching units, limit-sensing electronics, strip-chart recorder and an ac regulator as illustrated in Figure 4.4-4. The dc power supplies, including the backup supply, are of off-the-shelf designs incorporating line and load regulation, and automatic overload protection for both the power supply and the ESP. Remote sensing of supply voltage at the ESP to compensate for line losses incurred from extensive cable lengths is also included.
- <u>Operational Description</u> - The equipment supplies dc power to the ESP and ac power to associated OSE during system level tests at the factory and at KSC remote support areas with remote control by the STC, which monitors

GROUND POWER AND DISTRIBUTION EQUIPMENT

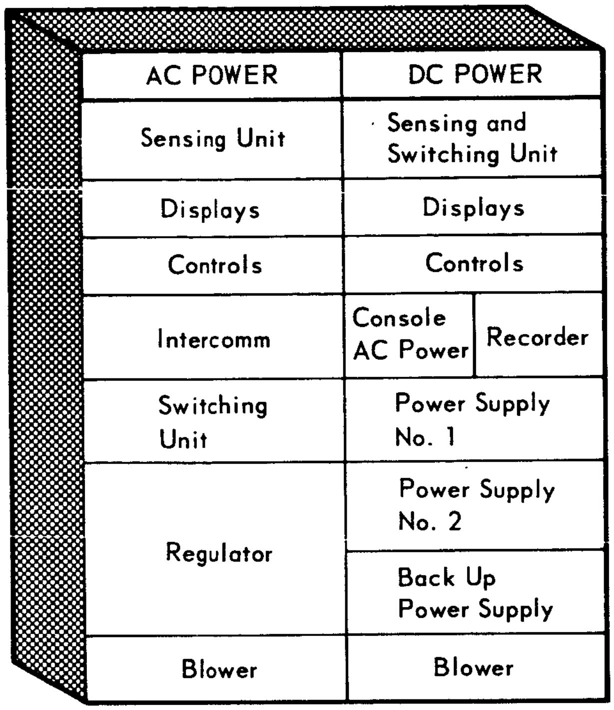


Figure 4.4-4

and controls the outputs. The equipment may also be controlled and monitored by the ESP Launch Monitor Panel in the LCC via hardlines. In addition, the equipment accepts emergency shutdown control signals from the CB, SL and PV Hazard Alarm Systems. Manual controls and monitors are built in for local operation.

- Performance Characteristics - The equipment includes electronic limit sensing that automatically monitors both ac and dc power, detects deviations beyond preset limits and generates both audible and visual alarms locally and transmits alarm signals in the CB STC. Fault isolation to the replaceable unit level is achieved by identification of the malfunctioning power supply or facility source. The electronic limit sensing circuitry has a self test mode that cycles test signals into the limit detectors to verify detector performance. The DC power supplies may be programmed by the CDS for ESP performance margin testing.
- Interface Definition - The interfaces of the ground power and distribution unit as shown in the functional block diagram of Figure 4.4-5 and 4.4-6 include:

  (1) Facility power - KSC power, pad power and emergency power.

  (2) Ground data transmission system - STC controls and data functions.

  (3) CB, SL and Planetary Vehicle hazard alarm systems - emergency shutdown.

  (4) ESP - ground dc power.

  (5) Launch Monitor Control Console - backup control and monitor functions.

  (6) Intercom - voice communication with controlling elements (STC, LCC).

4.4.8.2 Remote Stimulation Equipment

- Equipment Identification and Usage - This equipment provides a remotely controllable source of test stimuli to the ESP as required to support systems testing at the CB factory and KSC.
- Design Requirements and Constraints - The Remote Stimulation Equipment is required to apply the following test stimuli to the ESP: ac voltages, dc voltages, and resistive loads. The equipment operates under remote digital control from the Capsule Bus Computer Data System (CDS) via the Ground Data Transmission System (GDTS).
- Physical Characteristics - The remote Stimulation Equipment is mounted in a single standard cabinet as shown in Figure 4.4-7. It is located near the ESP in all Flight Capsule test configurations.

FUNCTIONAL BLOCK DIAGRAM
DC POWER CONTROL

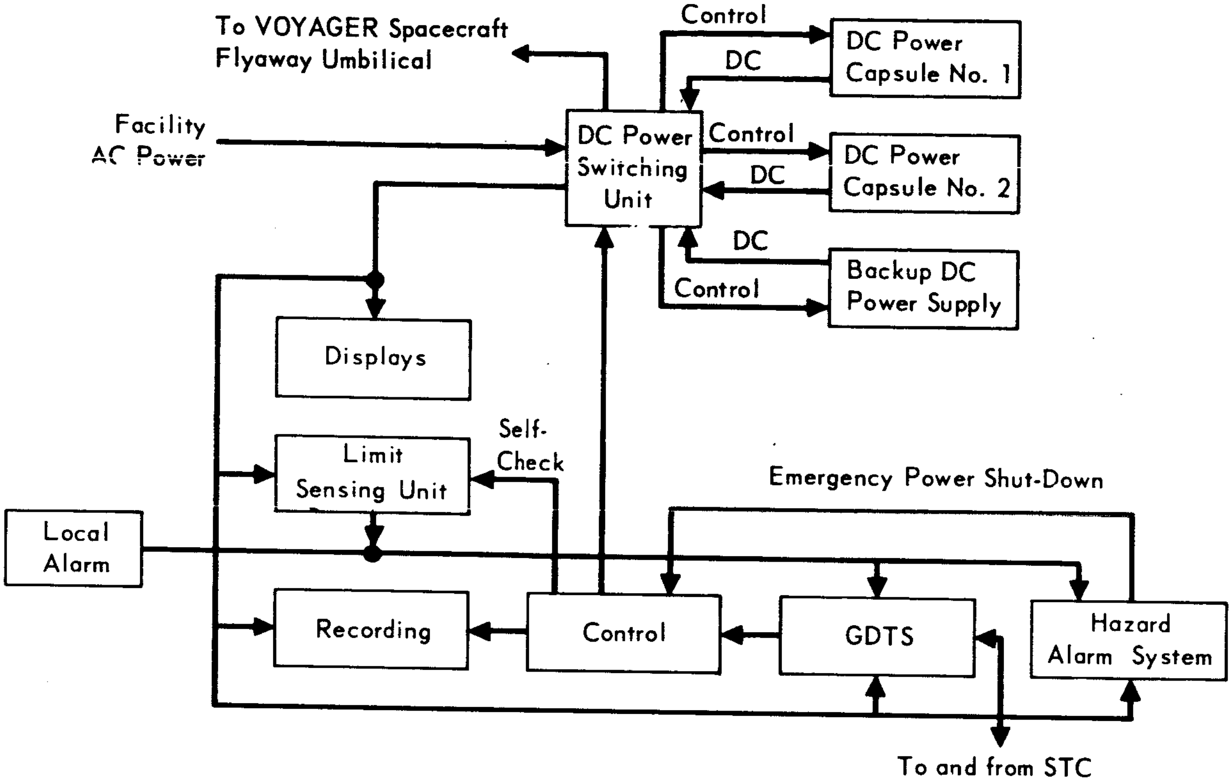


Figure 4.4–5

FUNCTIONAL BLOCK DIAGRAM
AC CENTRAL POWER CONTROL

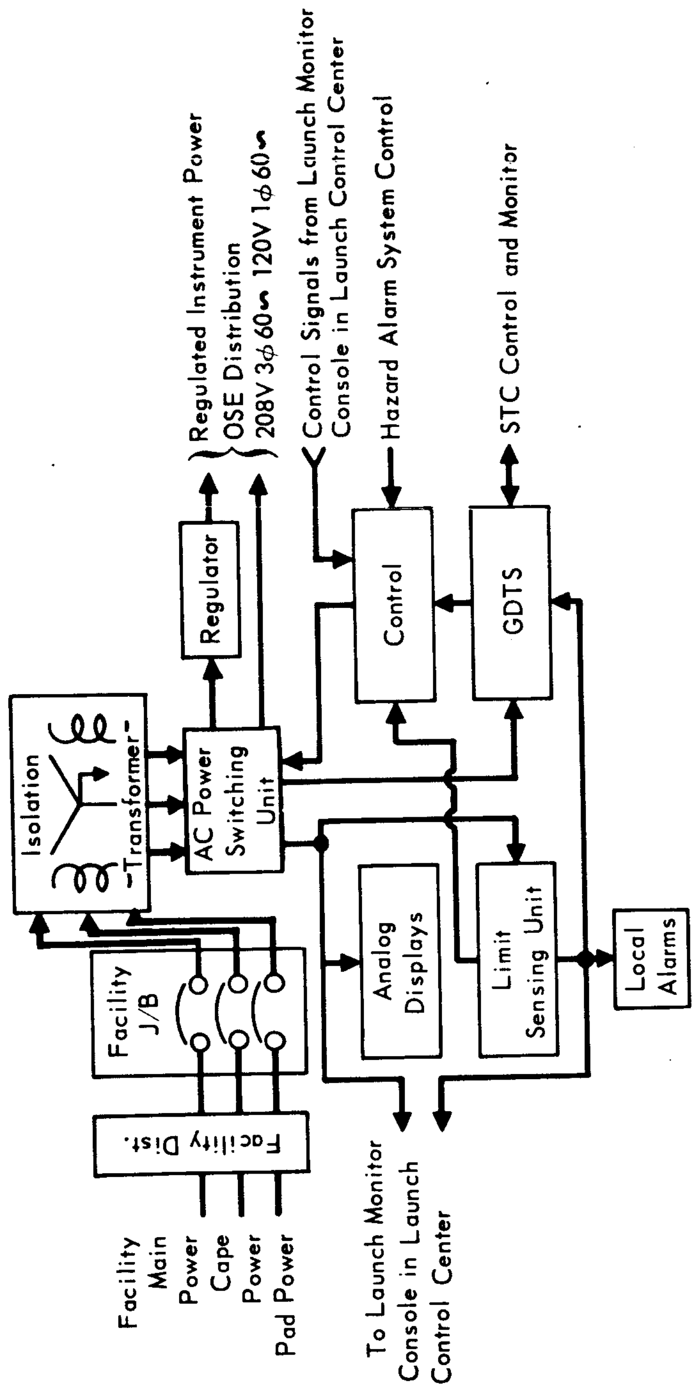
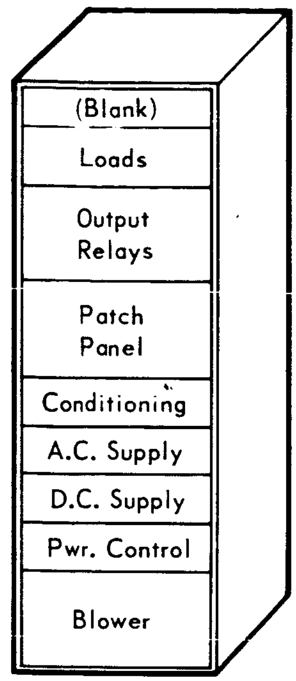


Figure 4.4-6

REMOTE STIMULATION UNIT



REMOTE STIMULATION UNIT FUNCTIONAL BLOCK DIAGRAM

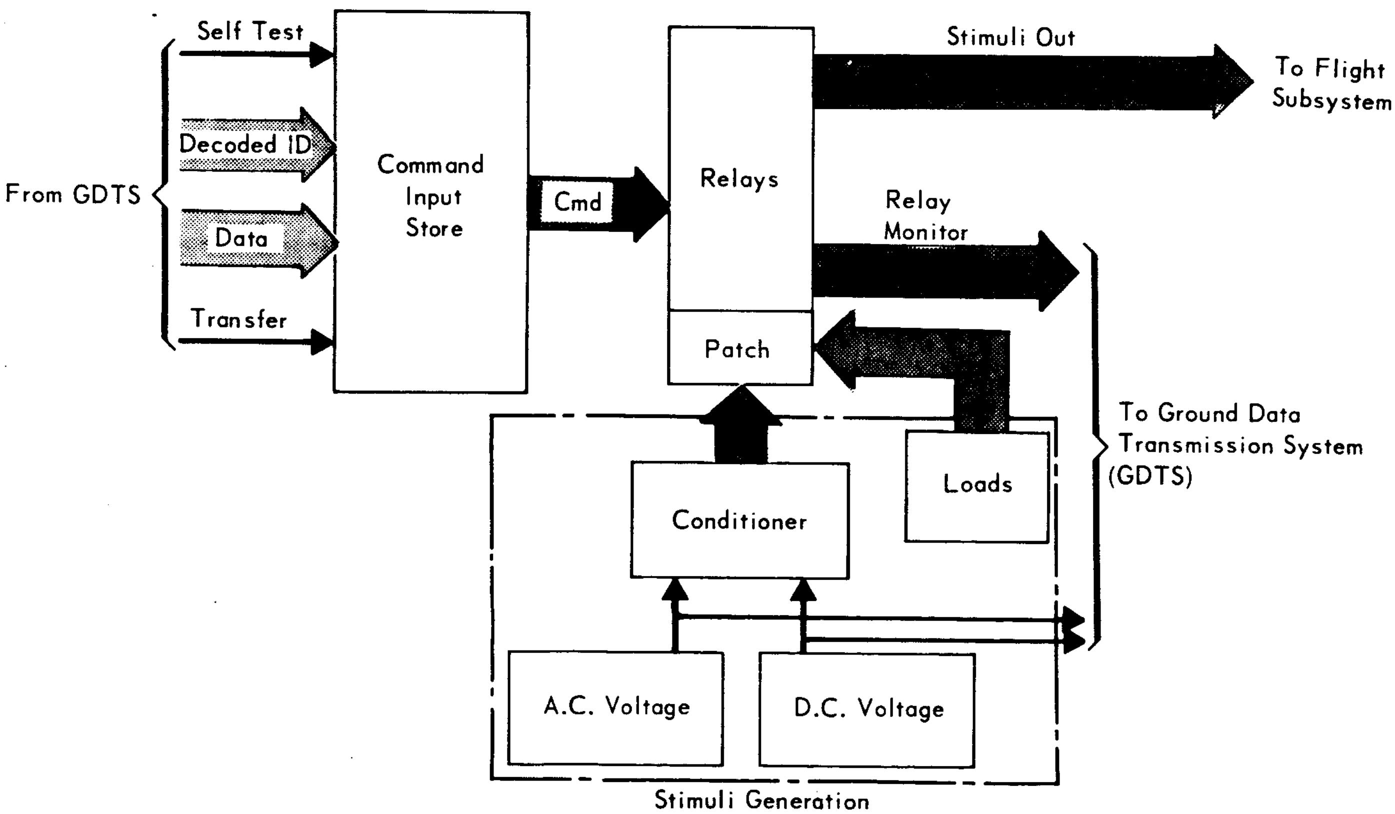


Figure 4.4-7

- Operational Description - The Remote Stimulation Equipment receives commands with identification lines from the GDTS. The equipment actuates a relay for each command received that controls the application of the selected stimulus to an ESP test point. A functional block diagram of the equipment is shown in Figure 4.4-7.

Test commands from the GDTS are received as discrete levels in 8 bit groups with an identification line for each group. The groups are shifted into the input storage by a transfer pulse from the GDTS. Outputs from the storage drive a relay coil with each bit position. The relay contacts connect the desired vehicle test point to the correct stimuli generated in the conditioner, or a resistive load via a patch panel. The conditioner contains voltage dividers that convert the power supply outputs to the desired stimuli levels.

Stimuli verification during normal operation is provided by monitoring a separate contact set on each relay via the GDTS. In this manner, the test point stimuli configuration is known at all times.

Self Test is performed by software in the CDS computer. A self test command sent from the CDS via the GDTS (removes the signals) from the stimuli relays. The CDS then checks all relays for pull-in and drop-out by issuing self test commands and verifying relay actuation via the relay monitor contacts. The stimuli power supply voltages are monitored constantly by the CDS via the GDTS to verify their correct operation.

- Interfaces - The remote Stimulation Equipment interfaces with the GDTS for its inputs in all configurations. The output interfaces for CB factory and KSC Flight Capsule tests are the Spacecraft/Capsule Bus umbilical and the OSE umbilical. For Planetary Vehicle integrated tests, only the Spacecraft umbilical is used for stimuli transfer to the ESP.

4.4.8.3 LCC Equipment

Identification and Usage - The Launch Control Center required LCE consists of an ESP panel mounted in the Capsule Bus Launch Monitor Console. It provides the operator with ESP status and test displays. It also provides controls and displays of critical ESP LCE functions.

Physical Characteristics - Figure 4.4-8 shows the ESP Launch Monitor Panel that is designed to be compatible with the Capsule Bus console. It contains discrete indicators and switches. The ESP status data is hardlined from the CB STC using a voice frequency tone system transmitted over standard phone lines. Critical functions are hardlined from the ESP LCE at the pad.

ESP LAUNCH MONITOR PANEL

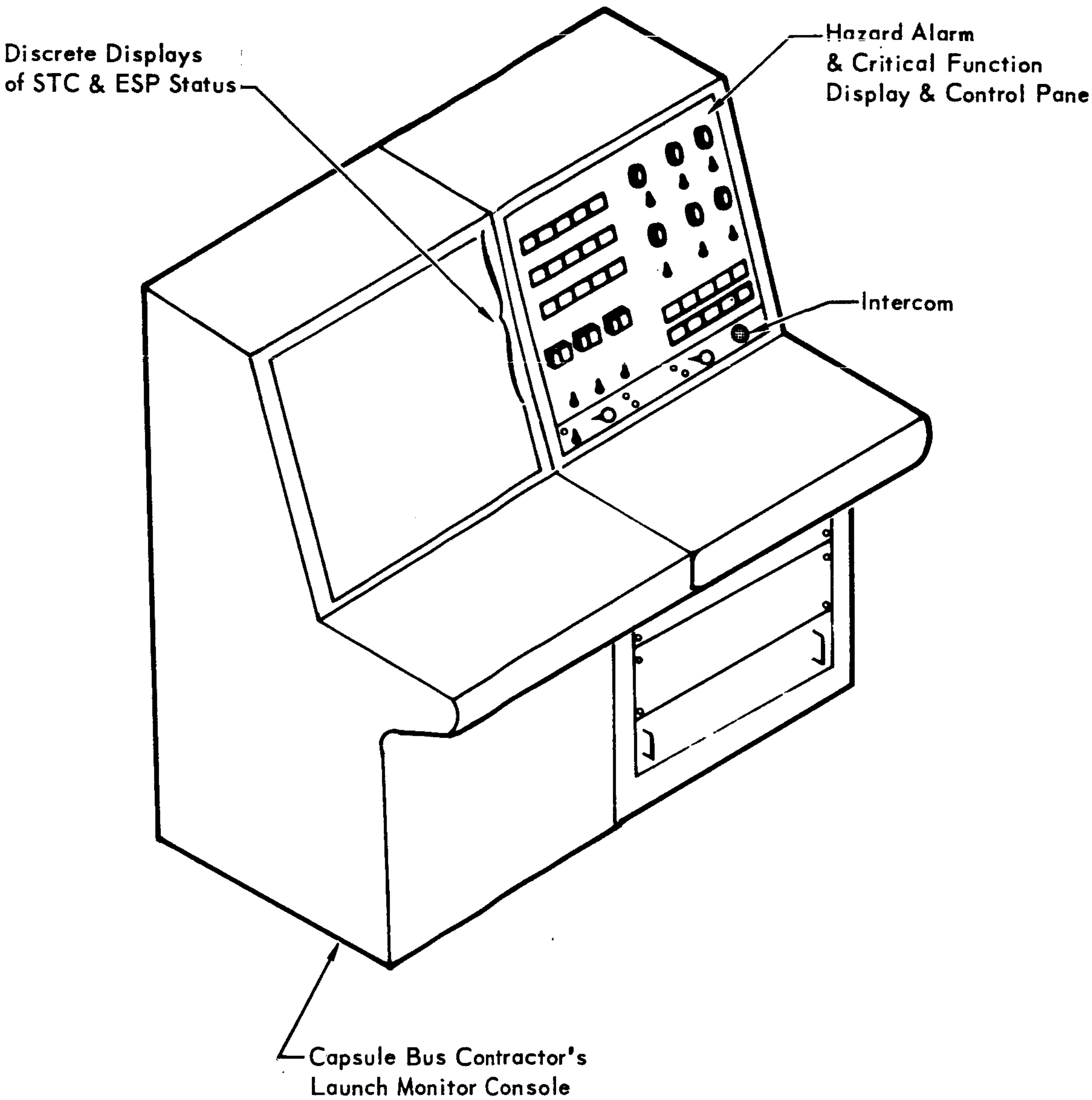


Figure 4.4-8

Operational Description - The console operator monitors discrete indicators that display the status of the ESP during system tests at the Pad. Discrete displays of ESP subsystem test status are also monitored. The operator uses the switches to control ESP ground power and other critical functions within the LCE at the pad. The functional block diagram of Figure 4.4-9 depicts the interfaces and major functions of the ESP Launch Monitor Panel.

4.4.8.4 LCE Required STC Equipment - The System Test Complex (STC) equipment is used in conjunction with the LCE to perform essentially the same functions as it does during ESP system testing, as described in Paragraph 4.3.

The STC interfaces with the LCE in the following manner:

- o via the Gound Data transmission System to the ESF and launch pad.
- o by standard phone lines (autiotones) to the LCC.

A more detailed description of the LCE/STC interfaces is shown in the previous Figure 4.4-1.

4.4.8.5 UHF Receiving System

Equipment Identification and Usage - The UHF receiving system consists of dual UHF receivers and RF monitoring equipment to perform measurements on the Entry Science Package UHF signals. The system is capable of remote control by the Capsule Bus Computer Data System via the Ground Data Transmission System (GDTS). This equipment is used for ESP/Flight Capsule integrated testing at the Capsule Bus factory and at KSC.

Design Requirements and Constraints - The UHF receiving system performs the following functinns:

- o Receives both 400 MHz ESP Radio Subsystem FSK modulated signals.
- o Demodulates the FSK Subcarrier and provides a serial Pulse Code Modulated (PCM) bit stream to the STC telemetry processing equipment via the GDTS.
- o Provides a means of measuring RF power and carrier frequency by remote control from the GDTS or by local manual control.
- o Provides spectrum analysis of the ESP transmitted UHF signals.

Physical Characteristics - The UHF Receiving System is housed in a single standard cabinet, as shown in Figure 4.4-10. The total weight is 350 pounds. AC power consumption is 900 watts.

Functional Description - The UHF Receiving System provides an RF interface with the ESP Radio Subsystem signals. RF monitoring and UHF receiving is controlled locally (manual) or by remote control from the Capsule Bus Computer Data System via the Ground Data Transmission System. A functional block diagram of the system

LAUNCH MONITOR PANEL BLOCK DIAGRAM

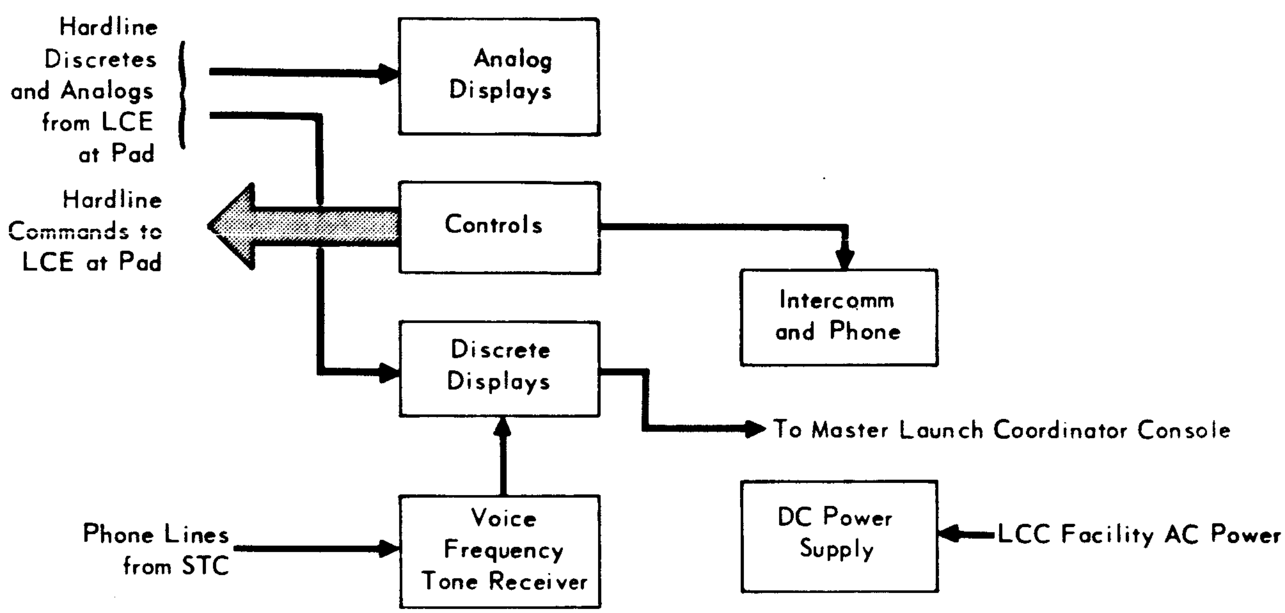


Figure 4.4-9

FUNCTIONAL BLOCK DIAGRAM UHF RECEIVING SYSTEM

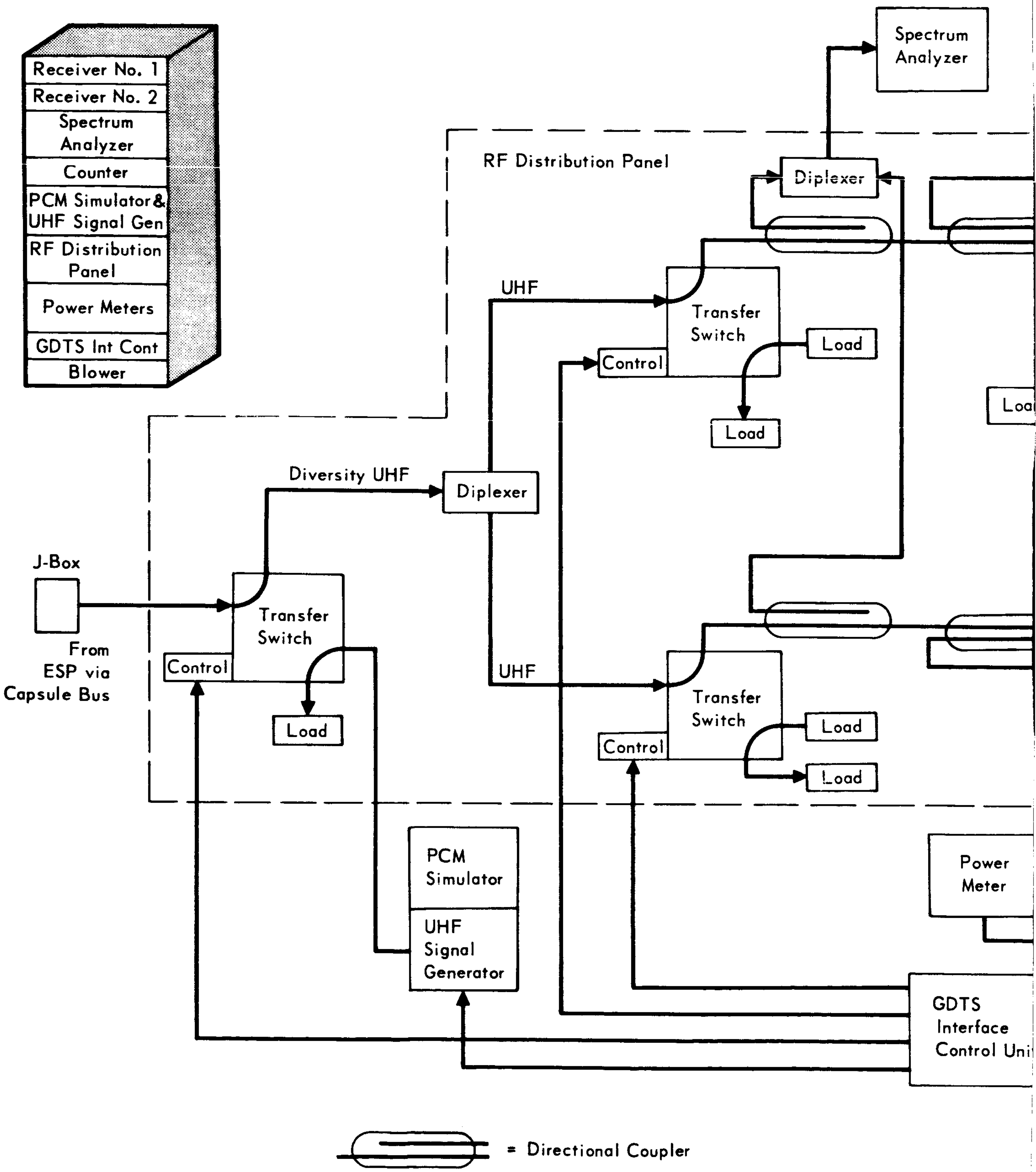
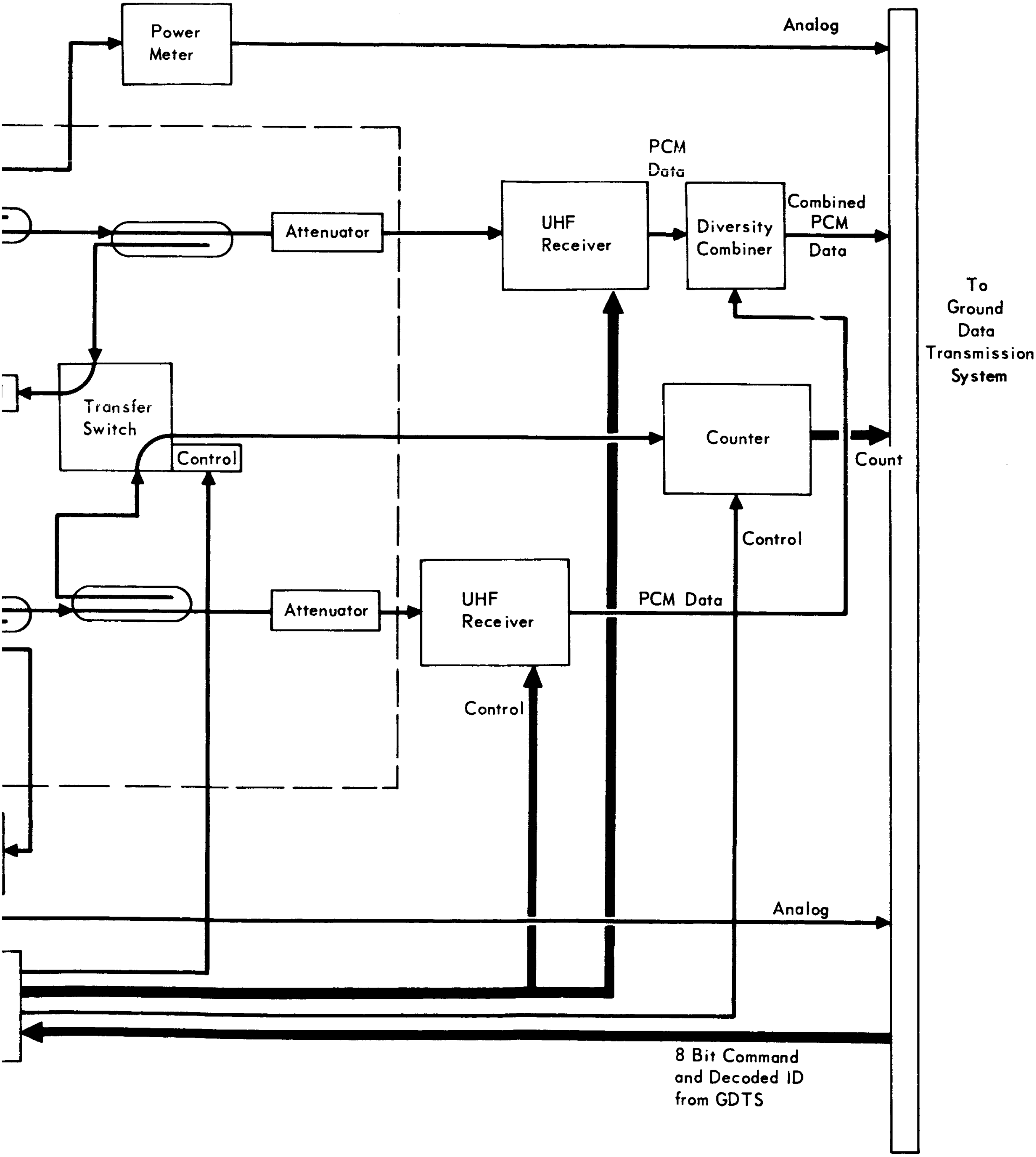


Figure 4.4-10



Power Meter
Analog
PCM Data
Attenuator
UHF Receiver
Diversity Combiner
Combined PCM Data
To Ground Data Transmission System
Transfer Switch
Control
Counter
Count
Control
Attenuator
UHF Receiver
PCM Data
Control
Analog
8 Bit Command and Decoded ID from GDTS

is shown on Figure 4.4-10.

The RF signals are routed to an RF distribution panel where they are coupled to power meters, an electronic counter, a spectrum analyzer, and the UHF receivers. The receivers demodulate the FSK signal and provide two PCM inputs to the diversity combiner. The combiner output is a single serial pulse code modulated (PCM) bit stream that is sent to the STC for decommutation via the GDTS.

The GDTS interface control unit controls the position of the transfer switches to connect either of the UHF signals to the input of the counter. It also selects the counter range and controls the frequency range of the UHF receivers.

The spectrum analyzer permits the monitoring of the spectral characteristics of the Capsule Bus transmitted signals to verify that no spurious radiation is present.

Self-test is performed by switching a 400 MHz signal generator into the receivers, power meter and counter, and monitoring the outputs locally or at the STC via the GDTS.

Interfaces - The UHF receiver system interfaces with the GDTS for data outputs and control inputs. The RF interface is with the Capsule Bus/Spacecraft interface connector before mating and the Spacecraft umbilical after Planetary Vehicle integration. The UHF radio frequency is brought out through these interface connectors on coaxial cables from parasitic antennas in the Capsule Bus, thereby allowing RF sampling during periods of RF silence.

4.5 ENTRY SCIENCE PACKAGE MISSION DEPENDENT EQUIPMENT (MDE) - Mission dependent equipment is required to enhance or supplement the capabilities of the Deep Space Net (DSN) sites and the SFOF. This MDE will support Entry Science Package telecommunications in the areas of telemetry data acquisition, processing and display and command generation and transmission. Special purpose procedures, routines and computer programs are also furnished as a part of MDE. This software is used in conjunction with the computers and data processing equipment at DSIF stations and at the SFOF for acquisition and processing of Entry Science Package data.

This discussion of Entry Science Package Mission Dependent Equipment is based on the assumption that the Flight Spacecraft MDE will provide to the Entry Science Package MDE the reconstructed, interleaved ESP output data serial bit stream as received in the Spacecraft via the UHF relay link. The spacecraft MDE also provides the bit sync required for operation of ESP MDE.

4.5.1 Requirements and Constraints - The Entry Science Package MDE provides hardware and software at DSIF sites and at the SFOF to meet the following set of rements:

a. Acquires the ESP output data from the Spacecraft MDE at DSIF sites.
b. Processes this data to separate ESP TV data from the other CB and ESP data.
c. Transfers ESP TV data to SFOF via video tapes and DSN communications links.
d. Processes non-TV ESP data to derive real-time, 50-second delay, and 150-second delay data.
e. Analyzes these data to derive resultant best quality single bit stream data.
f. Transfers data to Telemetry and Command Processor (TCP) for processing.
g. Transfers non-TV ESP data to SFOF via DSN communication links.
h. At the SFOF, assembles ESP data for processing in the Telemetry Processing Station (TPS) and in the Central Computer Complex (CCC).
i. Performs error detection and correction on these data.
j. Processes TV data for delivery to science experimenters.
k. Processes non-TV data and separates engineering and science data.
l. Transfers science data to science experimenters.
m. Enables display of engineering data in formats suitable for analysis and evaluation.

Additional requirements include compatibility with:

a. DSN equipment input/output characteristics
b. DSN communications link capabilities
c. DSN operational policies and procedures
d. Engineering analysis team data requirements

The major constraints considered in MDE implementation are:

a. The manner in which ESP data is transmitted via the Spacecraft S-band link to DSIF sites.
b. The configuration and operating characteristics of the Spacecraft MDE at DSIF sites and at the SFOF.
c. The format of ESP data as obtained from the Spacecraft MDE, at DSIF sites and/or at the SFOF.
d. The time-line availability and loading of the DSIF and SFOF Computer Complexes.
e. The method of interleaving ESP and CB engineering, science and TV data.
f. Data characteristics and formats required by the science experimenters.
g. The requirements for real-time or near-real-time processing and display of ESP science data at the SFOF.

4.5.2 Equipment Identification List - The ESP hardware MDE is identified in terms of equipment at the DSIF sites and at the SFOF. The related software for the DSIF and SFOF computers is discussed in Section 4.5.4.

The following equipment is utilized:

a. DSIF ESP Data Demultiplexing Equipment - This equipment accepts the interleaved CB, ESP, and ESP TV serial bit stream data from the output of the Spacecraft MDE, performs frame sync recognition, and separates the data into three bit streams; ESP TV and two streams of CB/ESP data.

b. DSIF ESP TV Data Processor - This equipment accepts the TV data from the ESP data-de-multiplexing equipment and performs TV frame sync and line sync recognition, buffers and formats the data on a line-by-line basis and delivers it to a digital tape recorder and a video communications processor.

c. ESP Video Tape Recorder - This multi-track tape recorder provides digital tapes of processed TV data for transport to the SFOF and for use by the TV science experimenters.

d. ESP Video Comm Processor - This equipment accepts TV data from the ESP TV data processor and formats this data for transmission to the SFOF via DSN communications links.

e. DSIF ESP De-multiplexer - This equipment accepts the interleaved non-TV CB/ESP data from the ESP data-de-multiplexing equipment, derives best quality data from the three time-redundant data streams, decommutates ESP data from CB data, and buffers and formats these data for entry into the DSIF Telemetry and Command Processor (TCP).

f. SFOF Data Display Equipment - These displays are provided for use of the ESP engineering analysis teams at the SFOF.

g. SFOF Display Interface Equipment - This equipment provides the interface between the Central Computer Complex (CCC) and Telemetry Processing Station (TPS) and the MDE display equipment and enables distribution of data to displays and to the science experimenters.

h. SFOF ESP Control Console - This console enables control of the display interface equipment and provides for alarm and status monitoring, performance level indication, and mission time and event identification.

i. DSIF Entry Science Package Simulator - This equipment, in conjunction with the Capsule Bus simulator, provides for checkout and compatibility testing of the ESP MDE at the DSIF. Data interfaces are provided; no direct RF interface exists between the ESP and the DSIF.

j. Command Interface Equipment - This equipment interfaces with the spacecraft command MDE and enables ESP command messages to be verified at the time of transmission.

4.5.3 Physical Characteristics - The configuration of the MDE is compatible with JPL specifications regarding size, shape factor, input/output connectors, cabinet finishes and related characteristics. Human engineering criteria developed by JPL are followed in the design of consoles and displays to facilitate their use by JPL and contractor personnel. Figures 4.5-1 and 4.5-2 show typical control console and display console configurations for use at the DSIF sites and the SFOF.

4.5.4 Operational Description - Operational utilization of the ESP MDE is described in terms of DSIF - located MDE, SFOF - located MDE, and communication links within the DSN. Identification is made of significant trade-offs in terms of location of major elements of MDE, utilization vs. duplication of segments of the Spacecraft MDE, and availability, channel capacity and reliability of the DSN communication links. A summary of the software requirements is presented to show the extent of utilization of the DSIF and SFOF computers. Figure 4.5-3 is a simplified block diagram of the major functional MDE elements in the DSIF and SFOF.

4.5.4.1 DSIF MDE - The MDE identified for use at DSIF sites enables the following functions to be accomplished:

- Acquisition of interleaved CB/ESP data from the Spacecraft main data stream.
- Separation of ESP data from the interleaved CB/ESP data.
- Derivation of best quality data from time-redundant data blocks.
- Processing of these data for transfer to SFOF via DSN communications links.
- Pre-detection and post-detection recording of receiver IF and data signals to provide a back-up source of data in event of failure within the DSIF system.
- Recording of ESP TV data to enable transfer to SFOF via magnetic tapes.
- Computer correlation of real-time and delayed data to analyze effects of multipath and ionization black-out.

4.5.4.2 SFOF MDE - The MDE identified for use at the SFOF enables the following functions to be accomplished:

- Acquisition of the data received from the DSIF sites via the communications links.
- Formatting of these data by the TPS for entry into the CCC.

ENTRY SCIENCE PACKAGE MODE CONTROL CONSOLE

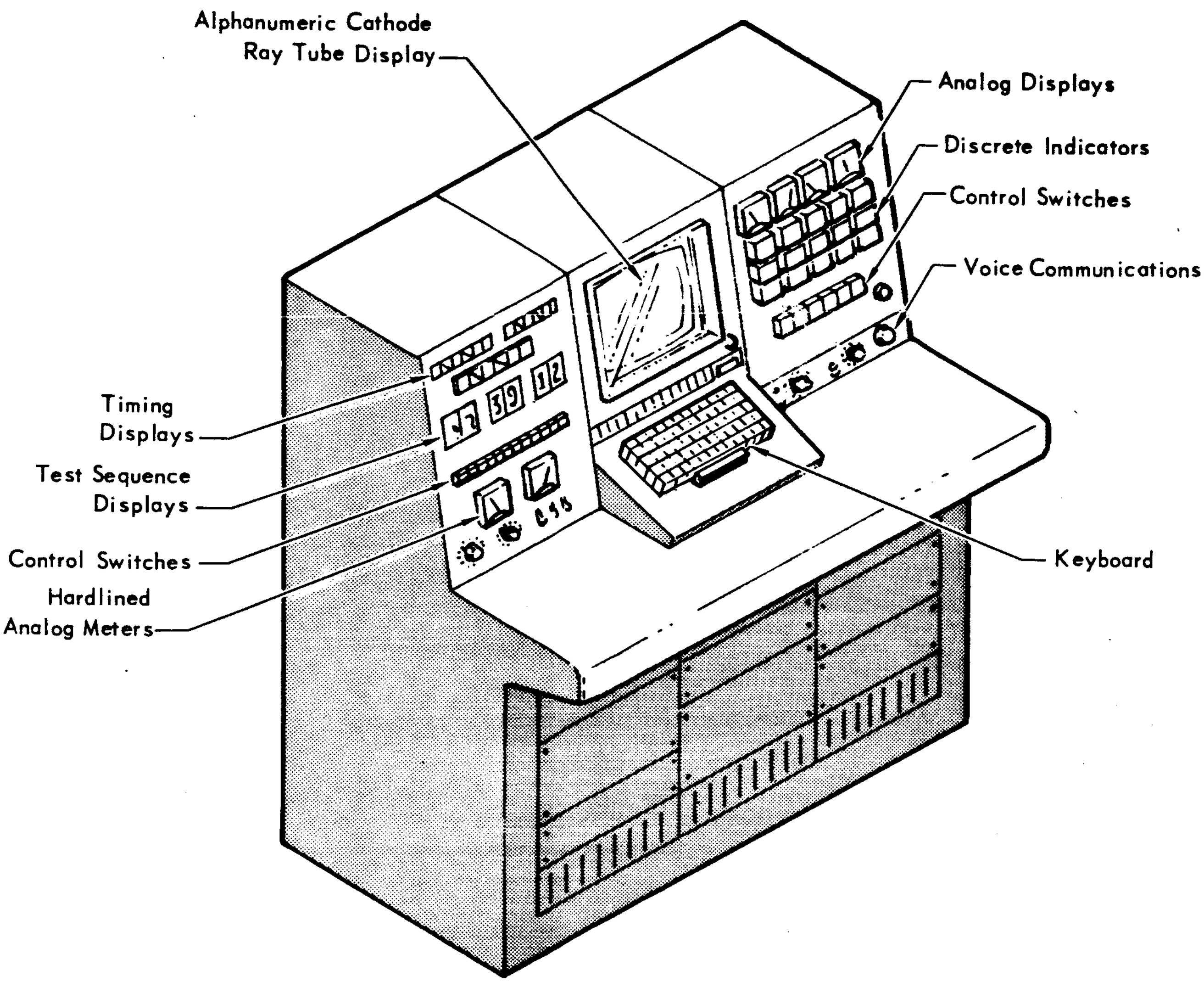


Figure 4.5–1

TYPICAL ESP MDE DISPLAY CONSOLE

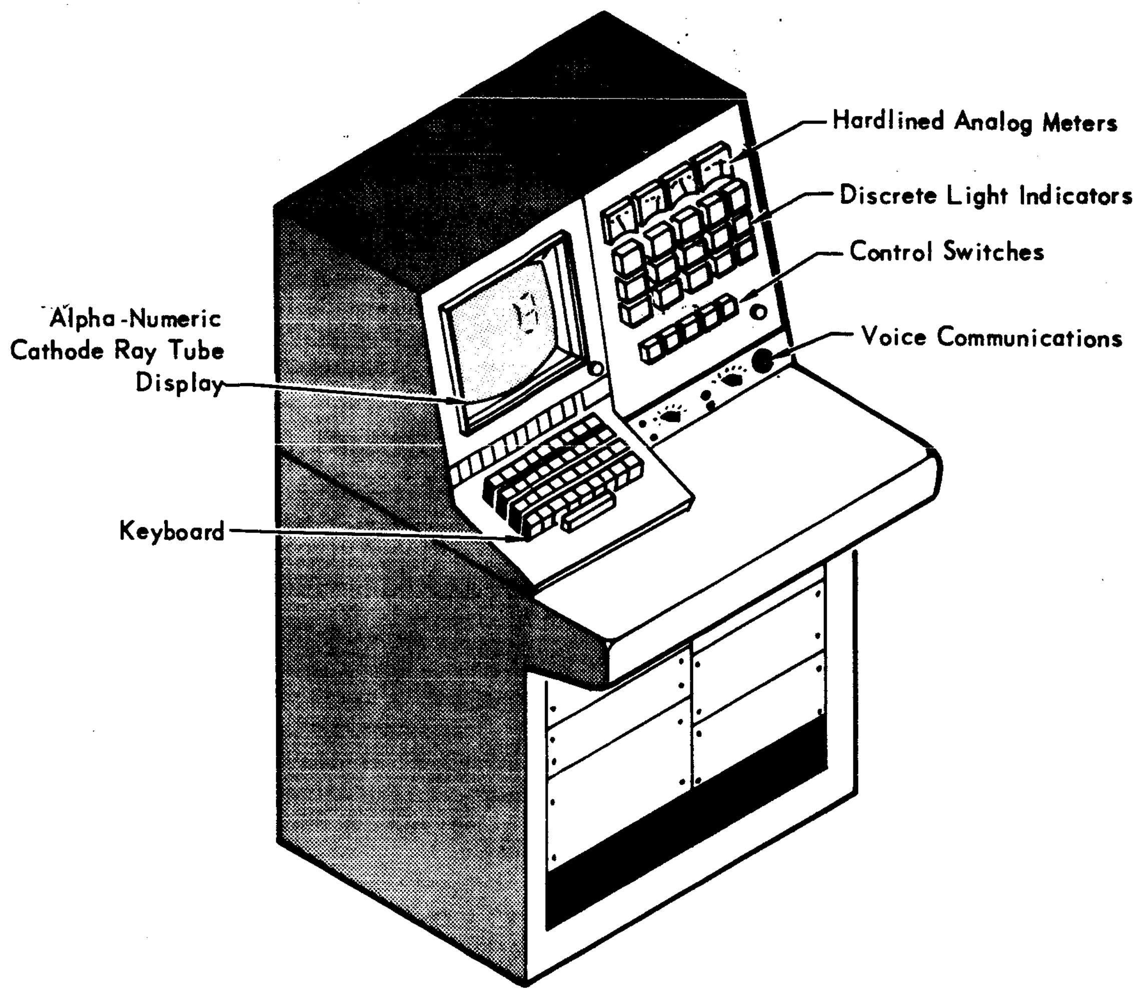
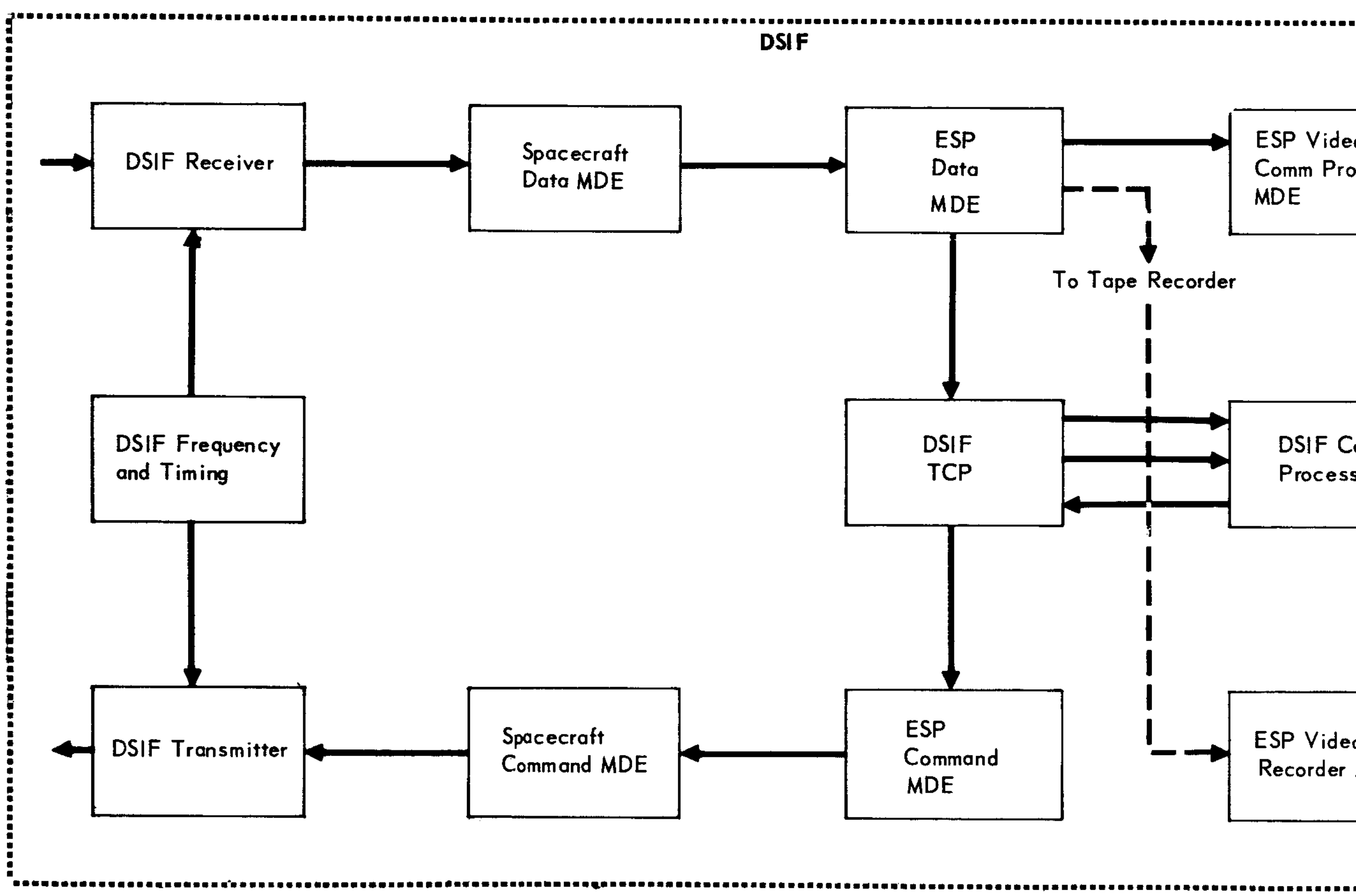


Figure 4.5-2

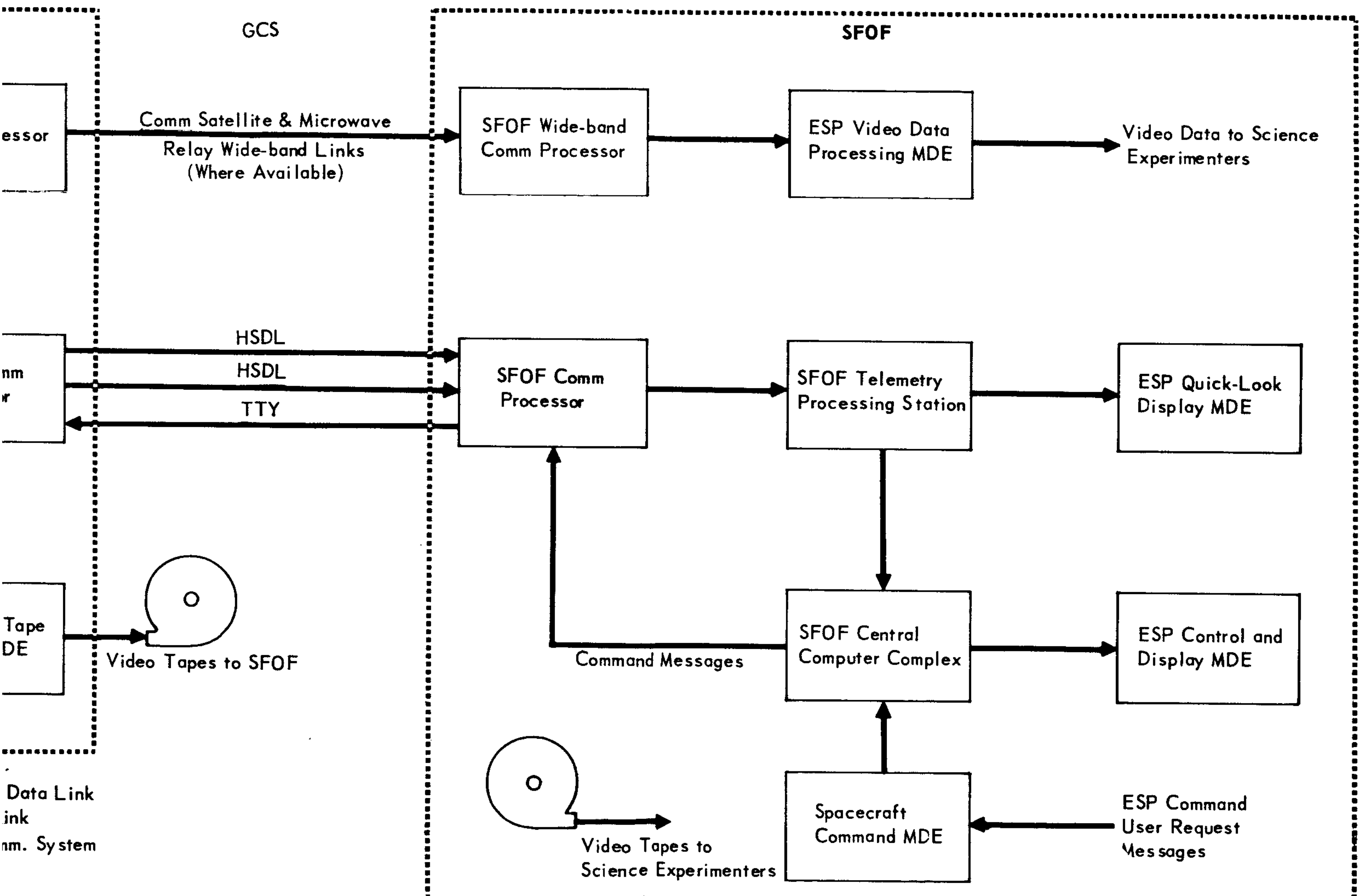
BLOCK



Note: HSDL – High Spee
TTY – Teletype
GCS – Ground C

Figure 4.5-3

DIAGRAM, ESP DATA FLOW



- o Processing and print-out of these data by the CCC.
- o Transfer of data to displays and read-out devices.
- o Display, print-out and recording of data for use by engineering analysis teams.
- o Selective compilation of data to facilitate failure modes and effects analysis.
- o Processing of data into formats required by science experimenters.
- o Transfer of data to the science experimenters.

4.5.4.3 DSIF MDE Computer Software - The software considered in this report includes computer programs for use within the Telemetry and Command Processor (TCP) at the DSIF sites. Software development provides computer programs which contain the following characteristics:

- o Performance in all operating modes with all permutations of input data consistent with capabilities of the TCP.
- o High probability of detecting submarginal performance or failure of ESP subsystems.
- o Minimal reprogramming of identical and/or similar functions to support the various levels and sequences of MDE operations.
- o Flexibility of operation to support changes in data formats due to contingencies or alteration in mission sequences.

The software modular design will ensure compatibility with the operational environment and computer program formats. Independent checkout of program modules and sub-programs will provide structural and linkage compatibility with mission-independent programs. Additional requirements relate to the capability to check out programs with simulated interfaces and in the actual operating environment.

The software enables the TCP to buffer, format, and edit the ESP non-video data stream as it is received from the MDE equipment. Each data frame is identified as it is stored in the input buffer. The data is then transferred to the communication processor for transmission over DSN high speed data lines to the SFOF. The TCP software developed for ESP data processing will be fully compliant with the current TCP computer configuration and with DSIF operating modes and data formats.

The concepts and criteria for software development outlined in Part J, Section 8 of this volume will serve as guidelines for MDE software.

Trade-offs regarding functions accomplished by equipment vs those performed by means of software for the DSIF and SFOF computers have been evaluated during the study. Programming costs and computer utilization effectiveness must be balanced against equipment costs, development time and reliability to allow the final decision regarding hardware vs software to be made during Phase C.

4.5.4.4 SFOF MDE Computer Software - Many of the same criteria considered for DSIF software also apply to the SFOF software. The utilization of the SFOF computers for mission control and operations, status monitoring and display control, and other non-telemetry data handling imposes additional constraints on the software structure for the Entry Science Package.

Software is provided to enable the telemetry processing station (TPS) to accept, process and format ESP non-TV data from the high speed data link. The TPS converts the data to an IBM - compatible, 36-bit digital format and produces bulk printer output for quick-look purposes. Data is time-tagged, frame synchronization is established, and these data are fed to the PCM signal conditioner and PCM decommutator within the TPS. The data is then transferred to a PDP-7 computer for further processing into a format suitable for entry into the 7288 Data Communication Channel, which serves as the input output buff or the IBM 7044/7094 system within the Central Computer Complex (CCC). The CCC processes the data into formats suitable for driving both the on-line and off-line data display devices, performs analysis of the data, examines data for failure mode effects and trends, and derives quality assessments for each telemetry data channel.

Modular software is required for the PDP-7, 7044 and 7094 computers within the SFOF. This software enables the accomplishment of the functions described in the previous paragraph, and will be patterned after similar programs developed by JPL for use in other deep-space missions. The software will be fully compatible with JPL computer programming policies and will utilize the optimum machine language for each phase of the mission.

4.5.4.5 SFOF TV Data Processing - Entry Science Package TV data is transferred from DSIF sites to the SFOF via DSN communications links and by means of magnetic tapes. The tapes enable introduction of the ESP video data into the SFOF closed-circuit television display subsystem and are given to the science experimenters as an alternate source of TV data. Transmission over the DSN communications links involves use of two facilities; the Goldstone-to-Pasadena microwave link and the wideband video channel provided by use of the communications satellites programmed for operation by 1973. These circuits have adequate capacity to handle the ESP TV data in "real-time" between DSIF sites and the SFOF.

4.5.5 Interface Definition - Significant MDE hardware and software interfaces identified during the study are shown in Figure 4.5-3 and are grouped in the following way:

DSIF Interfaces

a. Output of Spacecraft MDE and input to ESP MDE
b. Output of ESP MDE and input to the TCP
c. Output of ESP MDE and input to Ground Communication System (GCS)
d. TCP software used for Spacecraft, SLS and CB data processing and TCP software used for ESP data processing.

SFOF Interfaces

a. Output of Telemetry Processing Station (TPS) and input to ESP display interface equipment.
b. Output of TPS and input to ESP control console.
c. Output of Central Computer Complex (CCC) and input to ESP display control console.
d. Output of CCC and input to ESP control console.
e. TPS and CCC software used for Spacecraft, SLS and CB data processing and TPS and CCC software used for ESP data processing
f. SFOF control consoles/displays and ESP control consoles/displays

Operational interfaces relate to priorities assigned to ESP real-time data displayed at the SFOF vs Spacecraft, SLS and CB data. These interfaces are constrained by the loading on the DSIF TCP and the DSIF - SFOF communications channels.

Technical interfaces exist between data channels, sync channels, timing lines display drivers, control lines, and status monitors. Compatibility is required in areas of timing accuracy, sync jitter, noise immunity, signal isolation, data formats, and error detection and correction. In addition, the obvious requirements in terms of impedances, voltage levels, spurious signal rejection, and similar items will be met during the design phase of the program.

4.5.6 Reliability and Safety - Successful acquisition and processing of data during crucial phases of the mission is directly dependent on certain elements of the MDE. For this reason, the operational reliability requirements imposed on the MDE are similar to those for the Flight Capsule equipment. Sufficient functional redundancy is provided to prevent total loss of data in the event of failure of an element of the MDE. Both pre-detection and post-detection recording of incoming data is performed to back up real time data acquisition. In addition, recording of processed data prior to transmission over the DSIF-SFOF communications links provides for a back-up data source and use of an alternate communications link in event of failure of the primary link.

The design and implementation of MDE (including software) will prevent the existence of situations that are hazardous to personnel or potentially damaging to the equipment and facilities comprising the DSN, the Entry Science Package or any of its subsystems.

The full utilization is made of the time-redundant ESP data to ensure a high level of confidence in reliability of the data. In addition, software design is proven by detailed checkout routines accomplished on the TCP and CCC computers early in the program.

4.5.7 Development Status - No critical development problems are forseen for the equipment located at the SFOF. Displays and consoles, similar to those developed for JPL, the Manned Spaceflight Center and other NASA activities, present no significant new development effort.

The DSIF MDE development will proceed in parallel with that of the flight hardware. Absence of such design constraints as serilization requirements and compatibility with the space environment simplify the evolution of a suitable design. Where applicable, flight hardware circuits, components and techniques are utilized to provide operational compatibility and to ensure high performance and reliability. An example of such an application to MDE is the DSIF ESP data de-multiplexing equipment.

4.5.8 Growth Capability - The DSIF equipment and software design will recognize the possible expansion in data-gathering capability of the Flight Capsule systems. Trade-offs evaluated during the study in terms of processing data at DSIF vs at the SFOF indicate that sufficient growth potential is required in the MDE and DSIF sites to allow for partial unavailability of DSN communications links. Significant changes in Flight Capsule configuration will be accommodated by minor alterations to the MDE equipment and re-formatting of subroutines in TCP software.

Software development will provide sufficient flexibility to effectively accommodate changes in data requirements and formats. Subroutines will be structured to allow for variations in data content and alteration in mission sequences without the necessity for generation of entirely new programs. The SFOF equipment will permit addition of new control and display devices with a minimum of redesign or physical modification.

Extra input and output channels facilitate the inclusion of new sources of data into the information flow.

4.5.9 MDE Equipment Functional Descriptions - The equipment chosen to implement the major Entry Science Package MDE functions outlined in Section 4.5.2 is described in the following sections. The equipment uses digital logic modules implemented by use of high-performance integrated circuits mounted on plug-in circuit cards for ease of access and simplified maintenance. Where feasible, equivalent circuits and components to those in the flight hardware are utilized in the interests of high performance, reliability and standardization.

4.5.9.1 DSIF ESP Data De-Multiplexing Equipment - A simplified block diagram of this equipment is shown in Figure 4.5-4. Two signals are received from the Spacecraft MDE; the interleaved ESP output data and bit sync. These signals are fed via signal conditioning circuitry to frame sync recognition logic, which provides a frame sync pulse on recognition of the 31-bit frame sync word. Frame sync and bit sync control operation of the de-multiplexing circuitry, which shifts the blocks of data out to the processing elements at appropriate times. Frame sync and bit sync are also supplied.

4.5.9.2 ESP TV Data Processor - The Entry Science Package TV data blocks, consisting of 21 bits of identification data (frame numbers, iris setting, camera number, etc.) and 1200 bits of video data, are acquired by the ESP TV data processor. This unit performs frame sync and line sync recognition and buffers and formats TV data line-by-line for delivery to a digital tape recorder and to the ESP video comm processor. Frame sync, line sync and bit sync signals are also supplied to these units.

4.5.9.3 ESP Video Tape Recorder - The ESP video tape recorder is used to provide a backup source of TV data and produces video tapes which are sent to the SFOF for further processing and delivery to the science experimenters. Standard, high-quality instrumentation recorders will be used, with multiple-track recording of data used to minimize effects of bit distortion on the data.

4.5.9.4 ESP Video Comm Processor - The ESP video comm processor formats the digital TV data for transmission over the Goldstone-Pasadena microwave link and over Ground Communications System (GCS) circuits to communications satellite ground terminals. Use of comm satellites enables ESP TV data to be delivered in near-real-time from overseas DSIF sites.

Transmission of ESP TV data in digital form to the SFOF facilitates early utilization of picture enhancement techniques developed and successfully employed by JPL for the Mariner and Surveyor programs.

BLOCK DIAGRAM, ENTRY SCIENCE PACKAGE DSIF MISSION DEPENDENT EQUIPMENT

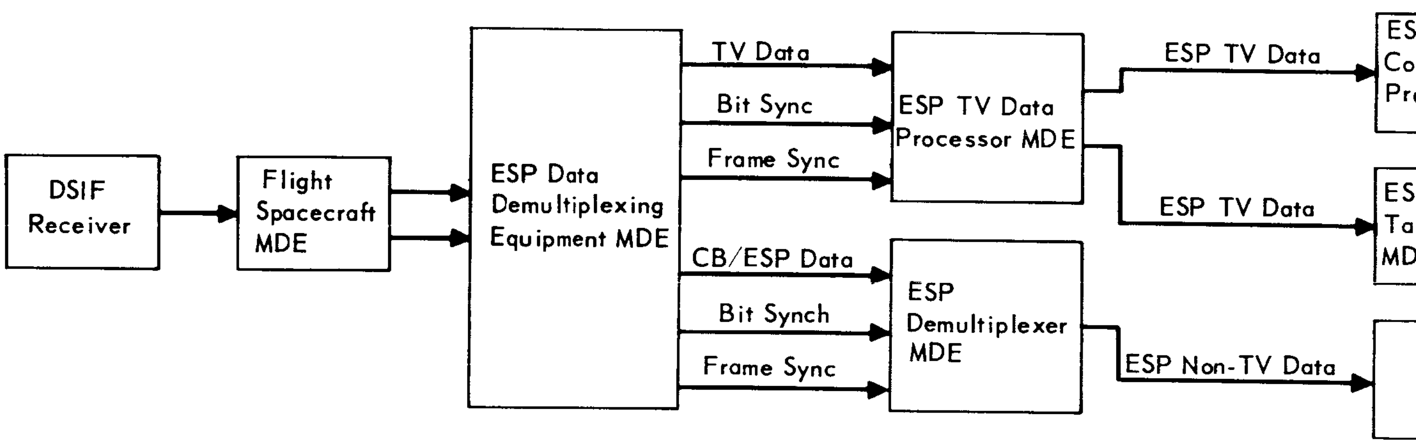
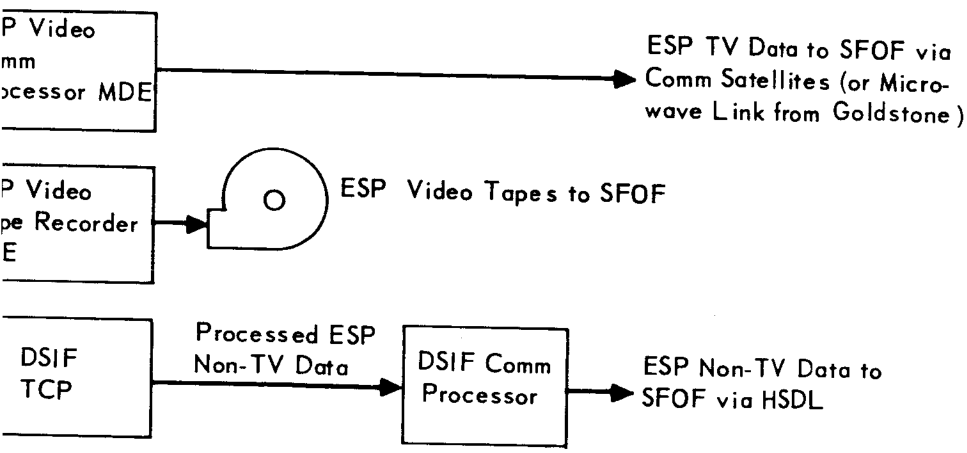


Figure 4.5-4



P Video
mm
ocessor MDE
ESP TV Data to SFOF via Comm Satellites (or Micro-wave Link from Goldstone)
P Video
pe Recorder
E
ESP Video Tapes to SFOF
DSIF TCP
Processed ESP Non-TV Data
DSIF Comm Processor
ESP Non-TV Data to SFOF via HSDL

4-64-2

4.5.9.5 ESP De-Multiplexer - The following discussion applies to one de-multiplexer, since the two units are identical and process the same bit stream which has arrived at different times over different data paths.

The time-redundant, interleaved ESP/CB data stream is obtained from the ESP data de-multiplexing equipment in blocks of 64 bits immediately following the 31-bit frame sync word. Each block of data is read into a 64-bit storage shift register. When 12 shift registers are filled, the data is read out in series in a first bit in-first bit out order to a 3-channel sequencer. The first bit goes to Channel A, the second bit to Channel B and the third bit to Channel C, and so forth. This places all the real-time bits in one channel, the 50-second delay bits in another, and the 150-second delay bits in the third. To identify which channel contains which bits, a three-channel time correlation process is accomplished, as shown in Figure 4.5-5. When correlation is indicated at the output of one of the time comparators, the channel having the 50-second delay is the real-time channel and the other channel is the 50-second delay channel. The remaining channel is the 150-second channel. The block diagram example assumes real-time data on line A.

The real-time data is applied via a 150-second delay to one input of a majority voter, the 50-second delay data is applied via a 100-second delay to another input, and the 150-second delay data applied with no delay to the third input of the majority voter. The output of this device represents an enhanced replica of the original, real-time interleaved CB/ESP data.

This data stream is now read into a de-interleaver where the Capsule Bus data stream is separated from the Entry Science Package data stream. The composite data is fed into a storage shift register whose length is sufficient to include both the CB and the ESP frame sync words, plus intervening data. Frame sync detection logic enables recognition of both frame sync words, enabling the two data streams to be separated. These data, along with associated frame sync, are buffered and formatted for entry into the TCP, and processed for transmission via the high speed data link to the SFOF.

4.5.9.6 DSIF Command MDE - This equipment interfaces with the Spacecraft command MDE to validate Entry Science Package commands prior to final transmission. A simplified diagram of a method of implementation is shown in Figure 4.5-6, "DSIF Entry Science Package Command MDE."

DSIF ENTRY SCIENCE PACKAGE DATA DEMULTIPLEXING MDE

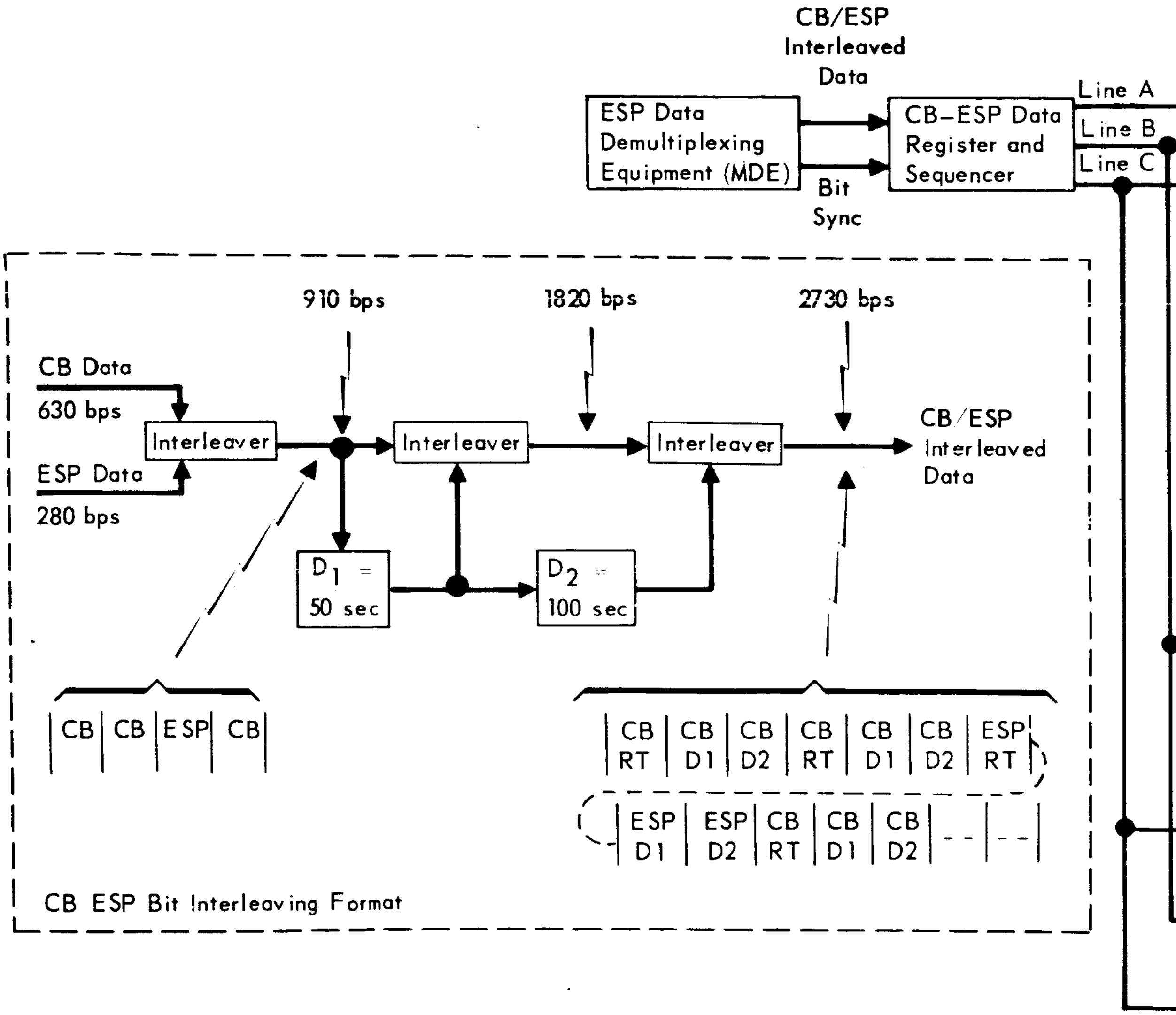
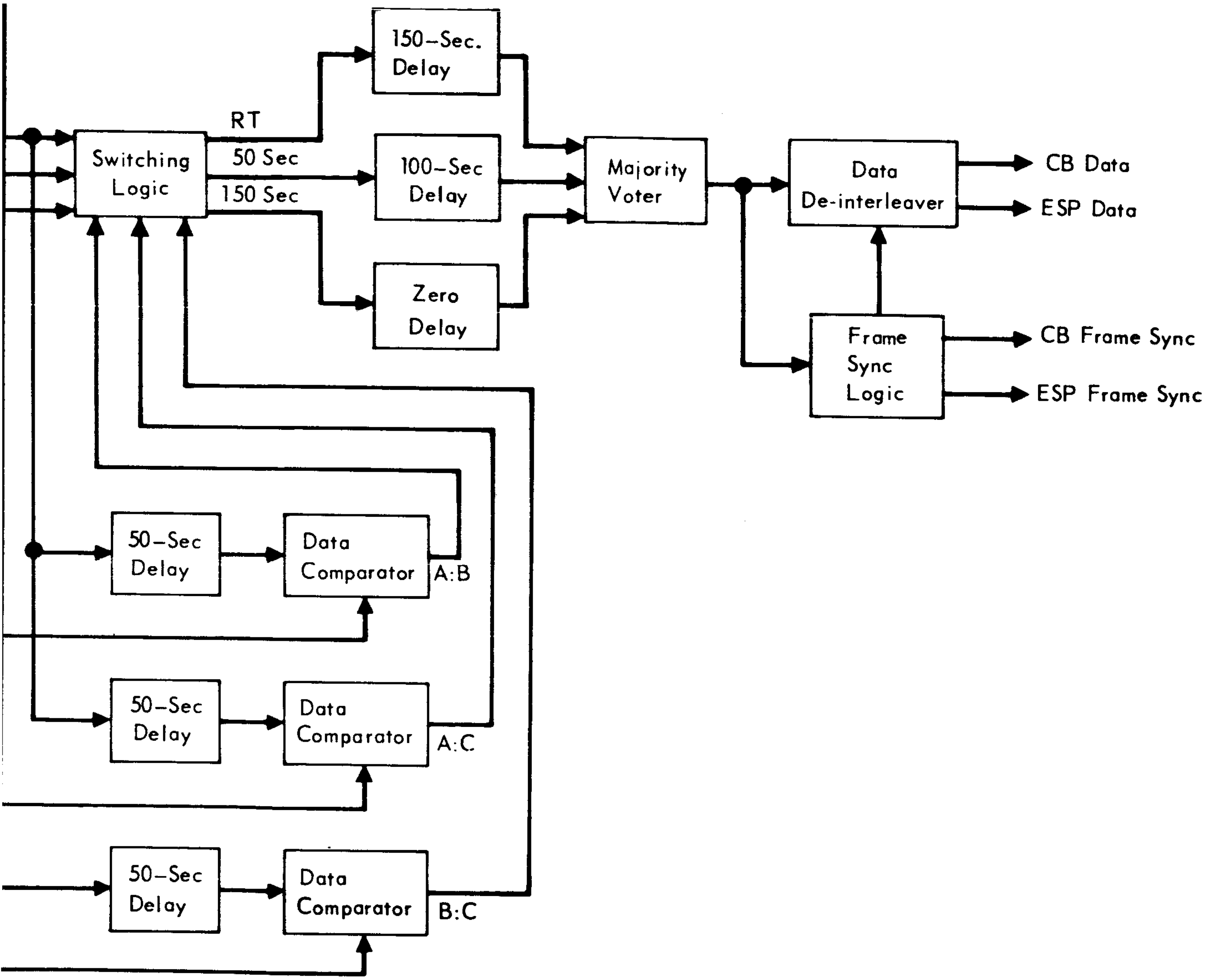


Figure 4.5-5


150–Sec.
Delay
RT
Switching
Logic
50 Sec
100–Sec
Delay
150 Sec
Majority
Voter
Data
De-interleaver
CB Data
ESP Data
Zero
Delay
Frame
Sync
Logic
CB Frame Sync
ESP Frame Sync
50–Sec
Delay
Data
Comparator
A:B
50–Sec
Delay
Data
Comparator
A:C
50–Sec
Delay
Data
Comparator
B:C

DSIF ESP COMMAND MDE

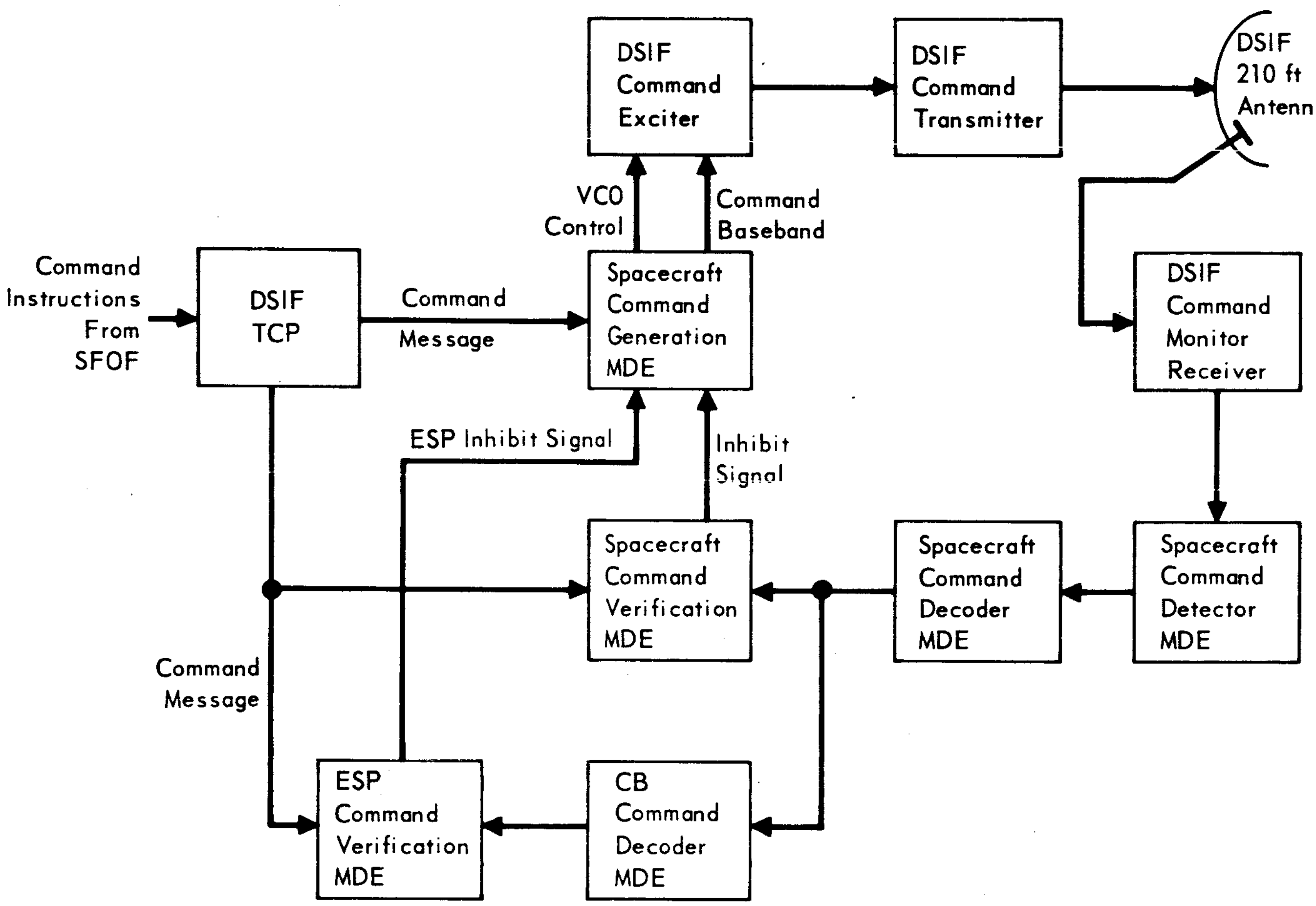


Figure 4.5-6

Composite command instructions are received via the DSN communications links from the SFOF; correct receipt of these instructions is verified in the TCP by use of Spacecraft (S/C) MDE software. The TCP then issues command messages in the S/C format; some of these messages contain ESP commands, prefaced by a CB command decoder address. A S/C command baseband is generated, and phase-modulated on the S-band up-link carrier. The DSIF monitor receiver acquires and demodulates this carrier, transferring the demodulated baseband to the S/C command detector and decoder MDE. The decoded command message at the S/C decoder output is compared with the original command message from the TCP by use of the S/C command verification MDE. If an error is detected, an inhibit signal is sent to the S/C command generation MDE to terminate the transmission.

The CB command decoder MDE recognizes the CB address in the output of the S/C command decoder MDE, decodes the ESP command message and transfers it to the ESP command verification MDE. This unit compares the received ESP command message with the ESP command message from the TCP and sends an inhibit signal to the S/C command generation MDE if an error is detected.

4.5.9.7 SFOF Data Display Equipment - This equipment consists of multi-function displays meeting the requirements of the Entry Science Package subsystem engineering analysis teams and implemented to make maximum use of the data received via the ESP telemetry link. Display configuration is fully compliant with JPL specifications regarding cabinet physical characteristics, human engineering criteria, display formats, and control and monitor functions.

System evolution will allow a more detailed development of engineering display requirements during Phase C. However, representative displays are described to outline the categories of equipment which have been considered.

Cathode ray oscilloscope displays which present English language alphanumeric lines of computer print-out data on either an automatic or a call-up basis are provided in each of the engineering analysis team areas. By means of adaptive programming, other data to be displayed includes actual vs. estimated values of selected parameters, status, performance indicators, mission alerts, and data nomenclature and engineering values. Numbers, capital letters and common symbols are available; special characters can be provided by plug-in changes to digital logic. A control panel allows changes in display operation to be manually controlled; certain display functions can be recalled or inhibited.

The second class of displays are X-Y plotters and multi-channel pen recorders. The X-Y plotters can either be driven from the computers in an automatic mode or from off-line data sources. The pen recorders display related subsystem parameters to provide a time-history record of subsystem performance and occurrence of critical or significant events. The X-Y plotters enable graphic display of trend data to indicate potential degradation in system performance. Alpha-numeric annotation of plotted data as it is displayed allows for maximum visibility of important information.

A television display unit is also provided to allow telecommunications personnel to monitor ESP TV data to evaluate performance of the ESP MDE, and, in conjunction with engineering telemetry data, to evaluate performance of other segments of the link.

4.5.9.8 SFOF Display Interface Equipment - This equipment accepts the output data from the Central Computer Complex and the Telemetry Processing Station and buffers and converts it into appropriate formats for distribution to the SFOF MDE display equipment and to the science experimenters. The following functions are provided:

- o Signal conditioning and level-changing
- o Parallel-to-serial conversion
- o Data combining and interleaving
- o Data switching and distribution
- o Isolation and line driving
- o Digital to analog conversion

In conjunction with the SFOF Entry Science Package Control Console, this equipment provides a focal point for collection, control and distribution of ESP data at the SFOF. Plug-in modules and circuit cards allow easy accommodation to changes in data dissemination and display requirements. Solid-state switches provide for speed, reliability and flexibility of control.

4.5.9.9 SFOF Entry Science Package Control Console - Management of ESP engineering and science data within the SFOF is implemented by use of an ESP Control Console. It provides for control of the display interface equipment described in Section 4.5.9.7 above, and allows the ESP system manager to have immediate access to critical segments of ESP data. An oscilloscope display similar to that described in Section 4.5.9.6 above enables ESP data to be displayed simultaneously with other mission oriented data to enhance visibility into mission operations. Status and alarm monitors, critical time and event indicators, and ESP system performance level read-outs are included to facilitate the making of decisions.

4.5.9.10 DSIF Entry Science Package Simulator - The MDE used for simulation of the Entry Science Package telecommunications system will be combined with that used for the Capsule Bus to facilitate control and interleaving of the data.

Figure 4.5-7 shows the major elements of the simulator. The PCM data generator generates several words of ESP PCM data at bit rates of 273, 630, 280, 910 and 2730 bps to simulate the several data modes of interleaved CB and ESP data. Data, frame sync, and bit sync are delivered to the data combiner, where tape playback data is also received. The tape playback unit enables recorded test data obtained during ESP system and subsystem tests to be processed through the DSIF MDE and TCP, and comparisons of input and output data made. Generated or playback data can be routed through the data delay unit and 50-second or 150-second delays imposed on the data, which is fed back into the data combiner. The mode control enables selection of generator bit rate, tape playback operation, selection of real-time or playback data, and selection of real-time, 50-second delay and 150-second delay data. It also enables bits to be dropped in a data sequence, interchanging of a real-time and delayed data to test decommutation synchronization, momentary removal of frame sync or bit sync, and setting of output levels. The signal conditioning amplifier provides isolation between data combiner outputs and the lines used to transfer data to the MDE, and enables the levels of these lines to be set.

Digital logic cards are used for mounting of the integrated circuits used to implement these functions. Standard controls, switches and connectors are used to provide compatibility with other JPL equipment.

DSIF ESP SIMULATOR

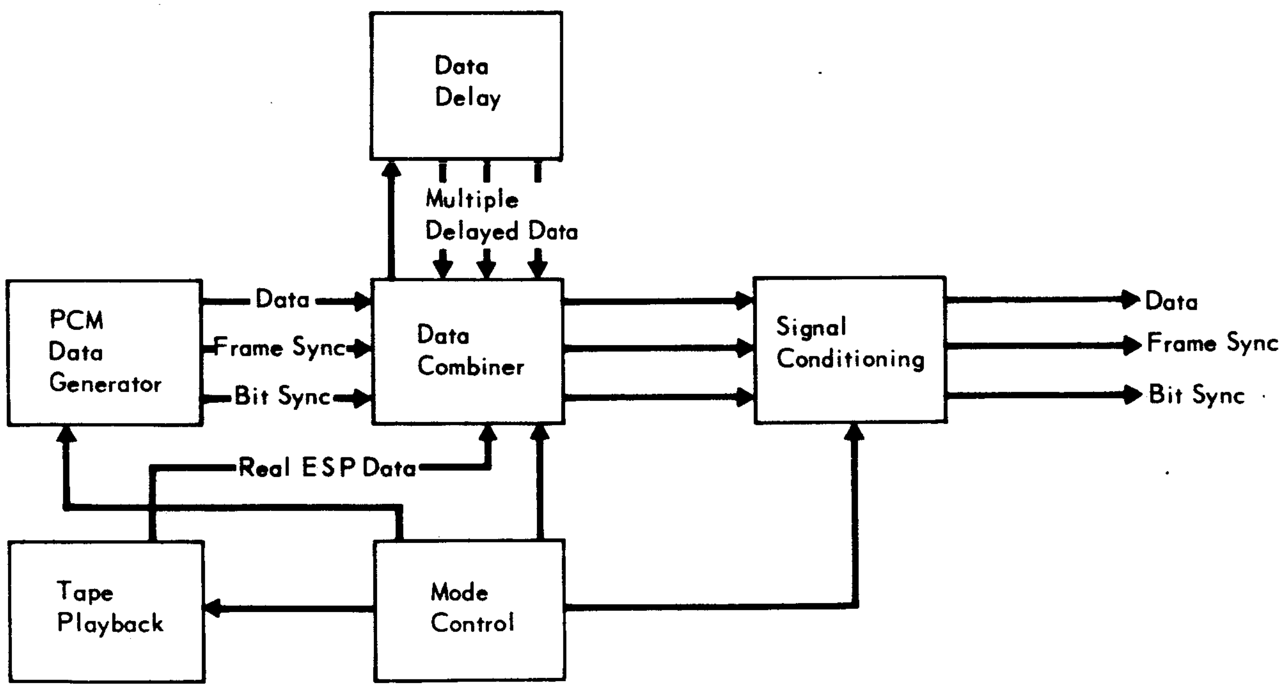


Figure 4.5-7

SECTION 5

ENTRY SCIENCE PACKAGE SUBSYSTEM-LEVEL TEST EQUIPMENT (SSTE)

Subsystem Test Equipment (SSTE) described in this section provides complete test capability for design and operational verification of individual flight subsystems which compose the Entry Science Package. Direct access to the subsystem or its elements through the flight and OSE connectors permits this portion of the subsystem test equipment, identified as Subsystem Test Sets(SSTS), to be used in the performance of detail-level subsystem tests and fault isolation to a replaceable subassembly. Descriptions of the test sets are based on the test functions and requirements of the Entry Science Package subsystems only, i.e., independent of Capsule Bus or Surface Laboratory subsystems test requirements. (An alternate approach, described in detail in Section 10.3, combines the test requirements of the Entry Science Package subsystems with those of the Capsule Bus or Surface Laboratory to effect a reduction in the total quantity of test equipment required for subsystem-level tests.)

5.1 SUMMARY - Entry Science Package Subsystem Test Sets provide the capability to accurately, thoroughly and expeditiously verify proper operational performance and to fault isolate the flight subsystem in the event of a malfunction. Each flight subsystem, or functional group of subsystems, is supported by its own test set to assure minimum schedule interference and OSE complexity.

Selected Entry Science Package Subsystem Test Sets that are automated for test sequence control, data gathering and evaluation, are the Telecommunications and Science Subsystem Test Sets. Analysis of the number and types of tests, test mechanization complexity and test time for these subsystems indicate test automation as an efficient, cost-effective approach.

Specific functions provided by the SSTS are:

a. Control, stimulate, power and measure responses of the flight subsystem or any of its elements in real time, repeatably, for performance verification.

b. Identify and record all test data for off-line analyses for those test sets which are automated; data gathering is performed by the operator for the test sets not automated.

c. Provide subsystem fault isolation ability to the replaceable subassembly level.

d. Provide self-test and calibration capability to validate the OSE prior to or during tests, automatically as a subroutine or manually by test procedure.

A resume' of subsystem test set performance characteristics of our selected concept follows in paragraph 5.2; the remaining paragraphs of this section provide detailed descriptions of each test set.

5.2 GENERAL - Performance and design features that are common to each of the subsystem test sets are discussed in the paragraphs that follow.

5.2.1 Equipment Identification and Usage - Test equipment comprising the Entry Science Package Subsystem Test Sets are functionally grouped for independent and/or simultaneous subsystem tests as follows:

Subsystem Test Set	Flight Subsystem Supported
Electrical Power	Electrical Power
Telecommunications	Antenna, Data Storage, Radio, Telemetry
Thermal Control	Thermal Control
Science	Science

An equipment functional check is performed on each subsystem and its elements, using the subsystem test sets prior to flight hardware installation into the ESP. Proper subsystem operation is thus verified prior to subsystem integration and continuity of test data (begun at the vendor) is maintained.

As subsystems are integrated into the package, the SSTS's are used to establish subsystems operational compatibility. During the latter phase of Entry Science Package integration, the subsystem test sets are used to provide a correlation between integrated subsystems test data and system performance. This correlated data is important for decision making in the event of anomalies during critical test phases at KSC or mission operations. All test results become a part of the test data bank and are used in the succeeding test phases at the contractor's facility and KSC. When the Capsule Bus is mated with the Canister and Adapter, direct accessibility by the subsystem test equipment to the ESP flight hardware is restricted, terminating detailed subsystem-level tests. However SSTS may be used during environmental tests of the Entry Science Package.

One complement of ESP subsystem test sets will be required by the Capsule Bus contractor for use during major module integration test phase and one complete set will be required at KSC for contingencies.

In addition to the preceding utilization, it is anticipated that subsystem test sets may be used to perform predelivery acceptance (PDA) test (design verification) prior to shipping the flight subsystem from major subsystem vendors. Several benefits result from this SSTS utilization which contribute directly to mission success, namely; elimination of test variables between the vendor and ESP contractor's facilities, a reduction in test time and costs at the vendor's facility, assurance of operable OSE hardware and software prior to receipt of the equipment at the ESP contractor's plant.

5.2.2 Design Requirements and Constraints - Design of the Entry Science Package Subsystem Test Set is in accordance with JPL and flight-hardware-derived requirements as discussed in Section 2, Part D.

An operational constraint is levied on use of the subsystem test sets by the mating of the Capsule Bus and the Adapter and Canister. Capsule Bus, Surface Laboratory, and Entry Science Package test data, following mating, are derived from the telemetry down-link and OSE umbilical test parameters available to the subsystem consoles in the STC.

During ESP subsystems test and integration, it is advantageous to have the flight hardware interface its test equipment via short cables to assure high quality test data and permit direct operator participation. Since equipment functional checks and subsystems level test are performed in the Class 100,000 facility, one complete group of SSTS is installed in the clean room to provide the physical proximity required. The subsystem test sets are therefore designed to conform to Class 100,000 clean-room requirements.

Several modules or panels within the test sets are of common design to reduce engineering costs, maximize total supportability of the test equipment and minimize operator indoctrination for the support equipment program. Out-of-tolerance monitoring and alarm circuitry, power and protection circuitry, analog and digital display panels, and analog-to-digital converters are standardized in design and hardware to the extent practical in each test set. Integrated circuitry is used extensively in the test set design with discrete components incorporated as required, for reliability, accuracy and physical compactness.

5.2.3 Physical Characteristics - Subsystem Test Sets are contained in standard electronic equipment cabinets with special cabinets for the automatic processor when included. Casters are provided to facilitate mobility. Power and environmental conditioning for the flight subsystem under test are provided by the test set during subsystem or lower level testing.

Interconnections between cabinets and flight equipment are made by terminal boards and connectors accessible from the rear or side of the test set. Connectors and cables are designed to minimize hookup time; connector-keying and color coding are used throughout the OSE to prevent erroneous connections.

A typical ESP subsystem test set installation is shown in Figure 5.2-1; the particular layout is the installation of the SSTS at the Capsule Bus contractor's facility for major module integration. The equipment is functionally grouped to optimize the electrical, physical, functional and man-machine interfaces required during subsystems and systems tests.

5.2.4 Operational Description - A functional block diagram of a typical SSTS is shown in Figure 5.2-2. The test set consists of three functional sections; an automatic processor, a computer interface unit, and the basic test equipment. The test sets that are not automated consist of only the basic test equipment. A computer interface may be added to the manual test sets if required; however, analysis of these subsystem test functions indicates that test automation is not cost-effective and therefore the interface has not been incorporated in the design.

The automatic processor provides test sequence control by the test program stored within its memory; the program may be modified by the teletype keyboard or the punched-tape reader. In addition to control, the processor monitors and compares subsystem responses to stored limits, outputs out-of-tolerance data to the teletypewriter, outputs all test data, time-tagged, to the paper tape punch for recording, and provides OSE self-test and fault isolation capability.

The interface unit processes the command data from the processor and controls the basic SSTS equipment. Response data is multiplexed and conditioned for use by the processor.

Equipment composing the basic test equipment consists of signal generators, displays, clock, loads, protective circuitry, oscillographic recorders and alarm monitoring circuitry. Items of test equipment are selected for multiple function capability, reliability and availability to reduce OSE operating and maintenance costs.

5.2.5 Performance Characteristics - Significant SSTS performance characteristics, common to all of the test sets, are summarized herein.

a. Measurement Accuracy - Accuracy of the SSTS measurement devices is in general an order of magnitude greater than that of the parameter measured.
b. Test Repeatability - Repeatability of tests is maximized by automation, fixed interconnections (by the use of matrix boards) and by incorporation

SSTS INSTALLATION AT CAPSULE BUS INTEGRATION SITE

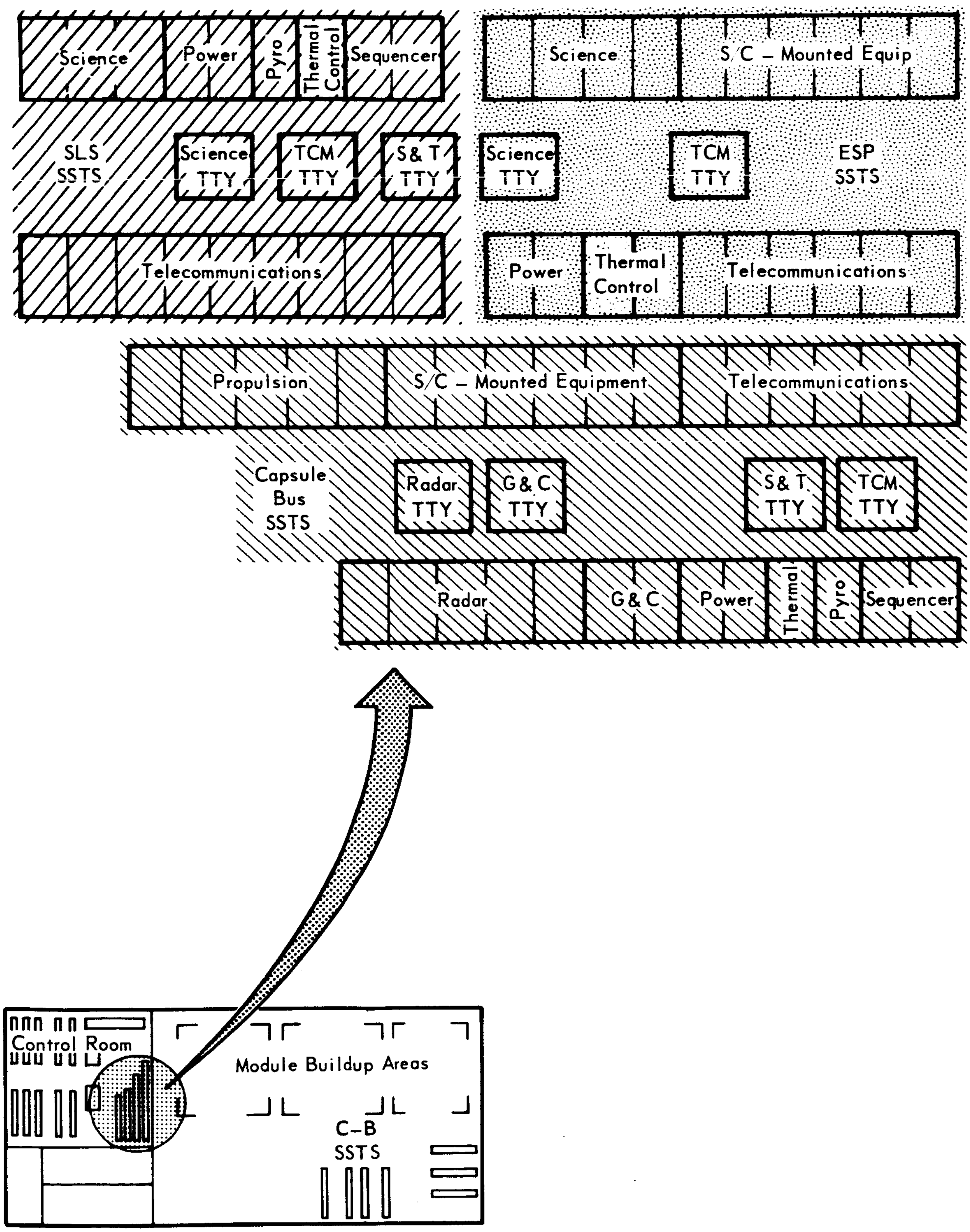


Figure 5.2–1

TYPICAL SUBSYSTEM TEST SET FUNCTIONAL BLOCK DIAGRAM

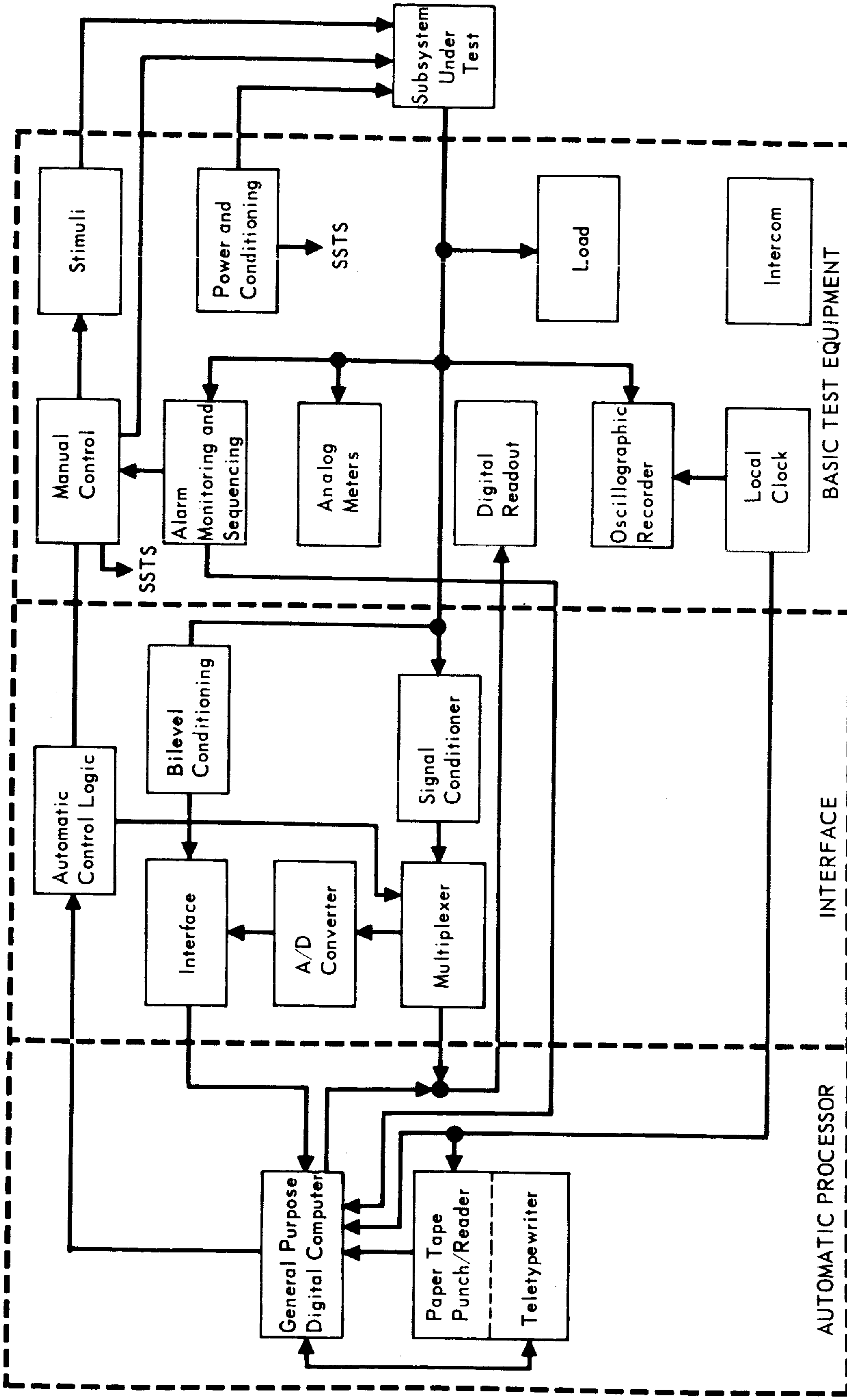


Figure 5.2-2

of digital techniques for measurement when possible.

c. Test Time - Time required for tests is minimized by automation where effective. Minimum test time reduces flight hardware operating time.

d. Marginal Testing - Stimuli are varied in time, amplitude, pulse width or frequency (according to the selected parameter) to determine marginal operating performance. Resulting test data are especially useful to launch commitment decision-making.

e. Protective Circuits - Protective circuits and devices are incorporated to assure improper or harmful signals are not applied to flight hardware or OSE.

f. Out-of-tolerance Parameter Indications - Should a parameter being monitored appear outside the tolerance established in the test program or procedure, a warning light on the test set control panel illuminates and the parameter and its value are printed out on the teletypewriter in the automatic control mode. Critical or destructive parameters are monitored and an out-of-tolerance condition causes hardwired protective circuitry in the test set to drive the test set and unit under test to a safe condition. If the out-of-tolerance condition is not of a critical nature, the automatic test routine permits the operator to clear the malfunction and/or continue the test.

g. Self-Test - An OSE self-check is incorporated at the beginning of a test sequence and at any point in the sequence when the functional setup is considerably changed. In addition, when a malfunction is detected by the test set, a self-test is prescribed automatically or manually as applicable to the test set.

5.2.6 Interfaces - Specific interfaces are listed with the description of each SSTS. The SSTS are capable of interfacing with a general purpose digital computer for test sequencing and monitoring, with the exception of those noted previously where automation is not a cost-effective approach. However, a computer interface may be added, if desired, to these test sets.

5.3 ELECTRICAL POWER SUBSYSTEM TEST SET

5.3.1 Equipment Identification and Usage - The Electrical Power Subsystem Test Set provides the capability to perform all pre-delivery acceptance (PDA) tests, equipment functional checks (EFC) and subsystem tests of the Electrical Power subsystem and supplies electrical power to the Entry Science Package (ESP) if the Electrical

Power Subsystem or any of its elements are not installed or operating.

5.3.2 Physical Characteristics - The Subsystem Test Set (SSTS) is packaged in two standard electronic equipment cabinets on castered bases. Cabinet configuration is shown in Figure 5.3-1.

5.3.3 Operational Description - Because of the fundamental nature of the tests, the simplicity of the measurements involved, and the relatively small number of operations performed, the SSTS is manually operated. Critical parameters are monitored continuously, and visual and audio alarms are provided by hardwired logic to indicate out-of-tolerance conditions.

Self testing is accomplished by simulating the subsystem parameters that are measured or controlled, by checking the response of all monitors and alarms in both marginal and nominal conditions and by verifying the stimuli applied to the flight subsystem by measurement with standard test equipment.

5.3.4 Performance Characteristics - The SSTS block diagram shown in Figure 5.3-2 is designed to perform the functions tabulated in Figure 5.3-3 and those discussed below.

Controlled dummy loads are provided to stimulate normal ESP electrical loads and to provide selected battery discharge rates. A constant voltage power supply having a range of 20 - 40V provides simulated battery power to the Electrical Power Subsystem in the ESP. A constant current power supply is provided for battery charging purposes. Current limiting, voltage limiting, and external voltage sensing devices, are incorporated in the SSTS design both for regulation and circuit protection.

Meters and recorders are provided to measure and monitor all power subsystem analog parameters such as battery voltage, charge and discharge current, and net ampere-hour charge and discharge.

The switching points of the DC bus voltage sensors are checked by varying the cruise power and backup power bus levels and determining when the sensor switches to the alternate power source. Switchover point of the ESP charger, from full charge to float charge, is checked by monitoring charger output current versus battery voltage to verify proper operation of the charger. The output of the battery charger is tested for voltage and current by standard test equipment. Known currents are passed through the subsystem current shunts and the results compared to the telemetry outputs to provide a calibration of the telemetry power level sensor.

ELECTRICAL POWER
SSTS

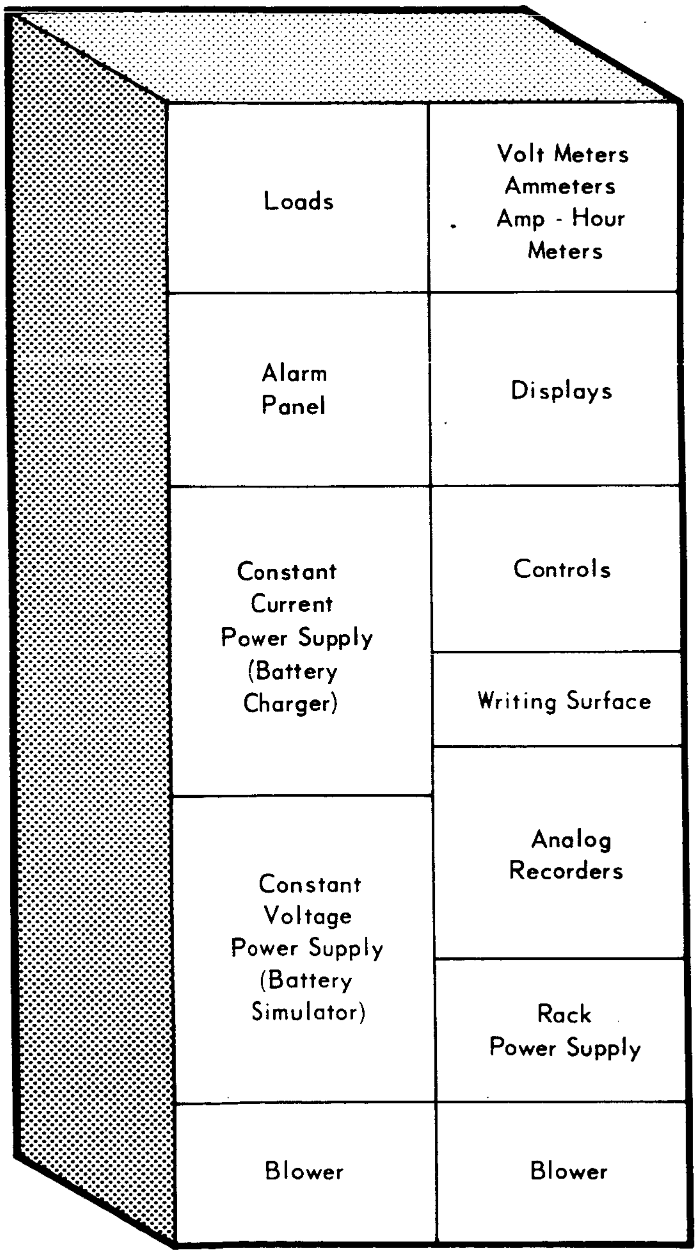


Figure 5.3–1

ELECTRICAL POWER SSTS FUNCTIONAL BLOCK DIAGRAM

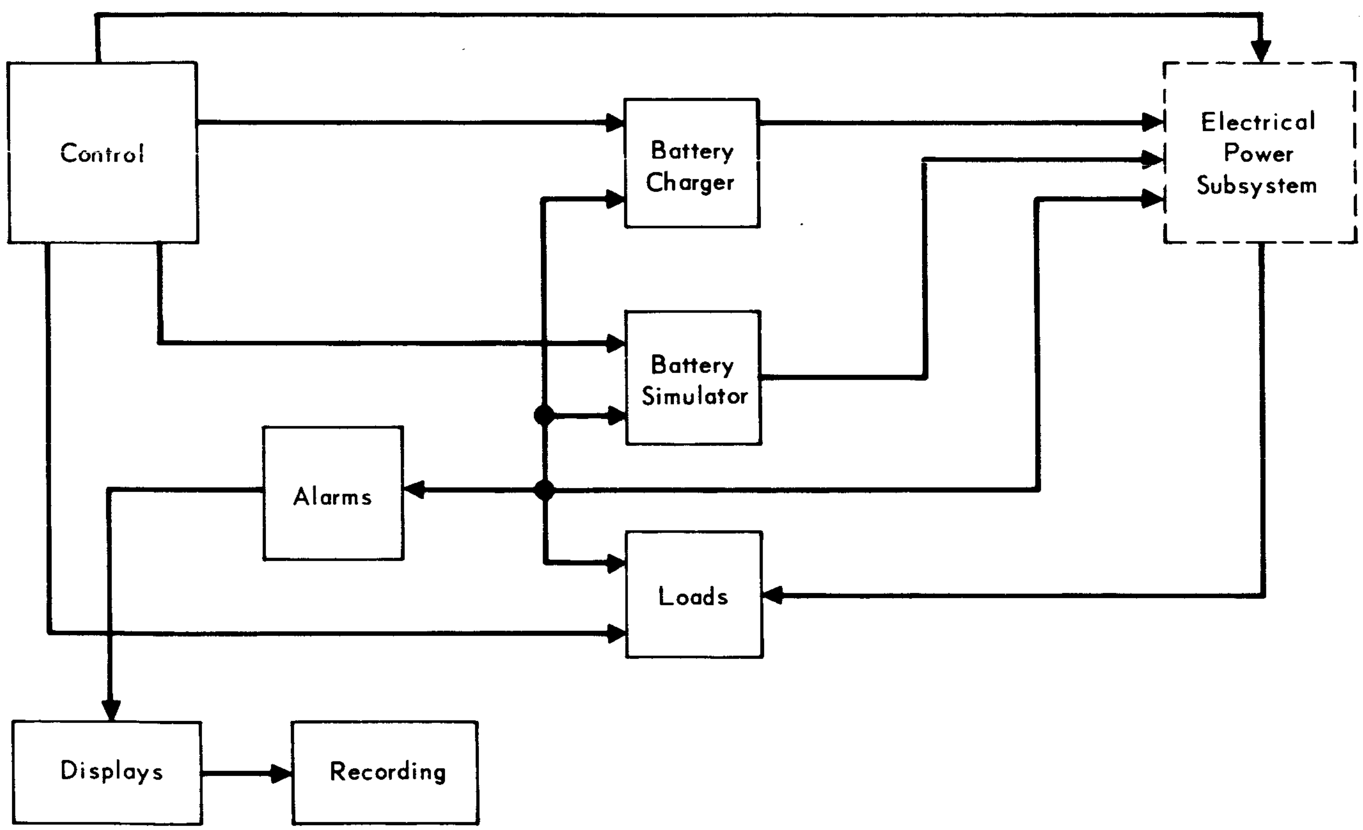


Figure 5.3–2

ELECTRICAL SUBSYSTEM TEST REQUIREMENTS

Measuring Device	Range and Accuracy	Parameter
Analog Voltmeter	15 - 40 ±0.1V	Bus Voltage Monitor
Digital Voltmeter	0 - 100 ± 0.1MV	Current Monitor All Telemetry Signals
	0 - 40 ±0.01V	Voltage Sensor #1 Voltage Sensor #2 Battery Voltage Monitor
Ammeter	0 - 50 ±0.05 AMP	Battery Charger Current Monitor Bus Current Monitor
	0 - 10 ±0.01 AMP	Shunt Calibration Current
Ampere-Hour Meter	999 ±0.1 AMP-HR	Battery Net Charge or Discharge
Visual Indicators	State 1 or 2	Power Switching and Logic Relay Positions

Figure 5.3-3

5.3.5 Interfaces - Interfaces are shown in Figure 5.3-4. The single-point ground concept used by the Entry Science Package Electrical Power Subsystem is maintained by the interface and the test set.

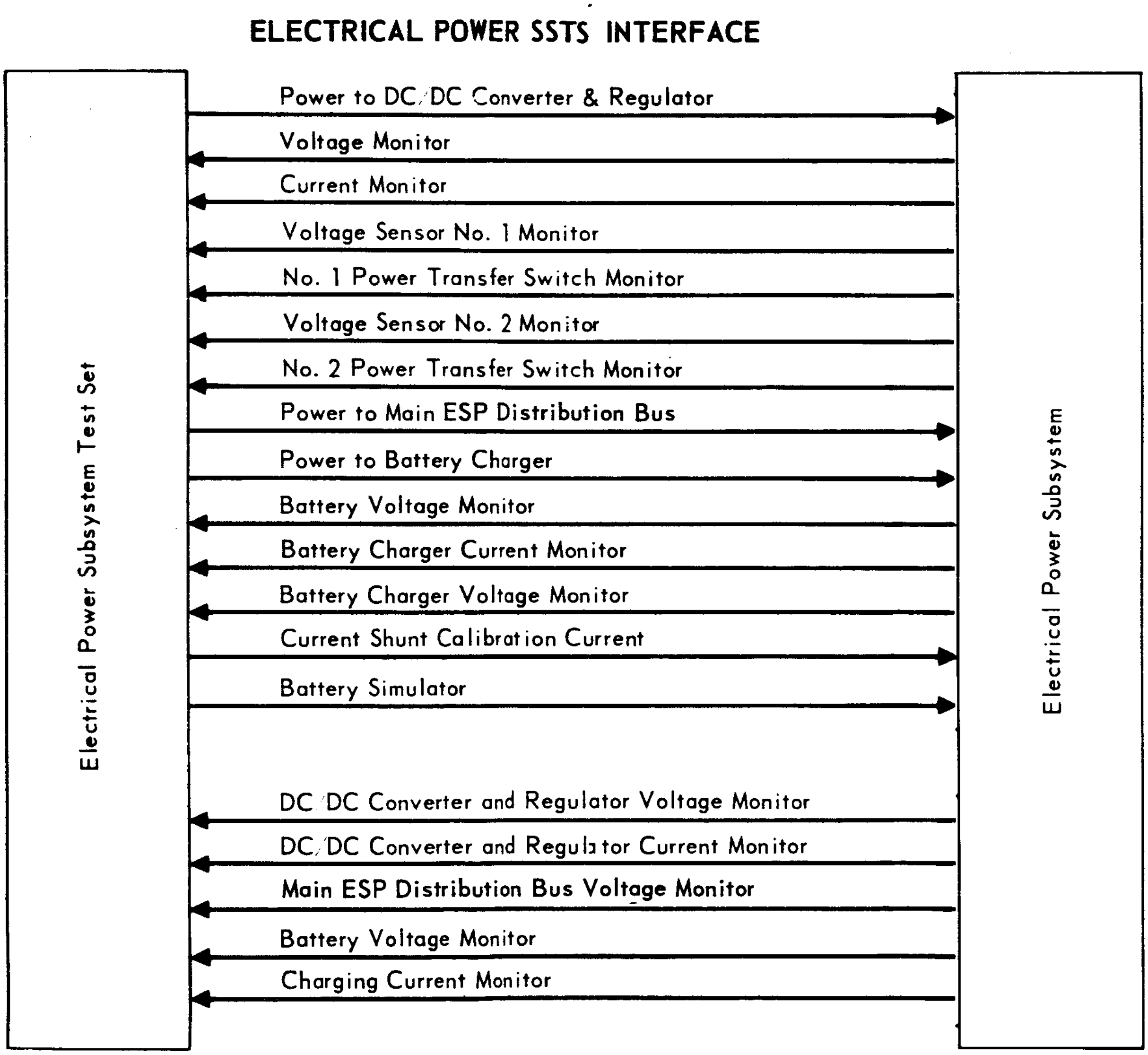


Figure 5.3-4

5.4 TELECOMMUNICATION SUBSYSTEM TEST SET (SSTS)

5.4.1 Equipment Identification and Usage - The Telecommunications Subsystem Test Set provides complete test capability for the following Entry Science Package TCM Subsystems.

a. Antenna
b. Data Storage
c. Telemetry
d. Radio

The test equipment is used for compatibility and qualification testing of the ESP TCM Subsystems, for system integration and functional testing at the ESP contractor's facility, major module integration tests at the Capsule Bus contractor's plant, and for test contingencies at KSC.

5.4.2 Design Requirements and Constraints - The Telecommunications Subsystems Test Set performs the following functions:

a. Provides simulated ESP engineering analog and digital data to enable testing of the telemetry multiplexer.
b. Provides simulated CB 630 and 2730 bps serial PCM data to enable testing of the telemetry interleavers during the simulated entry and landing mission phases.
c. Provides two UHF receivers for receiving the FSK-modulated RF carriers from the radio subsystem.
d. Demodulates the FSK subcarrier and provides a serial PCM (Manchester Coded) bit stream of telemetry data.
e. Provides decommutation of the telemetry data in simulated UHF relay, cruise and in-flight checkout modes at the 0.4375, 2730 and 55,860 bps data rates.
f. Provides a capability for displaying selectable telemetry channels for quick look analysis.
g. Provides the automatic processor with PCM telemetry data and test data from the digital voltmeter and electronic counter.
h. Provides the capability to record on magnetic tape the 50,400 bps TV data.
i. Interfaces with the automatic processor for automatic test sequence control. The equipments that accept external control in this mode are:
   1. Telemetry controller
   2. DVM input selector
   3. Counter input selector

4. Printer input selector
5. FSK data selector
6. Magnetic tape recorder
7. ESP mode control panel
8. ESP TLM data, ESP science and CB TM data generators.

5.4.3 Physical Characteristics - The Entry Science Package Subsystems Test Set is contained in seven standard electronic equipment cabinets and an automatic processor cabinet. The total weight of the test equipment is approximately 2,750 pounds. AC power consumption is approximately 4,850 watts. Physical arrangement of the SSTS is shown in Figure 5.4-1.

5.4.4 Operational Description - The ESP TCM Subsystems Test Set provides manual or automatic checkout of the combined ESP TCM Subsystems as well as manual checkout of the individual ESP TCM Subsystems. A functional block diagram of the SSTS is shown in Figure 5.4-2.

In the automatic mode, test equipment commands are generated from the ESP test program. The automatic processor decodes instructions, addresses, and routes the instruction to the proper portion of the test set for execution. The processor also selects the source of the data for logging and processing. Data are available from the digital voltmeter, counter, or telemetry processing equipment. All portions of the test set which are controllable by the processor are capable of manual control.

The ESP mode control panel supplies the power and control stimuli necessary to exercise the combined ESP TCM subsystems in all of their operational modes.

The CB TM and ESP TM data generators provide simulated data as inputs to the ESP Telemetry Subsystem. The ESP TM generator provides analog and digital inputs; the CB TM generator provides digital data at 630 and 2730 bps as a digital input to be be interleaved by the ESP TM Subsystem. All outputs from the ESP combined subsystems are routed to a patch panel for distribution to the test equipment. Each RF output from the ESP Radio Subsystem is routed to an RF power meter, the counter input selector, RF patch panel, and a test receiver. The TM signal conditioner accepts the detected FSK signal from the receiver and supplies the PCM serial data and clock to the TM data selector. This unit selects the in-flight checkout data, ESP cruise data, or the ESP UHF relay data to be processed, displayed, printed or routed to the automatic processor. The data distributor and data display provides for serial-to-parallel conversion and display of up to 32 data words.

ENTRY SCIENCE PACKAGE TCM SUBSYSTEMS TEST SET

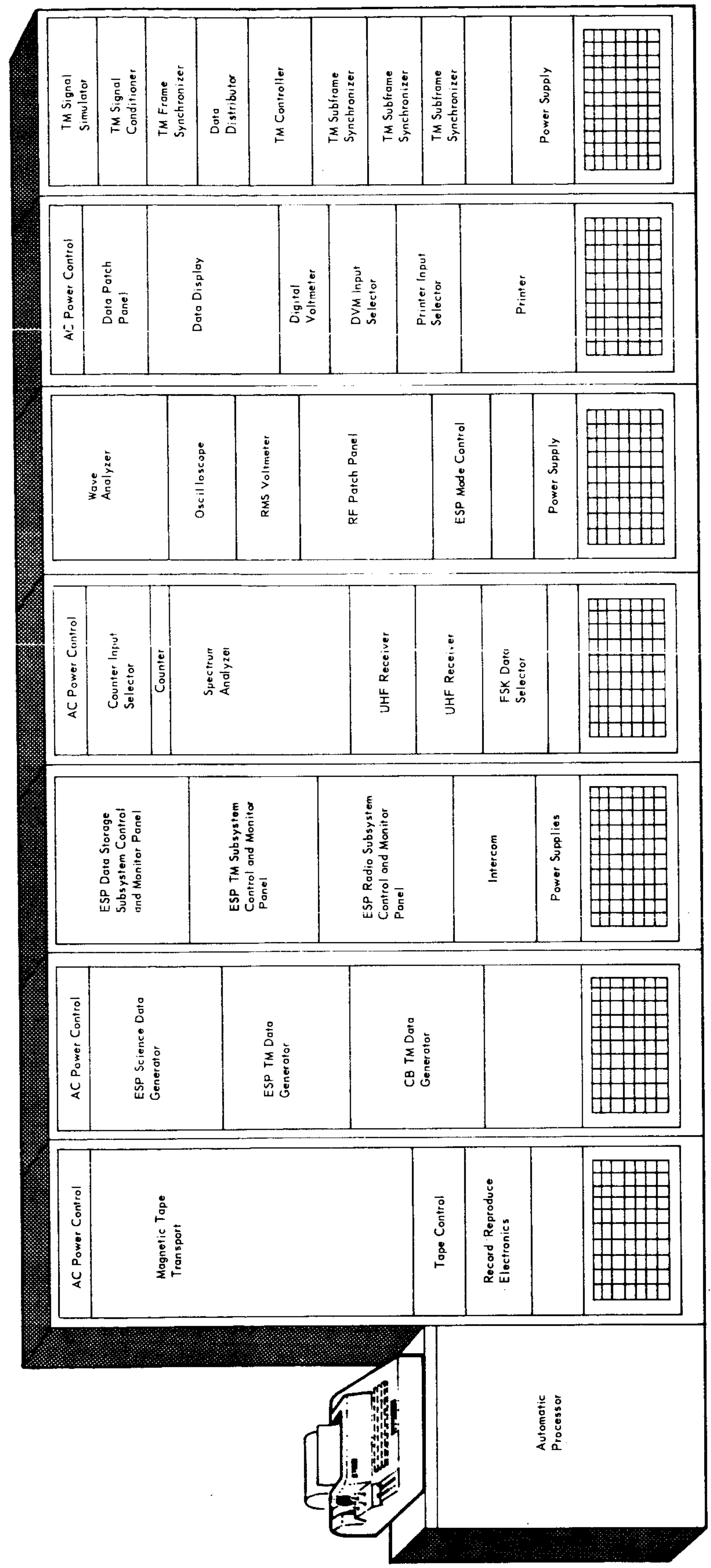


Figure 5.4-1

ESP TELECOMMUNICATIONS SSTS FUNCTIONAL BLOCK DIAGRAM

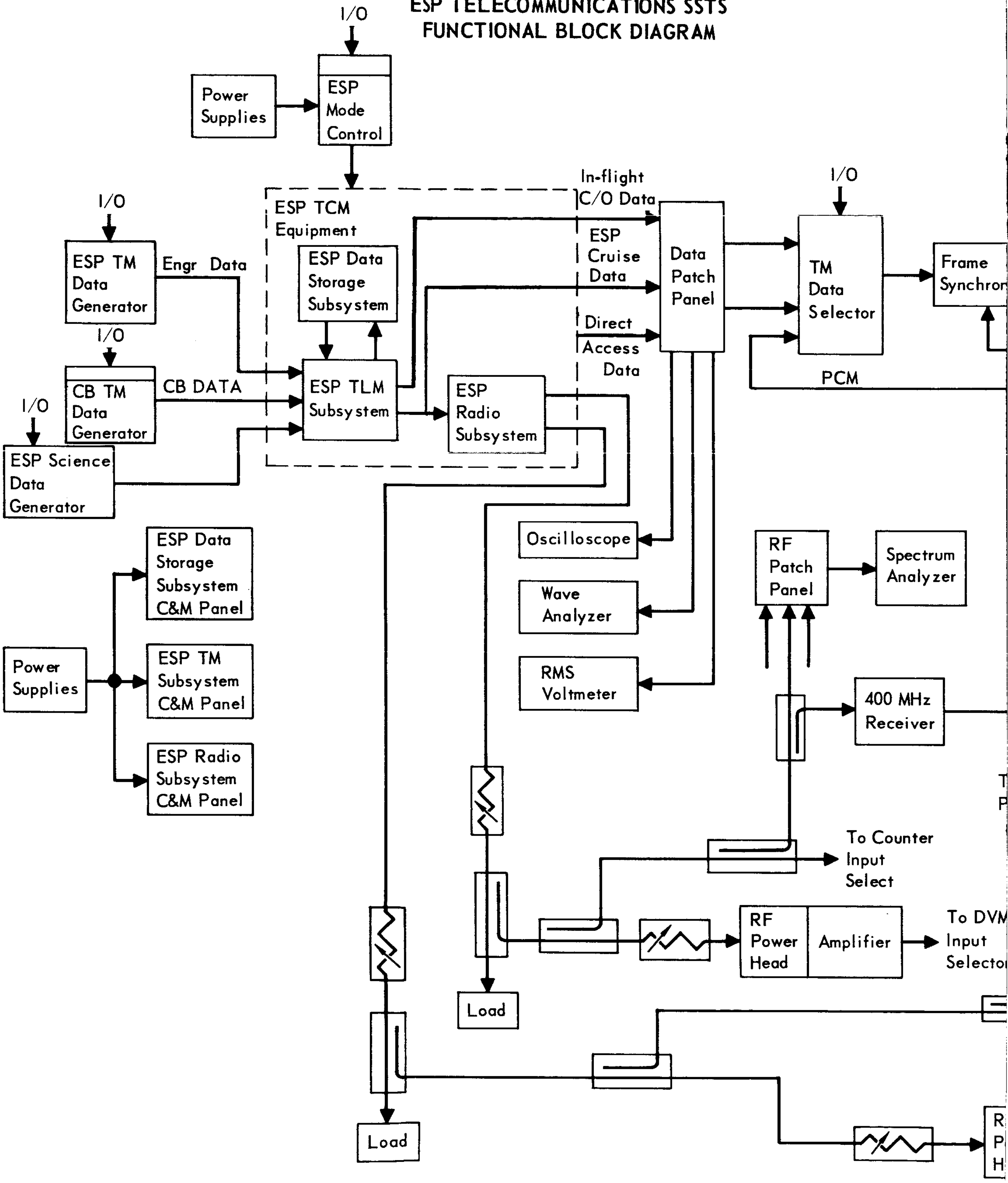
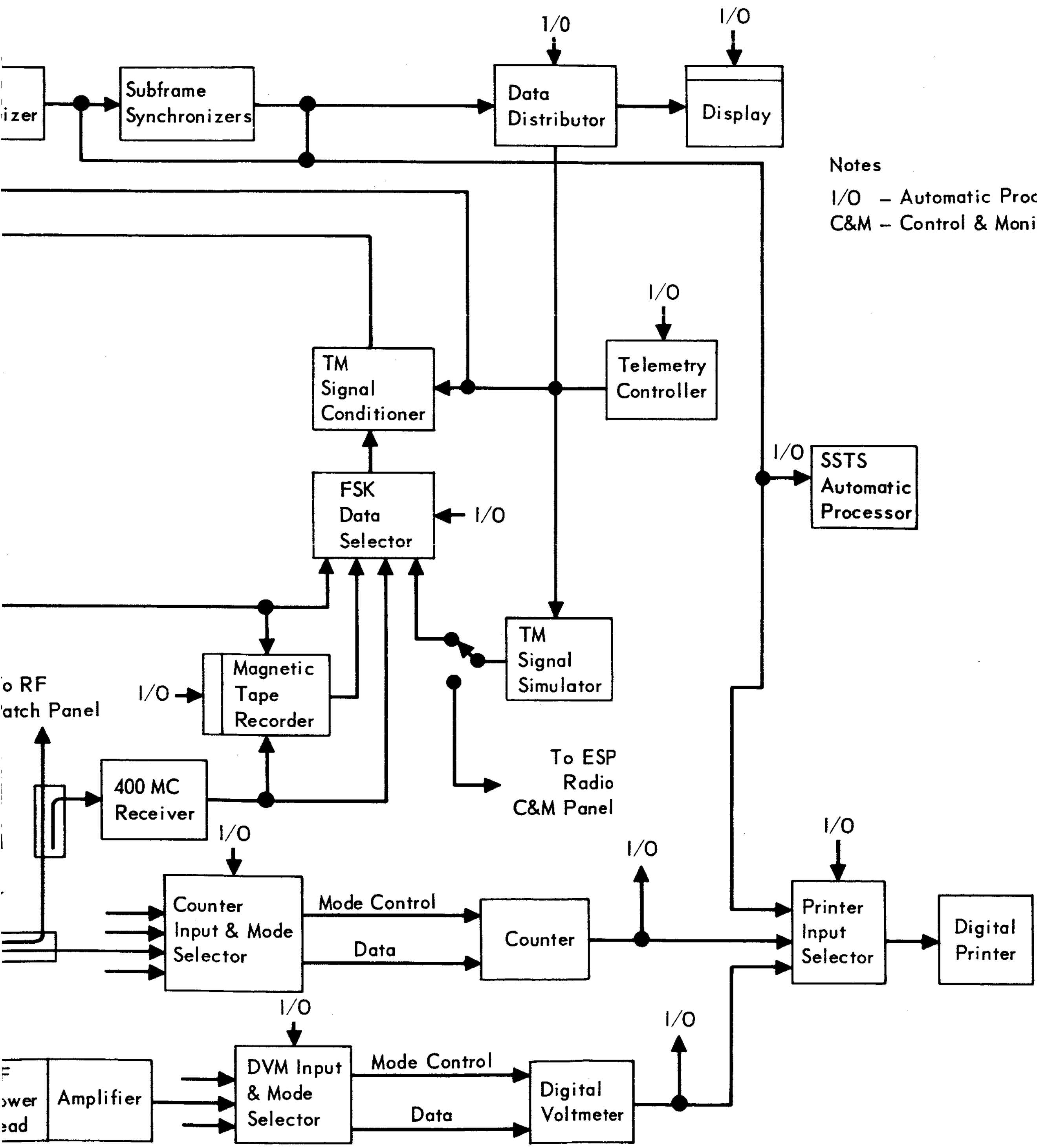


Figure 5.4–2



Notes

I/O – Automatic Processor Input Output

C&M – Control & Monitor

5-16-2

The test receivers perform the following functions:

a. Simulate spacecraft-to-capsule link space loss.

b. Provide a baseband output for telemetry.

c. Provide for monitoring the received signal condition.

d. Provide for monitoring test receiver operation.

Two test receivers are provided to facilitate simultaneous recording of both diversity FSK signals on a multi-channel magnetic tape recorder. The capability is also provided to record the decommutated PCM serial data.

The telemetry processing portion of the ESP TCM Subsystems Test Set consists of the following:

a. TM controller

b. TM signal simulator

c. TM signal conditioner

d. Frame synchronizer

e. Subframe synchronizers

f. Data distributor

The TM controller automatically sets up the proper bit rate, input code, polarity, detector type, phase-locked-loop width, capture and tracking range and output code of the TM signal simulator, the TM frame synchronizer, TM subframe synchronizer, the data distributor, and the TM signal conditioner. During the manual operating mode and in testing the individual TCM subsystems, the parameters are selected by manual switches on the individual equipment front panels.

The DVM input selector, counter input selector and printer input selector provide manual or automatic control of the data being supplied to the respective units. In the case of the DVM and counter, the range and function are also controlled by the input selectors. The recorder records data from the DVM and counter as well as data from the automatic processor in real time.

A multichannel magnetic tape recorder with tape speeds from 1-7/8 to 60 inches per second is provided to record the 55 kbps TV data during the simulated entry phase and to record the FSK-modulated subcarriers or the decommutated PCM serial bit stream.

The data interleaver is tested by setting two different known words into the ESP telemetry subsystem for non-TV data; one for real time data (630 bps) and the other for delayed data (2730 bps). A third known input word is used for the digitized TV data. The transmitted signal is received by the test receiver in a normal fashion and the detected output recorded by the magnetic tape recorder. The tape recorder is played back at a slower rate into the telemetry processing equipment and proper interleaving verified by the printout on the digital printer; also the tape record can be reduced and verified by the processor.

Output data and control signals are routed to a data patch panel, an oscilloscope, wave analyzer and true rms voltmeter are provided for analysis of these signal characteristics.

Provisions are made for automatic or manual self-check of the SSTS without test interruption. The DVM and counter input selectors contain calibrated input positions. Calibration can be verified by the processor at the instrument output, by printout, and by visual readout. The telemetry processing equipment is checked by setting known inputs from the TM simulator into the TM processing equipment and by checking the output.

A control and monitor panel for each subsystem provides power and test stimuli to the subsystem under test. Inputs to the subsystem are made to both flight and direct access connectors. The outputs are monitored by the telemetry processing equipment and RF monitoring equipment. Test requirements for the ESP TCM subsystems are summarized in Figures 5.4-3, 5.4-4, 5.4-5, and 5.4-6.

5.4.5 Interfaces - The ESP TCM SSTS interfaces with the TCM subsystems as follows:

a. Individual Subsystem Testing - Interfaces are made with both flight and direct access connectors as shown in Figure 5.4-7.

b. Integrated Subsystem Testing - Interfaces are made with direct access connectors and at flight connectors that interface with other subysstems as shown in Figure 5.4-8.

RADIO SUBSYSTEM

TEST REQUIREMENTS

Test	Measuring Instrument	Accuracy
RF Power Output	RF Power Meter	0.2 db
Power Amplifier Collector Current a	Digital Voltmeter	2%
Power Amplifier Collector Current b	Digital Voltmeter	2%
Power Amplifier Collector Current c	Digital Voltmeter	2%
Power Amplifier Collector Current d	Digital Voltmeter	2%
Power Amplifier Collector Current e	Digital Voltmeter	2%
Power Supply Voltage	Digital Voltmeter	0.1%
Case Temperature A	Digital Voltmeter	2%
Case Temperature B	Digital Voltmeter	2%
RF Drive (Detected)	RF PWR Meter	2%
DC Current Load	Digital Voltmeter	5%
Modulation Input	Scope/TM Sig. Sim	5%
Oscillator Frequency	Counter	1×10^{-8}
AGC Voltage	Digital Voltmeter	2%
Spurious Output	Spectrum Analyzer	1 db
Detected RF Power Output	Digital Voltmeter	0.5 db
RF Power Stability	RF PWR Meter	0.2 db
Oscillator Stability	Counter	1×10^{-8}
TM Monitors	Digital Voltmeter	2%

Figure 5.4-3

ANTENNA SUBSYSTEM

TEST REQUIREMENTS

Test	Measuring Instrument	Accuracy
Impedance/VSWR	VSWR Meter	5%

Figure 5.4-4

TELEMETRY SUBSYSTEM

TEST REQUIREMENTS

Test	Measuring Instrument	Accuracy
Nonoperative Test		
Multiplexer/ADC:		
Input Calibration Signals	Digital Voltmeter	1%
A/D Calibration Signals	Digital Voltmeter	1%
ESP Programmer:		
Input Commands	TM Signal Simulator	Digital
Output Gating Signals	TM Processing Equipment	Digital
Clock Generator	Counter/Oscilloscope	
CB Control Input	TM Signal Simulator	Digital
Digital Multiplexer:		
Input Data Digital Test Pattern	TM Signal Simulator	Digital
Operative Sequence	TM Processing Equipment	Digital
Cruise Commutator:		
Input Calibration Signals	Digital Voltmeter	1%
A/D Calibration Signals	Digital Voltmeter	1.0%

Figure 5.4-5

DATA STORAGE SUBSYSTEM

TEST REQUIREMENTS

Test	Measuring Instrument	Accuracy
Entry Data Storage		
Power Supply Voltage	Digital Voltmeter	3%
Power Supply Current	Digital Voltmeter	3%
Input Data	TM Signal Simulator	Digital
Memory Operation	TM Processing Equipment	Digital
Memory Control Signals	TM Processing Equipment	Digital
Output Data (50 sec delay)	TM Processing Equipment	Digital
Output Data (150 sec delay)	TM Processing Equipment	Digital

Figure 5.4-6

ESP TELECOMMUNICATIONS SSTS INTERFACES
(INDIVIDUAL SUBSYSTEM TESTING)

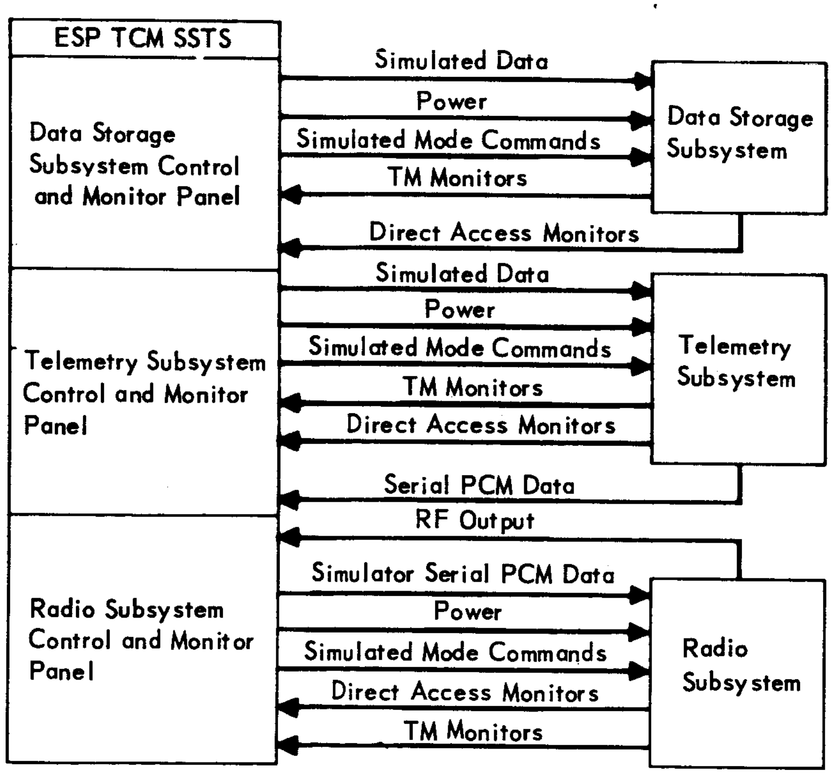


Figure 5.4-7

ESP TELECOMMUNICATIONS SSTS INTERFACES
(INTEGRATED SUBSYSTEM TESTING)

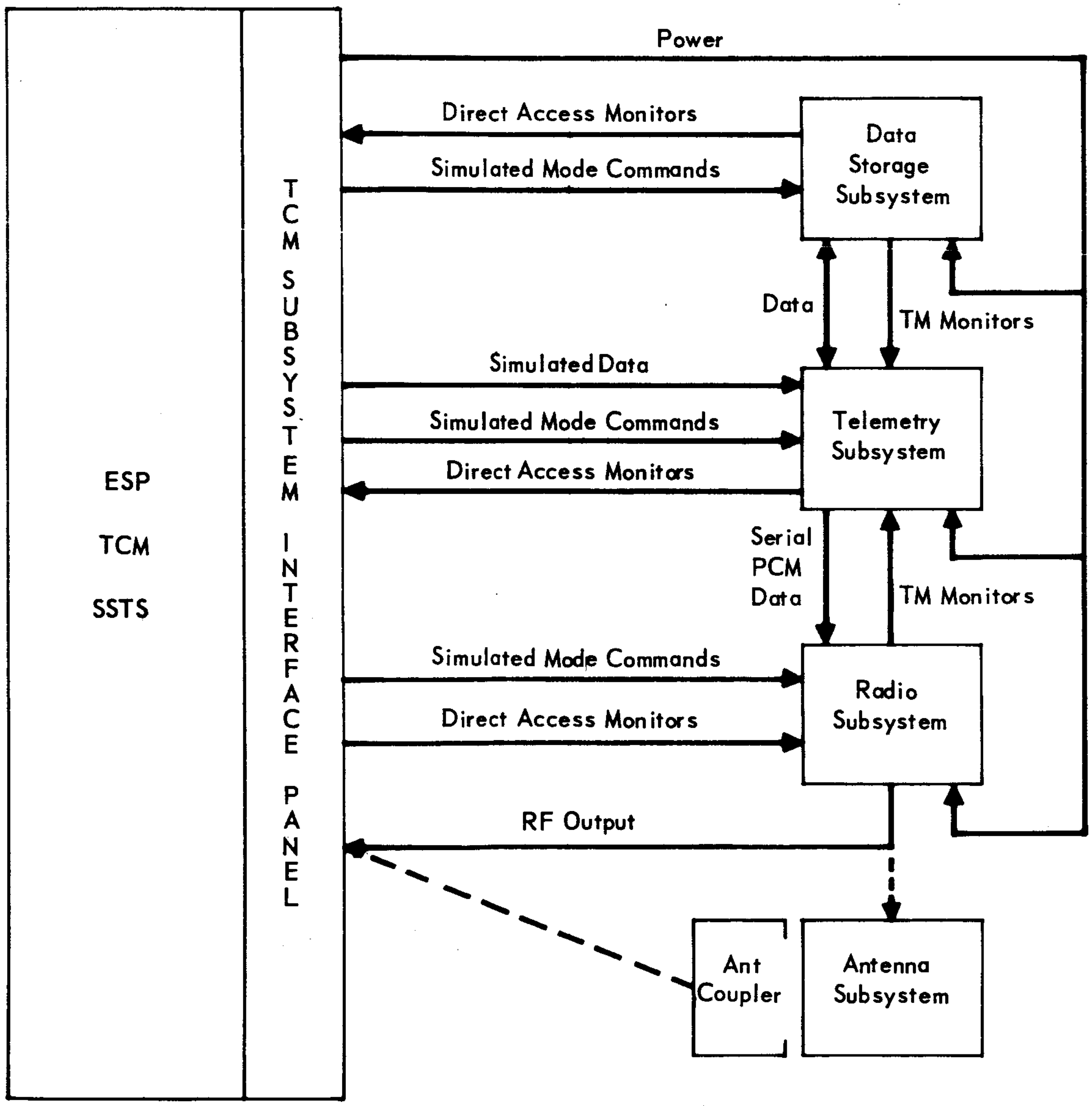


Figure 5.4-8

5.5 SCIENCE SUBSYSTEM TEST SET

5.5.1 Equipment Identification and Usage - The Science Subsystem Test Set is used to perform equipment functional checks (EFC) on the instruments at the Entry Science Package contractor prior to their installation into the ESP and to provide direct subsystem control and monitoring via the subsystem OSE test connectors, direct access points during subsystem-level, pre-delivery acceptance (PDA) tests. The test set may also be used at the Capsule Bus contractor's facility for supporting environmental chamber tests and is required at the KSC industrial area for contingency purposes only.

The Science Subsystem Test Set is used to test the seven instruments listed below:

a. Stagnation pressure
b. Stagnation temperature
c. Base region pressure
d. Base region temperature
e. Accelerometer
f. Mass spectrometer
g. Imaging

5.5.2 Physical Characteristics - The ESP Science Subsystem Test Set (SSTS) arrangement is shown in Figure 5.5-1. The caster-mounted test set is constructed to be easily disconnected and connected into the test complex cabling, facilitating mobility. The test set incorporates standard modules which are of common design for major subsystem test set usage, i.e., automatic processor unit, malfunction alarm unit, etc. The construction features growth provisioning, safety interlocks, fault isolation test points and plug-in components.

5.5.3 Operational Description - The test set is capable of performing EFC-level tests and subsystem-level tests by supplying all of the required inputs as a function of test level and monitoring diagnostic data and output signals independent of other OSE or flight subsystems. All of these functions are either controlled automatically by the automatic processor unit or manually by the test engineer in the backup/override mode.

The ESP Science Subsystem Test Set is capable of:

a. Simulating Sequencer and Timer commands.
b. Simulating Power inputs.
c. Monitoring diagnostic data provided by the instrument OSE test connectors.

SCIENCE SUBSYSTEM TEST SET

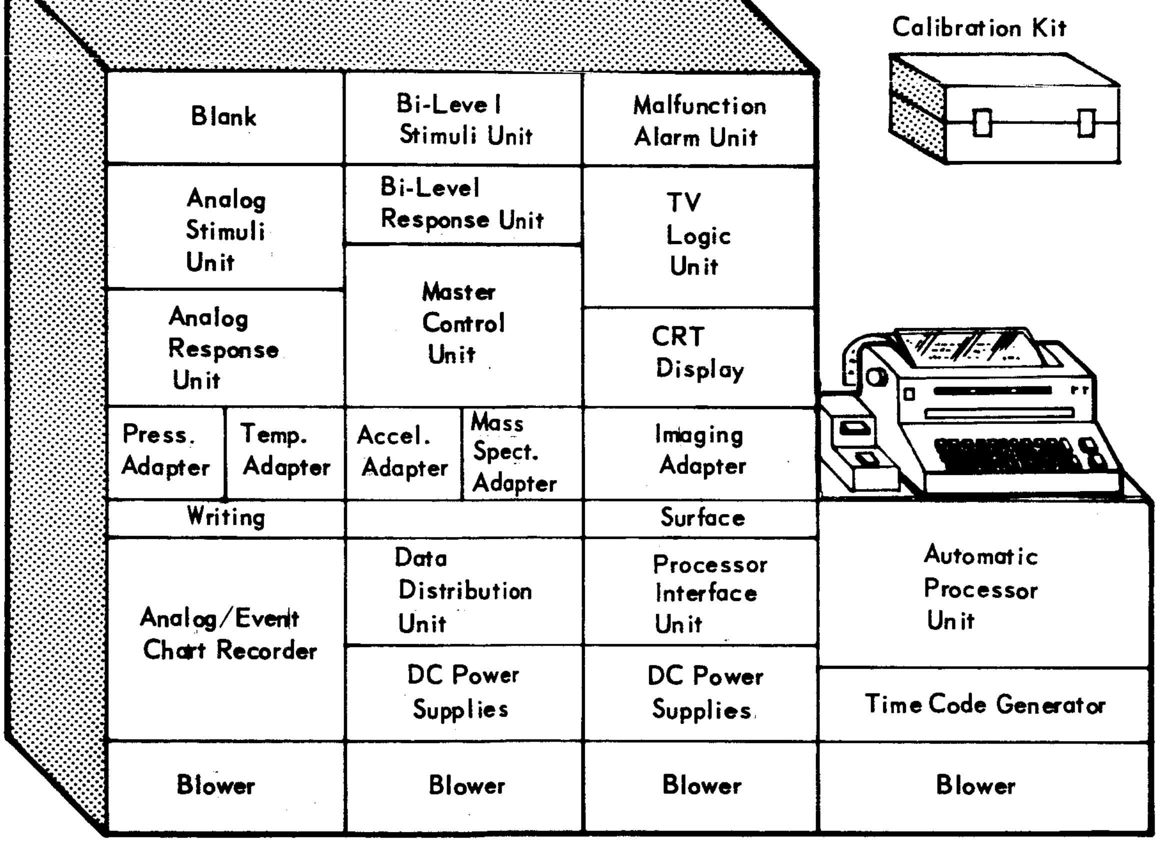


Figure 5.5–1

d. Monitoring and supplying loads for the instrument output signals to the data storage subsystem.

e. Automatic test sequence control, stimuli application and continuous alarm monitoring of key/critical parameters. Comparison of test measurements with stored tolerance limits and print-out of all test data on punched paper tape (for off-line data analysis) and hard copy print-out of out-of-tolerance data or of manually selected data on the teletypwriter (TTY).

f. Automatic OSE self-checks to isolate malfunctions to the flight science subsystem or OSE.

g. Analog/event chart recording of selected parameters.

h. Manual operation either by teletypewriter inputs to the automatic processor or by direct manual override of selected functions.

The test set (SSTS) block diagram is shown in Figure 5.5-2 and identifies the major functioning elements comprising the test set which are described briefly as follows:

a. <u>Automatic Processor Unit</u>: Provides for automatic test sequence control and instrumentation set up, data GO/NO GO comparisons and OSE self-check routines. The teletypewriter and paper tape punch reader are used for automatic processor input/output.

b. Analog Stimuli Unit: Provides programmable signal generators for analog stimuli application to the instruments under test.

c. Analog Response Unit: Provides an analog multiplexer, analog-to-digital converter and signal conditioning for measurement of analog parameters. The multiplexer is of the "on demand" type, to implement high sampling rates of defective or out-of-tolerance parameters.

d. Bilevel Stimuli Unit: Provides programmable bilevel sources for discrete commands.

e. Bilevel Response Unit: Provides bilevel sensors for monitoring discrete parameters.

f. Malfunction Alarm Unit: Provides analog and bilevel, settable hi/lo limit detectors for continuous monitoring of key/critical parameters. Visual/ audible alarms are used for indication of key parameter status with an automatic shut down routine for critical conditions.

g. Analog/event recorder/displays: Provides for selective recording/display of analog/bilevel parameters for time-line plots.

SCIENCE SSTS FUNCTIONAL BLOCK DIAGRAM

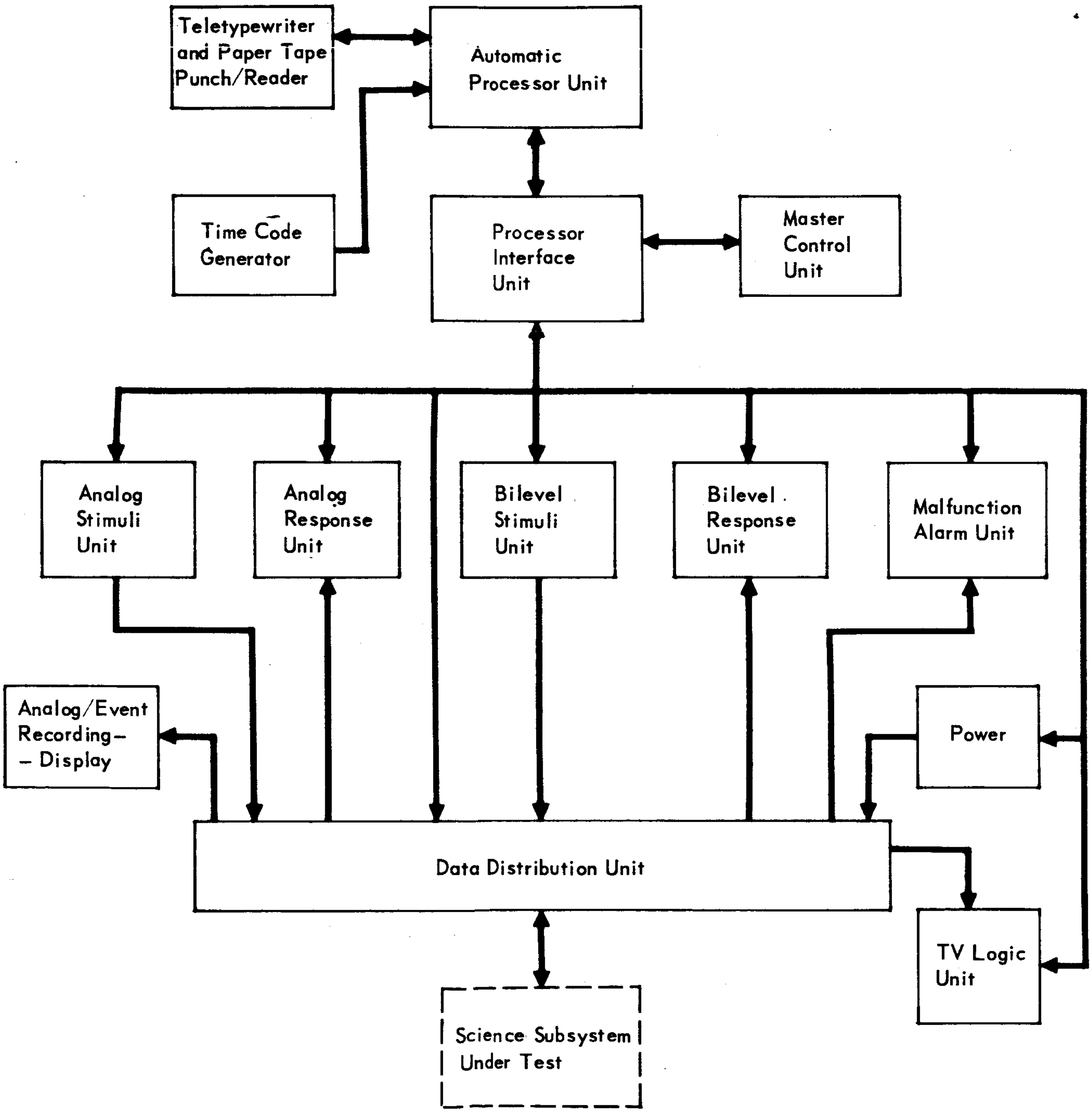


Figure 5.5–2

h. Power: Provides a programmable power supply for performance margin subsystem tests.

i. Time Code Generator: Provides for time-tagging recorded/printed data in real time.

j. Processor Interface Unit: Provides for data input/output to the processor, generates and receives digital data associated with the instruments and stores digital data for subsequent automatic processing.

k. Data Distribution Unit: Provides flexibility in signal routing between the instruments or subsystem under test and the test set modules.

l. Master Control Unit: Provides manual controls and displays for operating the test set in its automatic and manual modes and includes thumbwheel switches for setting in subsystem component serial numbers and other test information, for the data bank.

Additional description of modules commonly used in subsystem test sets are described in paragraph 5.2.

The ESP Science Subsystem Test Set performs individual instrument tests and subsystem-level tests by use of the functional blocks previously described. The instruments are connected to the applicable adapter units shown in Figure 5.5-1 for EFC-level tests and are connected to the test set by cable hookup via the OSE connectors for the installed subsystem-level tests. The test set applies power and control discretes to the instruments and monitors diagnostic and output signals by the applicable stimuli and response units.

Calibration of the instruments is performed at the vendor/supplier's plant using physical stimuli remote from the test set. The accelerometers include a capability for supplying torquer signals that are used for in-flight checkout. These signals are calibrated and are used for EFC and subsystem-level functional testing. Instruments that do not use in-flight checkout references read-out ambient conditions or values corresponding to the applied stimuli provided by the calibration kit. The TV mechanisms are exercised and a collimated light source-test pattern is used to facilitate measurement of camera and associated electronics performance, i.e., sensitivity, noise, blooming, stability, etc. Alignment to the Capsule Bus roll axis is also performed.

The TV output signal is routed to the TV logic unit for data storage, (sufficient storage to permit automatic processing and data print-out), frame and line synchronization, and D/A conversion for video application to a memory-type cathode ray tube display. The printout provides a record of iris, filter and shutter settings and camera, frame, line and gray scale number. The CRT usage, in conjunction with a photographic camera, provides a visual display and record of reconstituted picture. (Memory - CRT's investigated during this phase of study have a gray scale (intensity) range of 4 or 5).

The test program provides for automated test sequencing, beginning with the application of power to the instruments. Key/critical parameters are monitored continuously by the malfunction alarm unit and must be in acceptable limits before the tests can proceed. Appropriate stimuli are applied and diagnostic test point data and output responses are measured, digitized and printed out on punched paper tape.

A test program is prepared for each science instrument and is initiated by the test engineer via an executive command to the automatic processor. The installed subsystem-level tests are similar to EFC-level, except that a different test program is provided to account for the change in the interface, (OSE test connector data only). Direct subsystem test point data is lost to the test set after the ESP/CB is installed in the Capsule Canister.

5.5.4 Interface Definition - The functional interfaces between the ESP science subsystem and the Science Subsystem Test Set are shown in Figure 5.5-3.

5.5.5 Calibration Kit

5.5.5.1 Identification and Usage - This kit provides calibrated pneumatic and temperature stimuli for EFC, subsystem and system-level testing of the ESP instrumentation.

5.5.5.2 Design Requirements and Constraints - The ESP calibration kit is required to provide the following functions:

- o Generating temperatures in the range of 150° to 1200°K, ±1.2°K.
- o Generating temperatures in the range of 150° to 330° K, ±0.33° K.
- o Producing pressures in the range of 0 to 3.0 psia, ± 0.015 psia.
- o Producing pressures in the range of 0 to 0.5 psia, ±0.0015 psia.
- o Providing a supply of gas with mass numbers ranging from 10-60.
- o Applying these stimuli directly to the instrumentation under test.

5.5.5.3 Physical Characteristics - This kit shown in Figure 5.5-1 is portable and self-contained, requiring only facility power for operation. It consists of a vacuum pump, subambient temperature generator, superambient temperature generator, associated instrumentation, gas storage bottles, collimator and interconnecting cabling and plumbing.

5.5.5.4 Operational Description - The kit is manually operated. Display of flight instrumentation output is provided by the science subsystem test set. For stagnation

SCIENCE SUBSYSTEM TEST SET INTERFACES

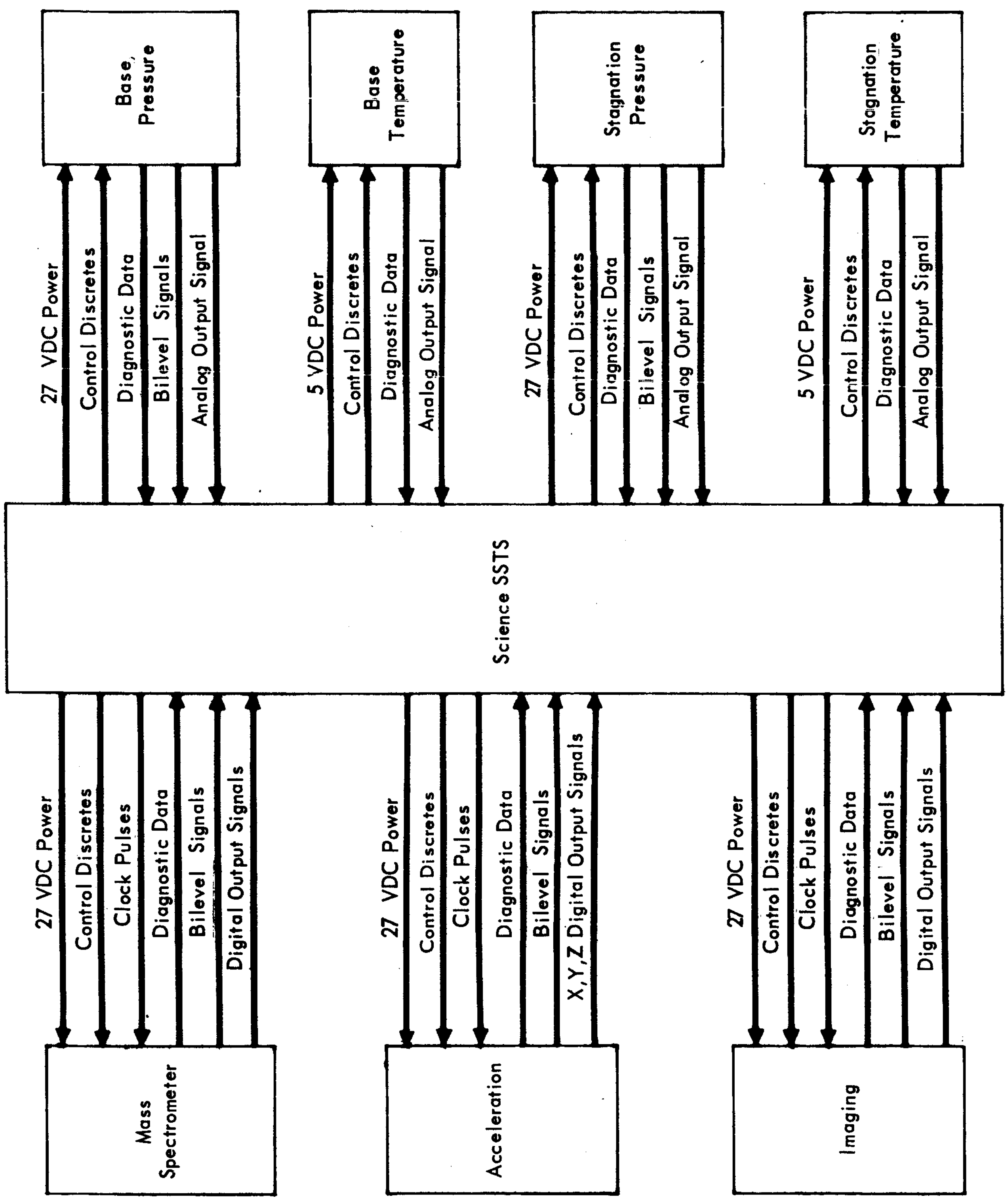


Figure 5.5-3

pressure and base region pressure transducer calibration, the vacuum pump is connected to the appropriate transducer sensing port and the transducer is evacuated. Absolute pressure gages are used to monitor this pressure in the transducer. Bypass valving allows the pressure to be maintained at selected levels. Stagnation temperature and base region temperature transducers are calibrated by applying the temperature generator probe directly to the transducer. Instrumentation in the probe provides a display of the probe surface temperature. The composition (mass spectrometer) calibration is achieved by introducing pre-analyzed gas into the instrument through a hose.

5.5.5.5 Performance Characteristics - The following characteristics are applicable to the design of the unit.

- The equipment is capable of holding a selected pressure or temperature within the specified tolerances for the required time to perform the calibration.

5.5.5.6 Interface Definition - In addition to interfacing with the flight subsystem transducers, the unit requires facility power for operation.

5.6 THERMAL CONTROL SUBSYSTEM TEST SETS

5.6.1 Equipment Identification - This equipment is used to test the Entry Science Package (ESP) Thermal Control Subsystem during the following test phases:

a. At the contractor's facility for functional check out of the Thermal Control Subsystem.

b. Subsystems-level testing during major module buildup at the Entry Science Package contractor's facility.

c. For contingency support at KSC.

5.6.2 Physical Characteristics - The SSTS consists of two units: the Thermal/Electrical Test Set and the Emissivity/Reflectivity Test Set. The Thermal/Electrical Test Set is contained in one standard electronic equipment cabinet and weighs approximately 500 pounds. The Emissivity/Reflectivity Test Set is contained in a mobile (caster mounted) cabinet and weighs about 230 pounds. The two tests sets are illustrated in Figure 5.6-1.

5.6.3 Operational Description

5.6.3.1 The Thermal/Electrical Test Set - The Entry Science Package Thermal Control Subsystem consists of thermostatically-controlled electric heaters in combination with blankets of insulating material, and special thermal coatings on selected surfaces.

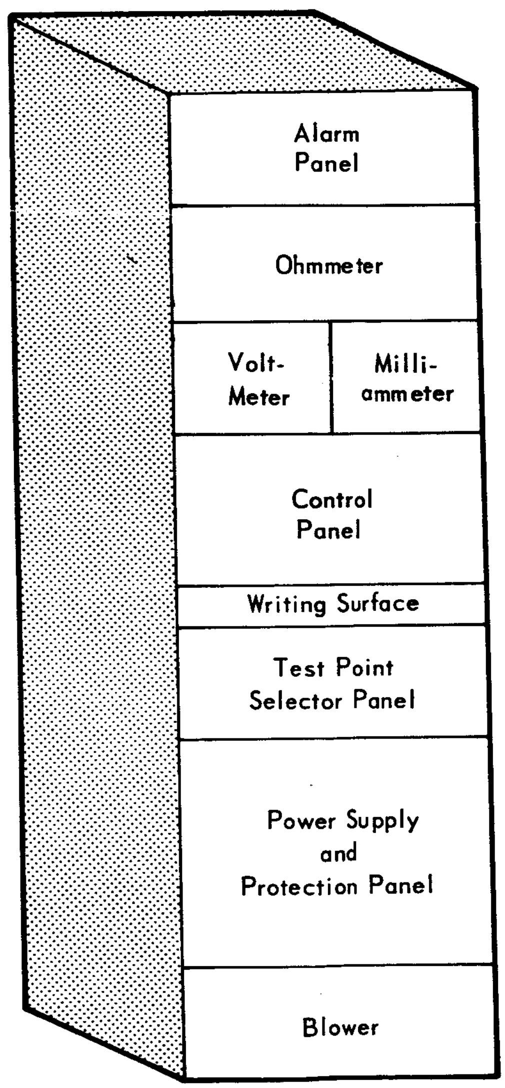
The selected means of testing the thermostatically-controlled electric heaters consists of cycling the flight temperature-sensing elements (thermocouples) and measuring the input power and/or the electrical resistance of the associated subsystem heater elements.

The temperature cycling of the thermocouples is accomplished by means of heat probes which are mounted adjacent to the thermocouples. The heat probe is a thermoelectric device, electrically driven to produce a lower or higher temperature than the set point temperature of the control system associated with the sensing thermocouple. This provides remote operation of each sensing thermocouple and of the associated control circuits that operate the subsystem heater power ON and OFF switches.

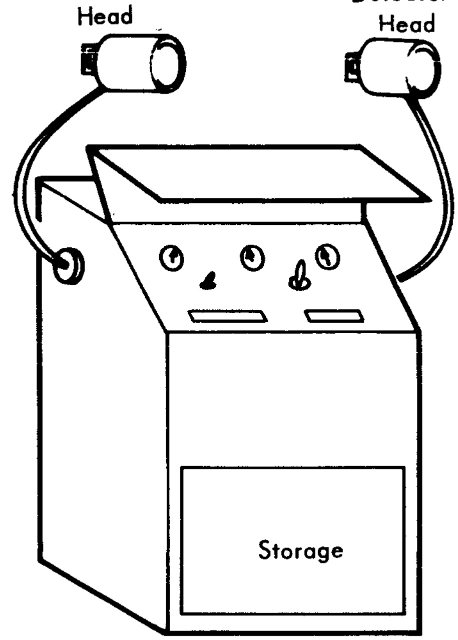
A block diagram of the Thermal Control Subsystem Test Set is shown in Figure 5.6.2. Controls are provided for varying the temperature of the heat probes. Self-test features are included in the test equipment. The circuit selector switches provide means of connecting these control and measuring instruments to the various heat probes and heater circuits of the ESP. Critical circuits contain protective sensors for overvoltage and excessive temperatures.

5.6.3.2 The Emissivity/Reflectivity Test Set - The selected means of testing the special thermal coatings of components is to measure their emissivity and reflectivity.

THERMAL CONTROL SUBSYSTEM TEST SET



Thermal/Electrical Test Set



Emissivity/Reflectivity Test Set

Figure 5.6–1

THERMAL CONTROL SSTS FUNCTIONAL BLOCK DIAGRAM

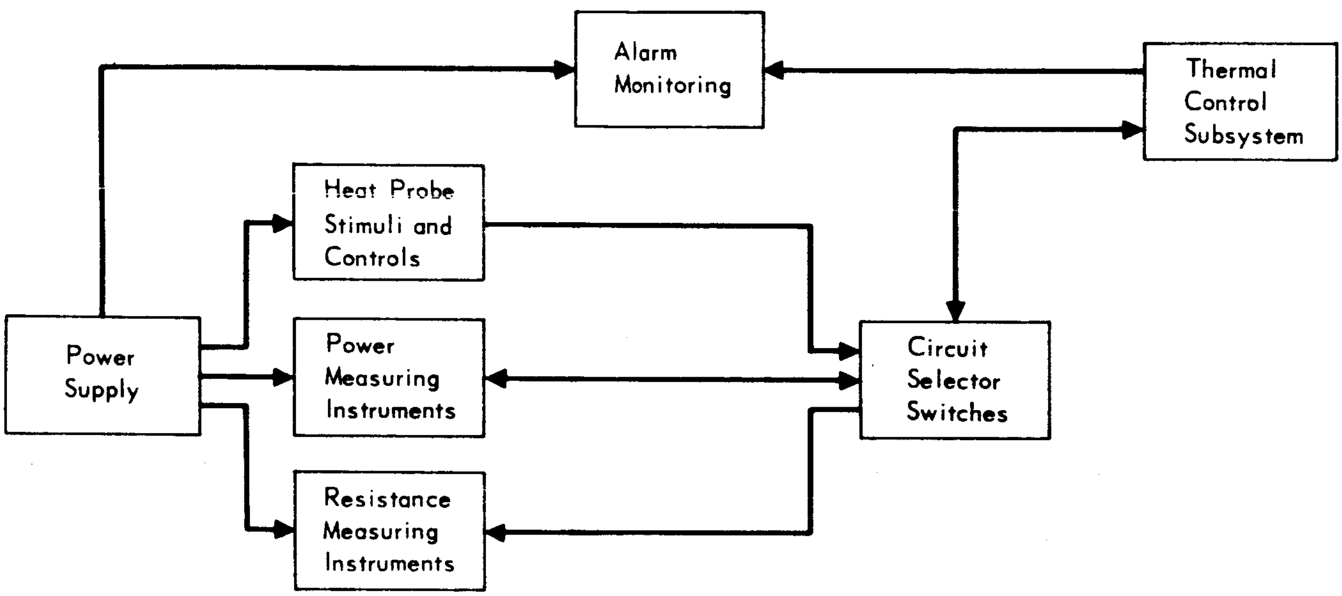


Figure 5.6-2

These measurements are made with hand-held detectors that interface directly with the surface under test. The emissivity detector head measures the emittance of an opaque surface at room temperature. The detector is composed of a radiometer and a heat source for the surface to be measured and is connected to the main cabinet with a flexible conduit. When a room temperature surface covers the radiometer opening, the detector has an output proportional to the infrared emittance of the surface. This output is indicated on a self-balancing potentiometer in the cabinet.

The reflectivity detector is connected to the cabinet, which contains the power supply and readout systems. The detector provides radiation from a Xenon lamp which is filtered and directed into an integrating sphere. When this radiation is directed onto a surface placed over the sample port, the detector has an output proportional to the amount of reflected radiation. This output is read by the indicating potentimeter in the cabinet. Special surfaces are supplied for self-test and calibration of the set.

5.6.4 Interface Definitions - The Thermal/Electrical Test Set makes electrical connection to the Entry Science Package Thermal Control Subsystem through the OSE connectors. Interface connections are summarized in Figure 5.6-3. The Emissivity/Reflectivity Test Set detector heads are physically placed on the thermally coated surface for both radiation and reflection measurements.

THERMAL CONTROL SSTS INTERFACE

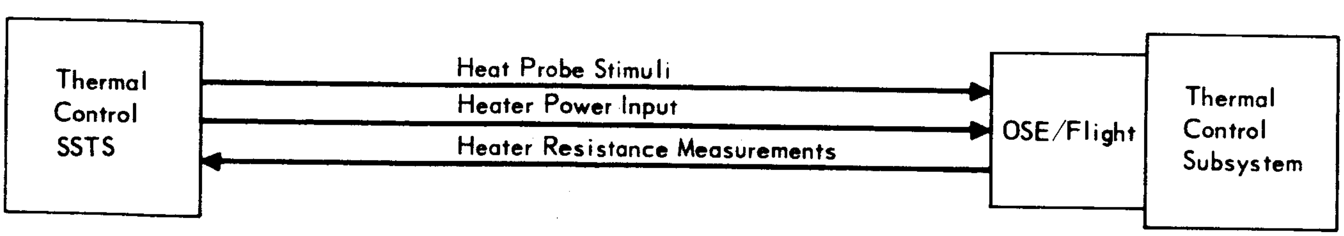


Figure 5.6-3

5.7 AUTOMATIC PROCESSOR

5.7.1 Equipment Identification and Usage - Automatic test sequencing, control, measurement and data recording are provided for selected subsystem test sets (Science and Telecommunication) by the automatic processor - a small (rack-mount), general purpose, digital computer and its peripheral equipment. Incorporating automatic test and checkout features in subsystem-level test equipment results in test schedule flexibility, independent and/or simultaneous test set operation, minimum flight equipment operating time for tests and operator-induced errors, and maximum test repeatability. These factors contribute significantly to the probability of mission success of the flight subsystems by providing accurate, thorough and consistant test data. The automatic processor selected is identical in each test set to simplify programming and maintenance and to minimize total costs.

5.7.2 Design Requirements and Constraints - The quality of system test data is of prime importance in the Entry Science Package program due to the loss of direct accessibility to the flight equipment after the sterilization canister has been installed. As a result, it is imperative that an adequate data bank or log be established that can be used during test operations for operating, anomaly, trend, and failure analyses, and to assist in decision-making during system tests through launch. To be meaningful for analysis, the data must be accurate, consistent (test repeatability), adequate in amount and depth and must be available in usable format. These requirements including costs, are summarized in the trade study of Section 9, which indicates that the optimum solution is test automation by incorporation of an automatic processor in selected test sets.

In addition, the following operational constraints are adequately provided for with the implementation of the selected SSTS-automation approach. The SSTS is capable of:

a. Interfacing with a general purpose digital computer for test sequence control, data gathering and display. The individual SSTS automatic processor performs the detail test routines, fault isolation sub-routines and data gathering. It also provides the potential for future operation in a "satellite" mode under the direction of a central computer, with a significant reduction in the programming complexity and memory capacity of the central computer.

b. performing all tests accurately, expeditiously, and repeatably.

c. Providing self-test capability without test interruption for isolation of problems to OSE or related ESP subsystem. Self-tests and calibrations are incorporated into the test program at strategic points to validate test data and isolate malfunctions without adding significantly to the test time.

5.7.3 Physical Characteristics - The automatic processor, teletypewriter, paper tape punch/reader and peripheral equipment are mounted in a special cabinet to permit sitdown operation. The control panel is mounted in a standard equipment cabinet with its associated logic and interface. An example of a candidate off-the-shelf processor with adequate speed and memory to meet the subsystem test set requirements is the Digital Equipment Corporation's model PDP-8/S, pictured in Figure 5.7-1.

5.7.4 Performance Characteristics functional tasks performed by the automatic processor are:

a. Control the application of stimuli to the subsystem under test.
b. Measure and compare subsystem responses to specified tolerances values.
c. Output out-of-tolerance data to the hard-copy printer.
d. Output all test data to the paper tape punch for recording.
e. Permit program input and modification by punched tape reader or teletypewriter.
f. Program SSTS self-test, calibration and diagnostic subroutines as a part of the normal test routine or "on demand."
g. Allow for manual override at any time.
h. Prevent equipment damage, both to the OSE and flight subsystem by driving to a safe condition in the event of a critical malfunction.

Software - Software for the SSTS is developed as a part of the software program as described in Section 8, Part D. The programming language is common to all SSTS that are automated to reduce costs and provide compatibility for all processors. Program de-bugging will be accomplished during the early development program phases utilizing the developmental models of the flight hardware.

Operational Parameters - Typical operational parameters required of the automatic processor are summarized below:

PARAMETER	SPECIFICATION
Memory Size	4K words, expandable to 32k words; (8k-word memory considered adequate)
Word Size	12 bits, minimum
Memory Cycle	$\leq$ 8.0 microseconds

AUTOMATIC PROCESSOR WITH CONTROL PANEL

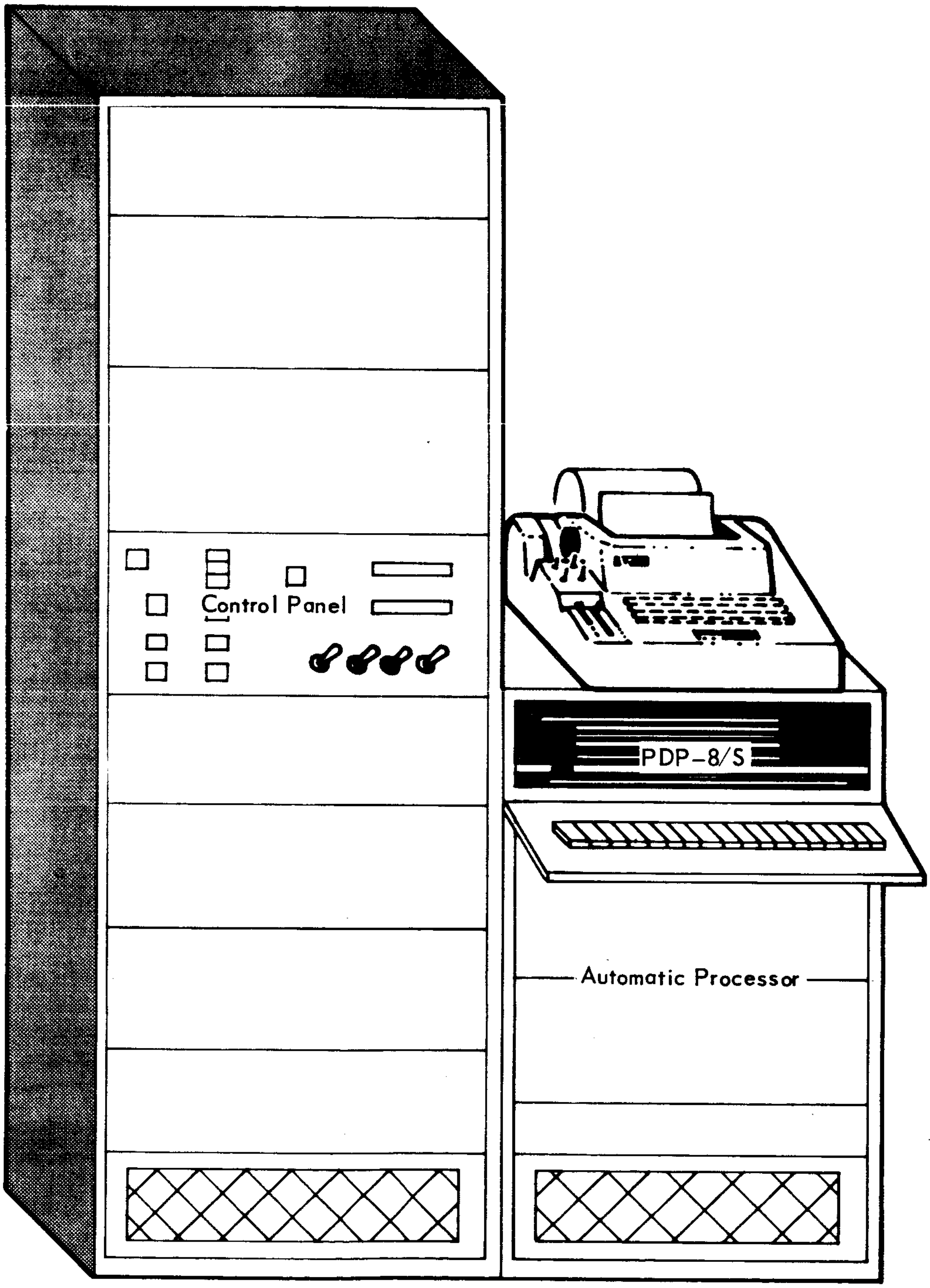


Figure 5.7-1

PARAMETER (CONTINUED)	SPECIFICATION (CONTINUED)
Execution Speed	
Load Word	$<$ 40 microseconds
Store Word	$<$ 40 microseconds
Add	$<$ 50 microseconds
Multiply, Divide (by subroutine)	$<$ 10 milliseconds
Priority Interrupt	Yes
Power Failure Protection	Yes
Compiler	Basic Fortran/Fortran II/IV
Index Registers	$\geq$ 8 (memory)

SECTION 6

ASSEMBLY, HANDLING, SHIPPING (AHSE) AND SERVICING EQUIPMENT

6.1 AHSE - No special equipment is required to assemble, handle, or checkout the Entry Science Package (ESP) or its components. Shipping requirements (including shock isolation and environmental protection) can be met by standard packaging techniques and procedures. Alignment of accelerometers and Descent TV Imaging Camera will be accomplished with laboratory test equipment during Lander assembly. A TV Camera Alignment Target Assembly is required for a final check of camera alignment with respect to the CB roll axis after insertion into the Capsule Bus.

6.2 SERVICING EQUIPMENT - The ESP requires no fluid servicing or checkout.

SECTION 7

SPACECRAFT MOUNTED ESP SUPPORT EQUIPMENT OSE (SCME)

7.1 EQUIPMENT IDENTIFICATION AND USAGE - Complete test capability for ESP subsystems installed in the spacecraft is provided by the ESP/SC-Mounted TCM Subsystems Test Set. ESP subsystems installed in the spacecraft are:

a. Antenna

b. Radio

c. Data Storage

The test equipment is used for compatibility and qualification testing of the ESP/SC TCM subsystems, for subsystems and systems integration, and functional testing. In addition, one set of test equipment is supplied to the Capsule Bus contractor for use during capsule integration and one set installed at KSC for test contingencies.

7.2 DESIGN REQUIREMENTS AND CONSTRAINTS - The ESP/Spacecraft-Mounted TCM SSTS performs the following functions:

a. Provides two stable UHF FSK-modulated signals to test the radio subsystems receivers and diversity combiner.

b. Provides simulated serial PCM data to verify performance of the ESP/SC storage subsystem

c. Provides decommutation of the telemetry data from the ESP/SC data storage subsystem at the 2730 bps and 55,860 bps data rates

d. Interfaces with an automatic processor for test sequencing. Elements of the test set which are automatically controlled are:

- o Digital voltmeter input selector
- o Counter input selector
- o Telemetry controller
- o Printer input selector
- o ESP/SC mode control

e. Provides a display unit to permit selectable channels of telemetry data to be viewed for a quick-look analysis.

f. Provides magnetic tape recording of either or both demodulated telemetry outputs from the ESP/SC radio subsystem.

7.3 PHYSICAL CHARACTERISTICS - The ESP/SC-Mounted TCM Subsystems Test Set is contained in six standard electronic equipment cabinets. The total weight of the test set is approximately 1500 pounds. AC power consumption is approximately 4,300 watts. The physical arrangement is shown in Figure 7.3-1.

7.4 OPERATIONAL DESCRIPTION - The ESP/SC-Mounted TCM Subsystem Test Set provides manual or automatic controlled checkout of the combined ESP/SC TCM Subsystems and manual checkout of the individual ESP/SC TCM subsystems. The functional block diagram is shown in Figure 7.4-1

The automatic processor generates equipment instructions from the test program and routes the instruction to the proper portion of the test equipment for execution. All portions of the test set which are controllable by the processor are also capable of manual control. The automatic processor also selects the source of the data for processing. Data are available from the digital voltmeter, counter, or telemetry processing equipment.

The ESP/SC mode control panel supplies the power and control stimuli necessary to exercise the combined flight subsystems in all of their operational modes.

The UHF transmitters are provided for simultaneous checkout of the two ESP/SC receivers and the diversity combiner.

The FSK-modulation signals for driving the test transmitter are supplied by the telemetry signal simulator. Precision variable attentuators are supplied in the test transmitters to vary the RF output level to facilitate sensitivity and dynamic range measurements. A noise source is provided for injecting noise on the RF carrier for receiver noise rejection tests.

The telemetry processing portion of the test set consists of the following:

a. TM controller
b. TM signal simulator
c. TM signal conditioner
d. Frame synchronizer
e. Subframe synchronizers
f. Data distributor

The TM controller automatically sets up the proper bit rate, input code, polarity, detector type, phase-locked-loop width, capture and tracking range and output code of the TM signal simulator, the TM frame synchronizer, the data distributor, and the TM signal conditioner. During the manual operating mode and in testing the TCM subsystem elements, the parameters are selected by manual switches on the individual equipment front panels.

ESP/SC-MOUNTED TELECOMMUNICATIONS SSTS

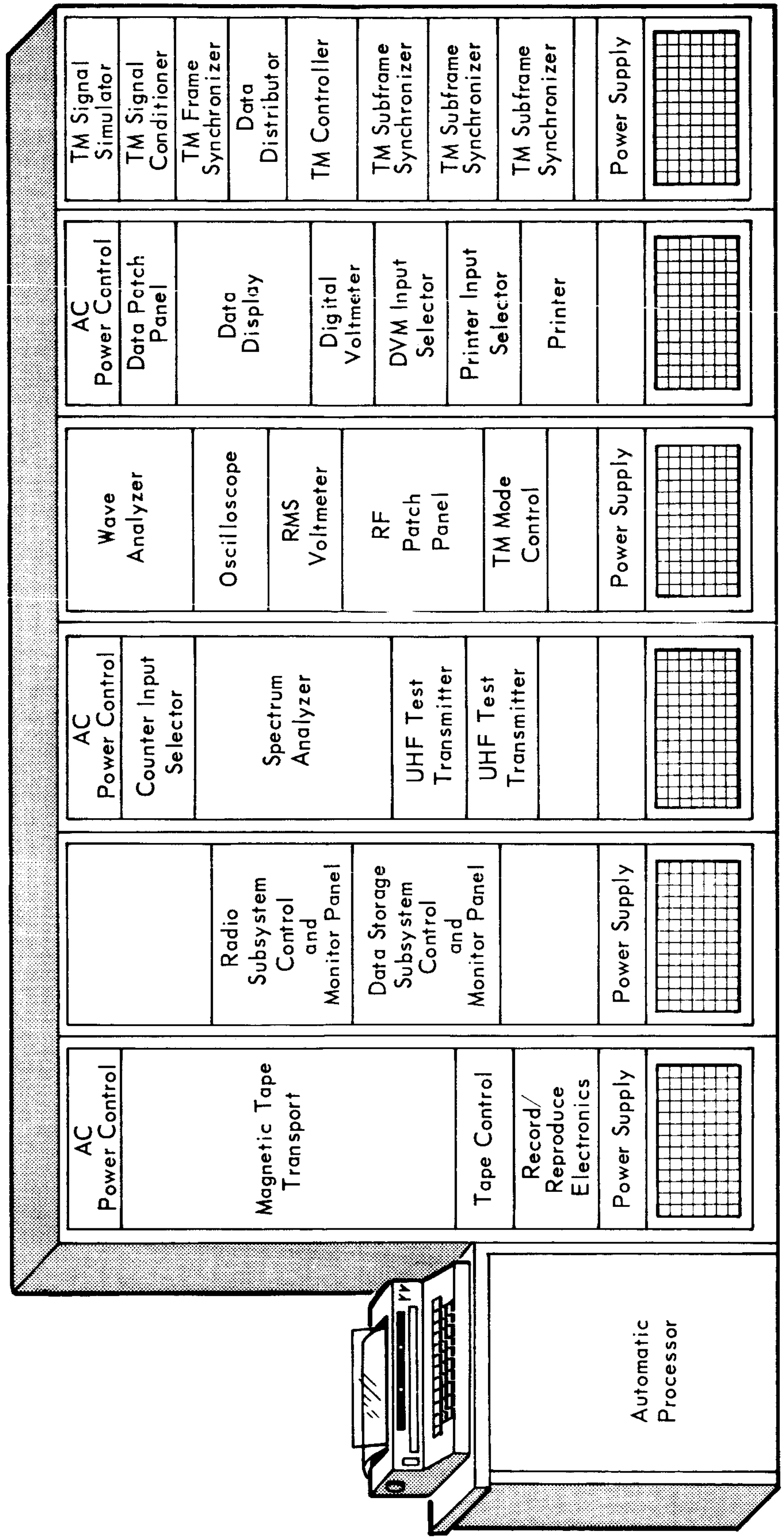
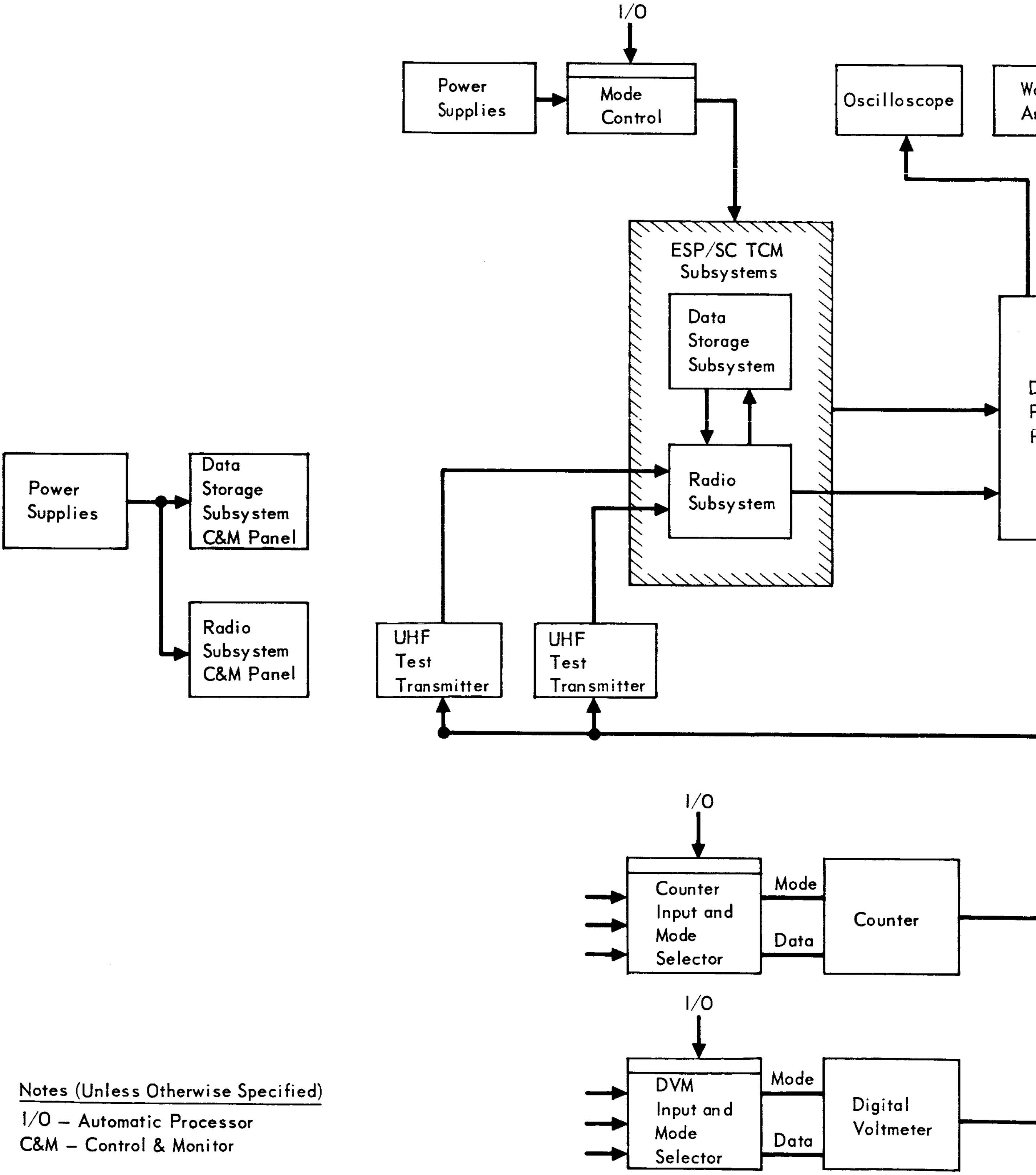


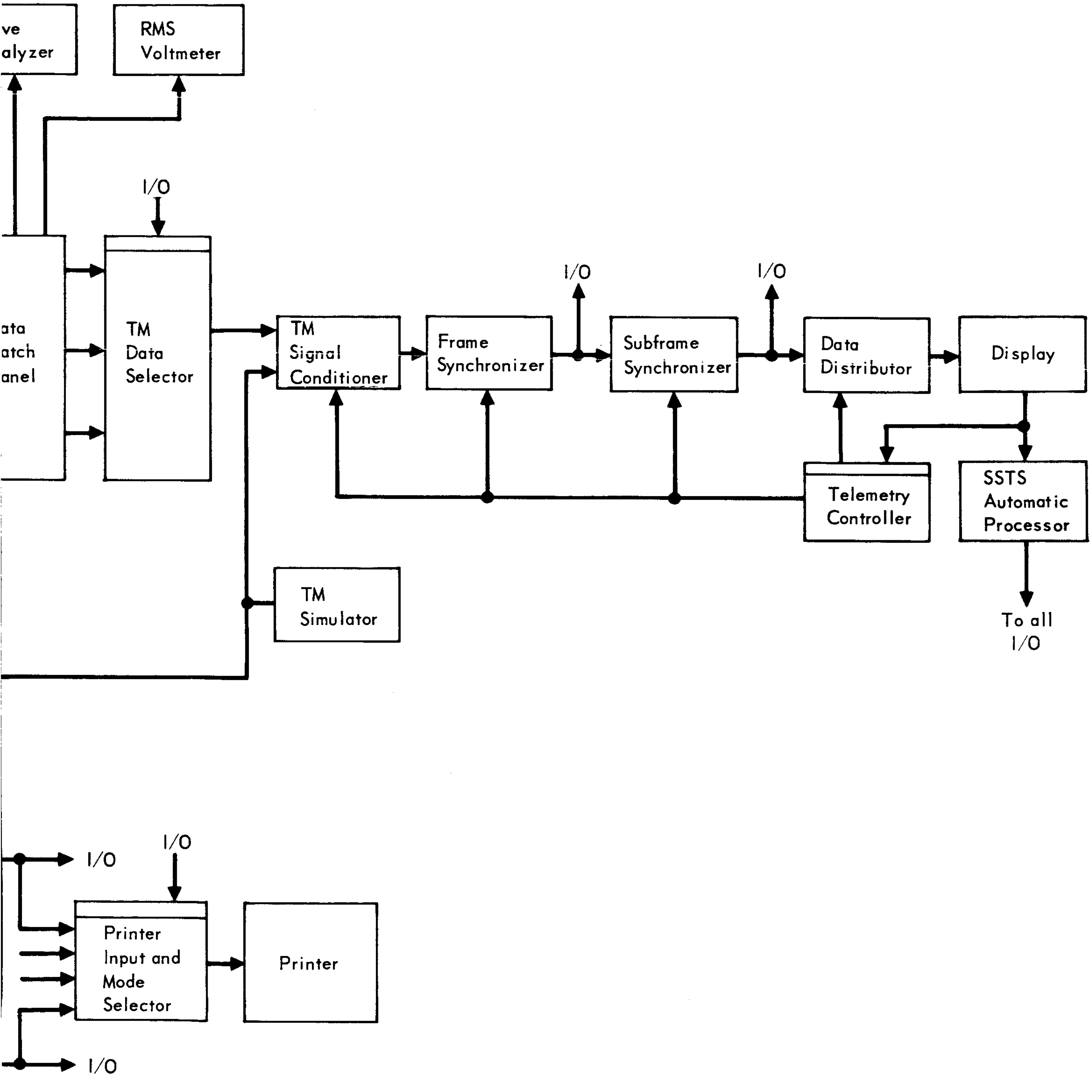
Figure 7.3–1

ESP/SC – MOUNTED TCM SSTS
FUNCTIONAL BLOCK DIAGRAM



Notes (Unless Otherwise Specified)
I/O – Automatic Processor
C&M – Control & Monitor

Figure 7.4–1


ve
alyzer
RMS Voltmeter
I/O
ata
atch
anel
TM Data Selector
TM Signal Conditioner
Frame Synchronizer
I/O
Subframe Synchronizer
I/O
Data Distributor
Display
Telemetry Controller
SSTS Automatic Processor
To all I/O
TM Simulator
I/O
I/O
Printer Input and Mode Selector
Printer
I/O

The DVM input selector, counter input selector and printer input selector provide control of the data being supplied to the respective units. In the case of the DVM and counter, range and function are also controlled by the input selector. The magnetic tape recorder records decommutated telemetry data during simulated cruise, in-flight checkout and entry phase modes. Data from the DVM and counter can be printed out on the printer as well as data from the processor, in real time.

Provisions are made for automatic or manual self-check of the SSTS without test interruption. The DVM and counter input selectors contain calibrated input positions. Calibration can be verified by the processor, by print out on the printer, and/or by visual readout. The telemetry processing equipment can be checked by setting a known input from the PCM simulator and checking the output on the printer, or display unit, or by the automatic processor.

A control and monitor panel for each subsystem provides power and test stimuli to the subsystem under test. Inputs to the subsystems are made to both flight and direct access connectors.

Test requirements of the spacecraft-mounted subsystems are listed in Figures 7.4-2, 7.4-3 and 7.4-4.

7.5 Interfaces - The test set interfaces with the SC mounted subsystems as follows:

a. Individual Subsystem Testing - Interfaces are made at all flight and direct access connectors as shown in Figure 7.5-1.

b. Combined Subsystem Testing - Interfaces are made at the direct access connectors and at the flight connectors that interface with the spacecraft and other Capsule Bus TCM subsystems as shown in Figure 7.5-2. Interface between TCM subsystems is made by a test harness or the Flight Capsule harness.

RADIO SUBSYSTEM

TEST REQUIREMENTS

TEST	MEASURING INSTRUMENT	ACCURACY
Threshold Signal	Text XMTR/RF Pwr Meter	0.5 db
AGC Voltage	Digital Voltmeter	2 %
Local Oscillator Freq.	Counter	$1x10^{-8}$
Mixer Current	Digital Voltmeter	5 %
Power Supply Voltage	Digital Voltmeter	0.1 %
DC Current Load	Digital Voltmeter	2 %
Dynamic Range	Test Transmitter/RF Pwr Meter	1 db
Bandwidth	Test XMTR/RF Pwr Meter	5 %
Noise Figure	Noise Source	0.2 db
Image Rejection	Test XMTR/Scope	1 db
Demodulation/Video Test	Test XMTR/Scope	5 %

Figure 7.4-2

RECEIVING ANTENNA

TEST REQUIREMENTS

TEST	MEASURING INSTRUMENT	ACCURACY
Impedance/VSWR	VSWR Meter/Slotted Line	5 %

Figure 7.4-3

DATA STORAGE SUBSYSTEMS

TEST REQUIREMENTS

TEST	MEASURING INSTRUMENT	ACCURACY REQ.
Input Data	TM Signal Simulator	Digital
Output Data	TM Processing Equip.	Digital
Memory Overflow Signal	Digital Voltmeter	2 %
Memory Empty Signal	Digital Voltmeter	2 %
Power Supply Voltage	Digital Voltmeter	2 %
Power Supply Current	Digital Voltmeter	2 %
Sequencing Clock Frequency	Counter	Digital
Tape Speed	Counter	0.1 %
Tape Direction	Digital Voltmeter	2 %
Tape Bias Voltage	Digital Voltmeter	2 %
Tape Motor Drive Voltage	Digital Voltmeter	Digital
Command Verification	Data Storage SS C&M Panel	Digital

Figure 7.4-4

ESP/SC-MOUNTED TCM SSTS INTERFACES
(INDIVIDUAL SUBSYSTEM TESTING)

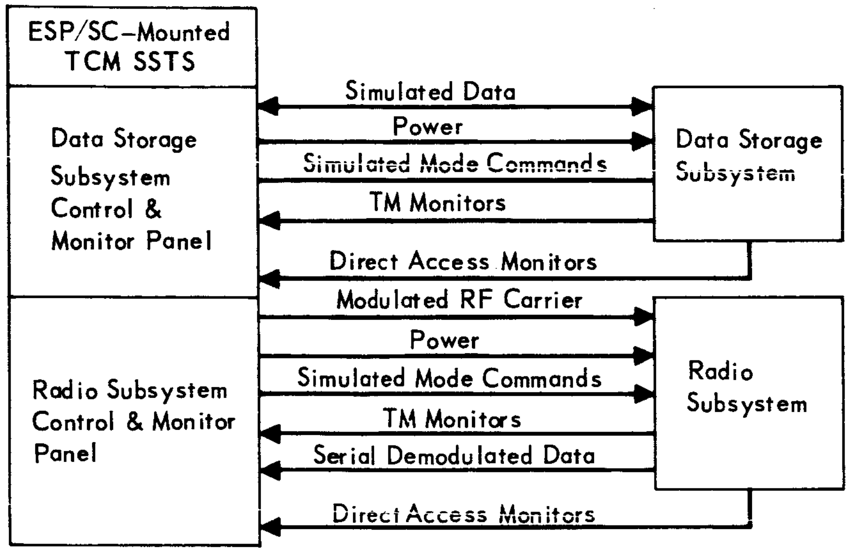


Figure 7.5-1

ESP/SC-MOUNTED TCM SSTS INTERFACE
(COMBINED SUBSYSTEMS TESTING)

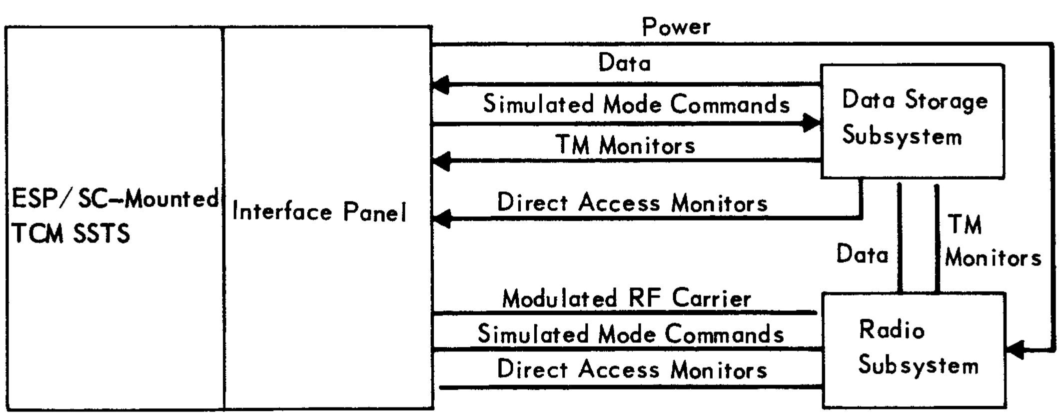


Figure 7.5-2

SECTION 8

SOFTWARE

Software is the vital link between the operator, the test program and the test equipment. It provides a means to translate commands, interconnect equipment, and gather and format the response data. Accurate and timely compilation of the data from the initial test to launch, and use of that data for analyses and decision making are significant requirements to ensure the success of the VOYAGER Program.

This section describes the total software package and its development and management for the Entry Science Package checkout and launch. Where separable, program packages are identified and described for each checkout phase. The total OSE program is designed as an integrated hardware/software marriage, utilizing economic and reliability merits of each in reaching decisions for tradeoffs.

8.1 SOFTWARE MANAGEMENT - Disciplined management of software packages ensures safe, reliable, and repeatable test sequencing and data processing, and provides uniform software documentation and control within major contractor task areas. The software configuration used in any given checkout operation is uniquely identifiable. Internal processing routines, as well as major test programs, must be included in configuration control.

8.1.1 Philosophy - Efficient software management requires that the total software package under development be divided into small manageable areas. Our packaging concept uses the natural division of discipline between machine language programming (support software) and test language programming (operational software) to establish logically separate software packages. These basic packages are further broken down into the following software areas:

a. Support Software for Subsystem Test Sets (SSTS)
b. Operational (Test) Software for Subsystem Test Sets
c. Support Software for the Capsule Bus Systems Test Complex (STC)
d. Operational Software for the Capsule Bus Systems Test Complex
e. Common (SSTS/STC) Support Software
f. Mission Dependent Equipment (MDE)

8.2 SOFTWARE PACKAGING - The following paragraphs describe the concept and configuration for the support and operational software packaging of both SSTS and STC.

8.2.1 SSTS Support Software - This software provides the basic tools for machine language conversion, program compilation, and preparation of higher level software. Routine utility software and computer diagnostic/self-test programs fall into this category. Support software includes those program packages that would normally be run off-line prior to or after a period of checkout or as background work in a time-shared system. In general, the computer supplier will provide a portion of these basic tools.

SSTS Peculiar - The SSTS peculiar Support Software includes:

a. A utility package comprising such programs as a Memory Dump, Paper Tape Copy, Dump and Compare, Character Conversion Routines and other basic programs usually required for computer operation. This software is generally available from the computer manufacturer in a checked out and usable form.

b. An assembler for generating machine language programs and possibly a Fortran type compiler. These also will be supplied by the SSTS computer manufacturer in a checked out and usable form.

c. Computer diagnostics for both maintenance and on-line verification of the computer. These diagnostics must verify the operational readiness of the computer logic, computer memory, and all peripheral equipment. They will be furnished by the computer manufacturer and will be expanded as necessary to accommodate operational developments.

d. A quick-look test results processor. This processor will produce hard copy printout from the paper tape, generated on-line by the SSTS computer during subsystem tests. The tape contains a record of all commands given and measurements made, time-tagged, and provides an on-the-spot means of post-test troubleshooting, or near real time printout of selected data.

8.2.2 SSTS Operational Software - All SSTS test programs executed/interpreted in real time constitute the SSTS operational software.

SSTS Peculiar

a. The basic SSTS peculiar operational program is the SSTS Executive. This program accepts mode control and direction from the control panel and provides positive indication of reception of direction. It sequences all operations of the test equipment and controls the SSTS displays. The Executive causes all command sequences, measurements, and time to be recorded on paper tape for post-test reports and trend analysis, and periodically self-checks the computer without interruption of any test in progress. The program controls the remaining processors in the SSTS computer for all required operations. A typical Executive flow is shown in Figure 8.2-1.

b. The SSTS Input/Output Processor handles all input/output between its computer and the remainder of the SSTS and between the computer and its peripheral equipment. All processors in the SSTS computer will use this processor for their input/output (I/O) to assure centralized control.

c. The Test Program Interpreter Processor functions under control of the Executive to keep track of test step numbers and to allow execution of each step of the test procedure. It accepts the output of the test procedures preprocesses and monitors execution of it. It also records test identification, date, time of day and serial number of equipment under test whenever it records a test sequence on paper tape.

d. The Alarm Processor executes shutdown routines if either the monitor/alarm interrupt occurs or if the test engineer requests it. These routines may be either permanently defined within the processor or defined by the test procedure in progress at the time of the alarm.

e. The On-Line Input Processor allows modification, during holds, of test limits or program logic, and allows control of individual stimuli and measurement devices from the typewriter. All actions in this mode are recorded as test results and will be included in any trend analysis or test results reduction.

f. The individual SSTS Test Procedures for each subsystem constitute the remaining operational SSTS software. Based on cost and schedule factors, these procedures will be written in the highest level language possible. The procedures will be executed under control of the Test Program Interpreter and will control application of stimuli, measure responses, compare measurements to limits in percent of full scale and output milestone or malfunction data on hardcopy, etc.

8.2.3 STC Support Software - STC Support Software is used only by the Capsule Bus Computer Data System (CDS) during integrated CB, SL, and ESP tests. It includes all off-line data processing required for Entry Science Package data and diagnostics.

Detailed specifications for ESP support software will be provided by the ESP contractor to the Capsule Bus contractor for generation of programs to be incorporated in the support software for the CB STC.

TYPICAL REAL TIME CHECKOUT EXECUTIVE PROGRAM FLOW

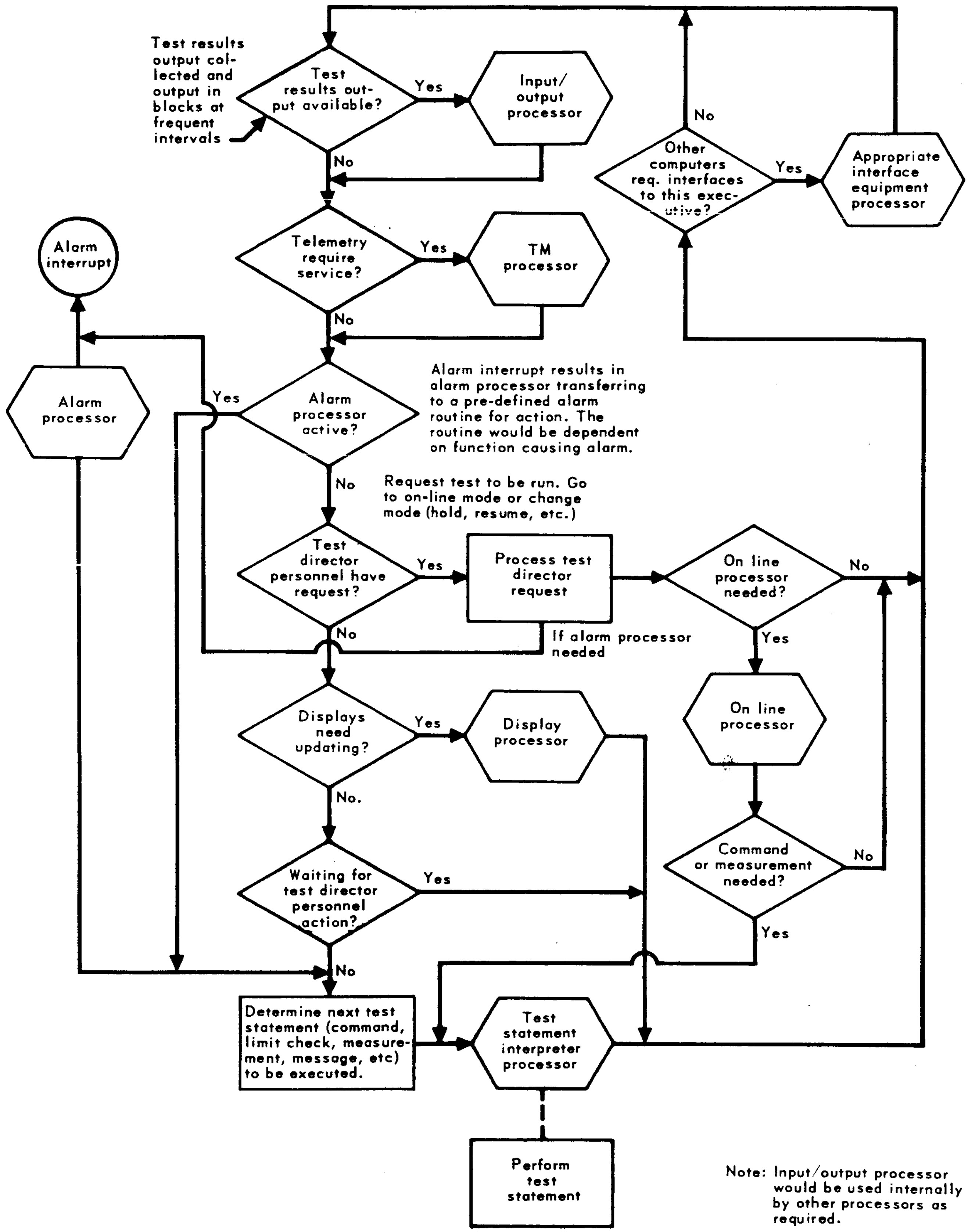


Figure 8.2-1

8.2.4 STC Operational Software - All Entry Science Package real-time, on-line, test programs performed at the systems level by the Systems Test Complex comprise the operational software. Software specifications, prepared by the ESP contractor, will be supplied to the Capsule Bus contractor as well as the support software specifications. ESP operational software includes the following programs which become a part of the total STC software:

a. ESP Executive - This program will be the central controller in the STC computer, responsible for all sequencing of the various processors in the STC computer, for accepting mode control and direction from the test director, and for keeping the test director aware of what is happening at all times. Data suppression will be accomplished when data varies by more than a specified amount on a line printer for any fucntions that the test director desires. The program will record command sequence, measurements, test site, range time, alarms, test procedure step numbers, etc. for post-test reports and trend analysis.

b. ESP Input/Output Processor - The I/O Processor will provide for data transmission between the computer and the ESP test equipment, and between the computer and its peripheral equipment for the various processors and the STC computer Executive.

c. ESP Test Program Interpreter - This program will function under control of the Executive to allow execution of each test sequence. It will accept the output of the Test Procedure Preprocessor and monitor and control execution of the test program. It also will record and type out test identification, date, time of day, serial numbers of equipment under test, etc., whenever it executes a test or directs the SSTS to execute a test.

d. ESP Alarm Processor and On-Line Input Processor are similar to those described for the subsystem-level test equipment.

e. ESP Display Processor - The Display Processor will handle the updating of all CRT and related types of displays for the ESP systems test console at fixed periods of time or at the option of the test director. The displays provide test data in engineering units. Out-of-tolerance values can be flagged as desired. The CRT-page type displays will show pre-planned measurement data. Fixed unassigned areas will be used for display of selected parameters at the test director's request, eliminating the need to change pages if a function needs monitoring but is not on the displayed page.

8.2.5 Mission Dependent Equipment (MDE) - The management, development, and documentation of MDE software for the Telemetry and Command Processor (TCP) computer is essentially the same as the approach described above for the STC computer. A similar packaging approach will be employed, except that the executive and processor programming requirements are significantly reduced. The major MDE software requirements are described in paragraph 4.5, Part D.

8.3 SOFTWARE DEVELOPMENT - Because there are several manufacturers and vendors participating in the Capsule Bus program, it is imperative that software development be centrally controlled and coordinated. Language format, procedures and techniques will be developed by the Capsule Bus contractor and applied to cognizant organizations. Test program software will be developed by the Entry Science Package contractor and by individual vendors involved in supplying the flight hardware and corresponding OSE, in conformance with these procedures. This centralized direction and control of software will be developed in concert with hardware design and test requirements integration, resulting in an effective and timely software and test program.

8.3.1 Philosophy - McDonnell-Douglas experience in developing support/test software for the Saturn S-IVB Automatic Checkout System (ACS) has shown that strict central organization and control ensures that the multitude of software interfaces will mate under all environments. Consistent, complete documentation, concurrent with program development, will minimize field support and maintenance staffing. Common software between test area and checkout systems will minimize software maintenance costs, maximize program reliability, and assure test sequence repeatability between areas. This is particularly true of the test language where the customer, vendor, ESP and Capsule Bus test engineers must think in common terms.

8.3.2 Development Phases - In general, software development has four phases: definition, programming, debugging, and production. These will be described in detail below.

8.3.2.1 Support Software Development - Figure 8.3-1 is typical of support software development. The total software package provides maximum reliability and flexibility to fully utilize available computing equipment. Consistent with the total software design concept, individual programs will be defined in detail in Software Request Documents (SRD). Once the SRD is approved, detailed subroutine specifications will be prepared followed by analysis, flow charting, and coding. The individual routines and checkout drivers will be assembled/compiled, desk checked, and debugged. Then the entire program will be debugged as an entity

SUPPORT SOFTWARE DEVELOPMENT AND MAINTENANCE

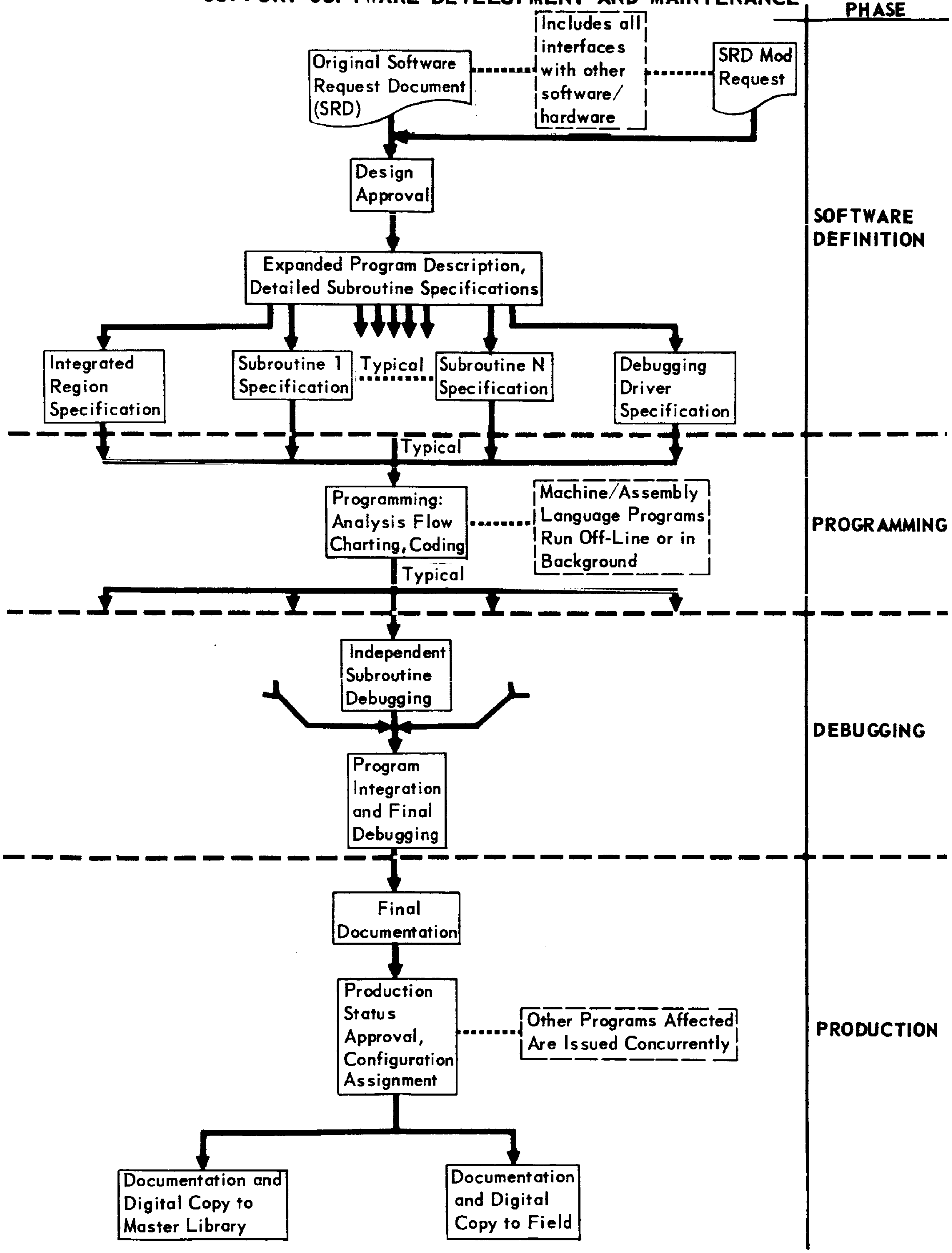


Figure 8.3-1

prior to documentation and approval for production status. A central library of test programs (digital and hard copy) will be maintained at the Entry Science Package contractor's factory, with a satellite library at the Capsule Bus contractor's facility, at KSC and appropriate vendors.

8.3.2.2 Operational Software Development - The procedures shown in Figure 8.3-2 are typical of test program development. A minimum number of test programs will be developed to fully checkout the ESP and its subsystems in all of its operating modes. A Test Requirement Documents (TRD) will be prepared to completely define the purpose of the test, the equipment to be tested, and the test sequencing constrained by the operating concepts. The test programs will be prepared from approved TRD's in the VOYAGER test language. The preprocessor will process the source test program and produce a test sequence listing and an object program for operation under the control of the Executive. It also will produce error notes for use in correcting the programs. Once the program listing is free of error notes, the program will be run against engineering development models which will serve two purposes: test operations personnel will become familiar with the test procedure and OSE equipment operating concepts; and further debugging of test procedures and test equipment will be accomplished. The checked-out test program will then be copied; one copy will be distributed to each using area, with the master retained at the tape library. Prior to mating with equipment to be tested, OSE TRD's will be written for self-test of the OSE. A typical test phasing plan for a checkout area is depicted below:

- o OSE manual setup/calibration procedures.
- o Automatic OSE end-item setup/self-test procedures.
- o Automatic OSE self-test (with special patching routing command signals to measurement channels).
- o Automatic OSE configuration self-test (patching configured to match the system about to undergo test).
- o Use flight system development hardware for test program development which will be phased to minimize the possibility of endangering equipment due to improper manufacture or test sequencing.
- o Mate to subsystem and perform automatic checkout with checked out test programs.

Test results processing will be performed to augment on-line test milestone and malfunction data for post-test troubleshooting and selloff. Test results processing

TEST PROGRAM DEVELOPMENT AND MAINTENANCE

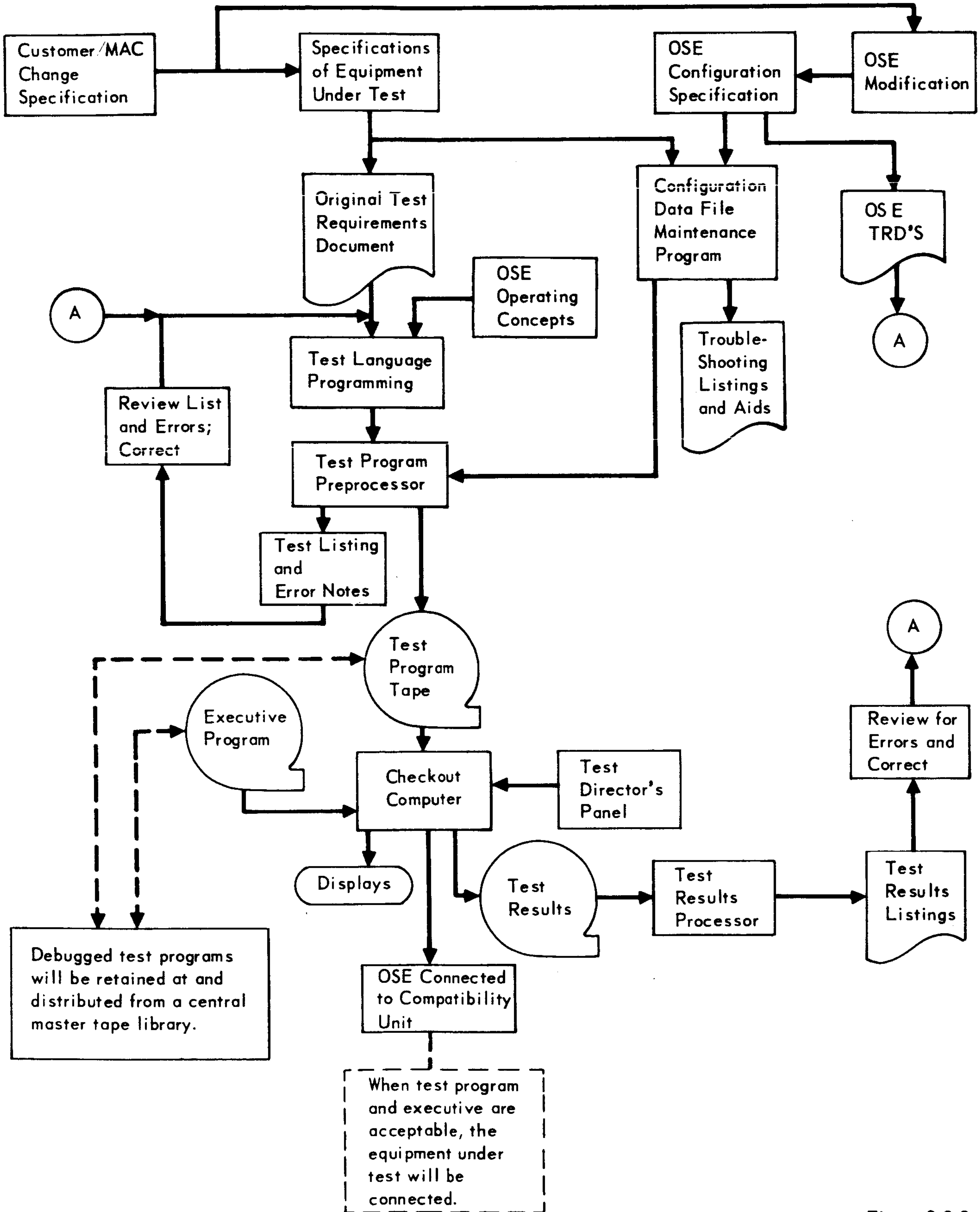


Figure 8.3-2

will be used extensively during the initial test development and test director training phases.

8.4 SOFTWARE CONTROL/DOCUMENTATION - A Software Request Document (SRD) will be required to define pertinent specifications for the support program. The actual programming can be begun only after the specifications, including hardware and software interfaces, are reviewed and approved. A Test Requirement Document (TRD) also will be required for the test procedures, including all sequences necessary for any potential hardware/test director actions, prior to compiling a test program. Detailed, standard format documentation must be provided. Support program/routine descriptions will include input/output specifications, interface formats, flow charts at the detailed subroutine level, and assembler/compiler listings annotated with functional explanations. Test program documentation also will include a description of the equipment under test, a functional schematic/block diagram, a brief description of the purpose of the test, and the test language processor listing, which will contain remarks describing major blocks of test.

All support and operational software are circumscribed by the following software standards:

a. Modular programming, applying subroutine techniques, will be used. Standard format conversion routines, table lookups, etc. for use by all programs, will minimize programming development time.

b. For built-in error checking and diagnostics, the Executive/supervisor will contain a computer diagnostic routine that will be performed periodically, possibly between test statement execution. A built-in software sensing feature will verify that all executive program tasks are being performed.

c. Independent routines will be checked out separately, using a building block approach, then integrated and debugged. The test cases and simulated software interfaces used for debugging will become a part of the routine/program documentation for later use.

d. Uniform man-machine communication formats will be used to eliminate incorrect message interpretations and enable positive command/control and test intervention as required.

8.4.1 Test Procedure Language - Following are brief descriptions of the advantages and disadvantages of the four principal programming techniques:

a. Machine Language

b. Fortran, etc.

c. A Fixed-Format Test Language

d. A Free-Format Test Language

Machine Language requires a programming specialist to program the computer at a low level of machine instruction. Many programming steps are required for even a simple operation. Machine language is detailed and extremely complicated, and requires trained programmers to produce efficient and useful programs. Programmers would be required at each test area to prepare and maintain test programs.

Fortran is an algebraic, higher level, scientific language. It can be used to write programs in a simpler form than machine language, but they would bear no resemblance to manual procedures and a great deal of additional training would be required before operations-type personnel could understand them. Also, large Fortran-type programs, as required on VOYAGER, rapidly become as complicated and difficult to understand as machine language programs. It is probable that frequent excursions into machine language would be required, and obscure capabilities of the language would have to be used to achieve the capabilities needed for checkout.

Test Languages, both Fixed and Free Format, have been used in automatic checkout by several contractors in the past, including McDonnell-Douglas. These languages, e.g. Saturn Test-Oriented Language (STOL), are usually oriented to general checkout, with some features unique to the particular system due to peculiarities in designs.

In a Fixed Format Language, fixed columns on an IBM card are reserved for the operator, the operand, etc. The cards must be filled exactly or the test language preprocessing program will consider it an error, thus necessitating a rerun because no object code would be generated.

In most Fixed Format Languages the operand field is not large enough for a standard component title or even a recognizable abbreviation. Thus the test programmer must know the system and OSE configurations well in advance of testing, unless dummy symbols are assigned to known commands and measurements and later defined to the preprocessor or Executive by a cross reference index. It is also awkward to provide for retention of several measurements so that arithmetic operations may be performed with a Fixed Format Language.

In a Free Format Test Language such restrictions are minimized or do not exist at all, as demonstrated in one checkout language used currently on the Saturn Program (STOL).

<u>Summary</u> - Both the Fixed and Free Format Test Languages especially the latter, are far easier to understand and use than either Fortran or Machine Language. They do require a special preprocessor to be written which will convert from the test language (English) form to a language the computer understands. The free format preprocessor is more difficult to write than the fixed format preprocessor. However, it is believed that amortizing the Free-Format Test Languages Reprocessor costs over the length of the VOYAGER program will cost less than the use of machine or Fortran languages when we consider the personnel training costs required for Fixed Format Language implementation. On this basis, a Free Format Test Language is recommended for Entry Science Package software.

SECTION 9

OSE EQUIPMENT SUMMARY

The Entry Science Package (ESP) Operational Support Equipment requirements identified during Phase "B" are tabulated in Figure 9-1. Included in this summary are simulators, and Mission Independent Equipment that are considered GFE and are to be supplied by NASA or other system contractors.

Figure 9-1 illustrates equipment required at the primary using areas, but does not indicate the quantity required. As noted in the previous text, the ESP equipment requirements have been determined essentially on the basis of assembling and testing the ESP at a separate facility. These requirements will change significantly when ESP technical responsibility is established and test functions shared. Prior to Phase C, a schedule and quantity analysis will be conducted to provide a more detailed site utilization, and the exact quantity of OSE required at each site.

OSE EQUIPMENT SUMMARY

ENTRY SCIENCE PACKAGE

OSE	AREA UTILIZATION FACTORY	KSC	DSN	CB CONTRACTORS PLANT
SYSTEM TEST COMPLEX (STC)				
ESP Command and Display Console		X		X
Ground Data Transmission System		X		X
D/A Converters and Decoding Equipment	X			
Voice Communication Panel	X	X		X
TCP/SSTS Interface Equipment	X			
△1 ESP MDE (Ref. MDE List)	X	X		X
△3 △2 TM & Command Processor (TCP) Computer	X	X		
△3 △2 TCP Peripheral Equipment	X	X		
△4 Computer Data System (CDS) Computer		X		X
△4 CDS Peripheral and Interface Equipment		X		X
Junction Box	X	X		X
Complex Cabling	X	X		X
△2 CB Thermal Simulator	X			
ESP to SC Simulator	Used at SC contractor's plant			
ESP to CB Thermal and Electrical Simulators	Used at SC contractor's plant			
LAUNCH COMPLEX EQUIPMENT (LCE)				
Launch Monitor Panel		X		
Ground Power & Distribution Equipment	X	X		X
Remote Stimulation Equipment	X	X		X
UHF Receiving System		X		X
MISSION DEPENDENT EQUIPMENT (MDE)				
△1 Data Demultiplexing Equipment	△1 X	△1 X	X	△1 X
△1 ESP Command Equipment	△1 X	△1 X	X	△1 X
ESP Simulator			X	
△1 TV Data Processor	△1 X	△1 X	X	△1 X
△1 Video Tape Recorder	△1 X	△1 X	X	△1 X
△1 Video Comm. Processor	△1 X	△1 X	X	△1 X
△1 Demultiplexer	△1 X	△1 X	X	△1 X

Figure 9-1

OSE	FACTORY	KSC	DSN	CB CONTRACTOR'S PLANT
		AREA UTILIZATION		
SFOF Data Display Console			X	
SFOF ESP Control Console			X	
SFOF Display Interface Equipment			X	
SUBSYSTEM TEST EQUIPMENT (SSTE)				
⚠5 Power Subsystem Test Set (SSTE)	X	X		
⚠5 Thermal Control SSTS	X	X		
⚠5 Telecommunications SSTS	X	X		
⚠5 Science SSTS	X	X		
SPACECRAFT MOUNTED SUPPORT EQUIP OSE				
ESP/SC Mounted TCM Subsystem Test Set	X	X		

⚠1 MDE/Duplicate used at STC

⚠2 GFE Supplied by NASA or Voyager System Contractor

⚠3 Mission Independent Equipment (MIE) used in STC.

⚠4 CB contractor's equipment time shared with ESP contractors.

⚠5 Selected items of SSTE used in STC at ESP contractor's plant

Figure 9-1 (Continued)

SECTION 10

SUPPORTING ANALYSIS AND TRADE STUDIES

This section contains a discussion of the approach to OSE concept selection, a list of selected concepts and alternatives, and the trade studies and analyses to support the major concepts. A summary of the major OSE concept alternatives evaluated during Phase B, and the selected approach are illustrated in Figure 10-1. Significant concepts documented by trade studies are summarized in Figure 10-2.

10.1 CONCEPT SELECTION APPROACH - The selection of OSE concepts follows a system engineering logic pattern similar to that used for flight subsystem selection. The process relies heavily upon engineering judgement and experience coupled with a knowledge of the VOYAGER objectives and Entry Science Package (ESP) design and test requirements.

Ground Operations and Test Plan - The Integrated Test Plan (Vol. VI, Part B) describes the test and operations performed on the Flight Capsule (including ESP) from equipment installation to launch. Functional analysis of this plan establishes the test and operations requirements and forms the basis for OSE concepts. Feedback and iteration of OSE and test concepts are maintained throughout the concept selection process.

ESP Flight System Design - The initial design of the ESP is analyzed to establish preliminary functional and test requirements. The interaction of OSE and flight systems engineering is emphasized in areas such as test point availability and accessibility, test stimuli and monitoring, use of in-flight checkout and built-in-test, and depth of fault isolation. The preliminary OSE concepts are fed back through flight systems engineering for evaluation, and the flight system to OSE interfaces are integrated as a balanced system.

Project Level Selection Criteria - The OSE concept selection is based on VOYAGER project level selection criteria values developed by Flight Capsule systems integration engineering, as follows:

Probability of Mission Success	.35	Flexibility	.15
System Performance	.20	Cost	.10
Development Risk	.20		

The program selection criteria is translated into unique OSE selection factors that are meaningful to the evaluation of a particular type or configuration of OSE. A list of typical OSE selection factors is shown in Figure 10.1-1. A standardized

BASELINE CONCEPT SUMMARY

OSE CATEGORY	OPERATION	ALTERNATIVES AND SELECTED BASELINE	REMARKS
Subsystem Test Sets	Degree of SSTS Test Automation	• Selected Automatic with Manual Backup (Automatic to the extent practical)	• Minimizes total test time. • Reduces operator-induced malfunctions. • Quick reaction to critical conditions. • Rapid malfunction verification • Facilitates test repeatability. • Flexible for equipment growth thru total program life.
		• Manual	• Simplest – lowest in cost.
	Central or Local Automatic Control	• Local	• Independent of central control – maximum test flexibility. – allows simultaneous subsystems testing. – operation not affected by central control down time – permits possible usage of SSTE at vendor's facilities or remote test sites. – permits independent OSE self-tests.
		• Central	• Complex programming and computer interface
	Test Sequence Control and Comparison	• Satellite Computer (Small, digital, general purpose)	• High reliability. • Possible reduction in central computer memory requirements. • Self-test easily implemented. • Quick reaction. • Random access permits test flexibility. • Minimizes central computer interface.
		• Punched tape	• Moderate cost
		• Electro-mechanical	• Possibly lowest in cost.
		• Magnetic tape	• Relatively high cost.
		• Hard-wired	• Inflexible – not easily modified.
	Test Parameter Monitoring	• Digital Readout (Analog readouts as required)	• Increases test repeatability – reduces interpretation error. • A/D conversion facilitates: – data printout/logging. – data output to central computer. – direct digital data comparison. – digital recording for trend/data recording.
		• Analog Meters	• Simplest • Multiple readouts or ranging required.
		• A/N CRT	• Costly. • Centralizes readout for multiple parameters. • Requires minimum panel space for multiple – parameter display.

Figure 10–1

	Test Data Printout	• Hard-Copy Printer in SSTE • Central printer	• Direct, readable record of test results immediately available to operator. • Reduces visual display requirements – permits time-sharing of display, plus callup capability • Provides printout of telemetry data to SS engineer. • Each subsystem test data compiled separately. • Minimum cost
	Analog/Bi-Level Recording	• Local Recorder (each SSTE) • Central recorder.	• Oscillograph, X–Y plotters as required by each SSTE. • Data directly available to subsystem engineer. • Data inaccessible to subsystem engineer during test.
	Data Time Tagging	• Central Clock for all SSTE. • Individual clock • No time-tagging	• Makes all SSTE data time coherent. • Requires synching for systems testing. • Recorded data loses significance.
	OSE Self-Test (Malfunction verification to OSE or flight subsystem a constraint – 5.2.1.h)	• Fault Isolation to Depth Possible) • Malfunction verification only.	• Expedites OSE maintenance. • Limited due to use of off-shelf support equipment. • Provides OSE operational status. • Requires support equipment for OSE. • Time-consuming.
	Alarm Monitoring.	• Local (SSTE) and Central Alarm Capability • Local alarm only. • Central alarm only	• Provides alarm monitoring of both TM and direct subsystem data. • Incomplete monitor capabilities • Restricts independent SSTS operation.
System Test Complex (STC)	System Test STC Mobility	• Entire STC (Equipment, Data Links, and cabling) moveable • Equipment and interconnecting cabling moveable data links fixed. • Van mounted STC	• Maximum cabling disassembly and hookup time • Maximum confidence in STC verification. • May not be compatible with STC facilities and associated contractors implementation.
	Degree of Test Automation	• Mariner C approach (Analog displays and computer controlled data evaluation) • Mariner C approach and semi-automatic test sequencing and manual backup • New System, fully automatic – closed loop with manual backup • Use existing Apollo ACE Installation	• Does not provide for automatic test sequence operation • High repeatability • Reduced test time • Imposes operational complexities on operating personnel. • No real savings in test and display functions. • Creates more complex equipment • High repeatability • Reduced test time • Not computer dependent for critical displays and commands. • Not software dependent for test sequencing. • Maximum expandibility and flexibility for future requirements. • May interfere with Apollo operations. Further study intended.

BASELINE CONCEPT SUMMARY (Continued)

OSE CATEGORY	OPERATION	ALTERNATIVES AND SELECTED BASELINE	REMARKS
System Test Complex (STC)	System Test Data Display Method	• Digital Alpha-Numeric CRT • Digital readouts (NIXIE, projection, etc.) • Analog meters	• High flexibility • Accurate • Capable of symbolic display • Requires more panel space. • Requires D/A conversion • Limited accuracy
	STC Location at KSC	• Hangar AO .... • Alternate existing location (MSO) • New location	• Customer to confirm, (Candidate location presently used by Mariner)
Launch Complex Equipment (LCE)	Ground Power Control	• Local control and monitor • Remote control and monitor	• Slow reaction time during emergency. • Power supplies are located at remote sites. Centralized control and monitor from STC provides maximum coordination with other systems.
	Ground Data Transmission	• Digital Test Commands • Analog Test Commands	• Compatible with TCM command subsystem • More suitable for transmission of commands over STC to launch pad distances • Difficult to transmit over long distance.
	Test Data Multiplexer	• External MPX • Add test MPX to flight System • Expanded flight TCM	• Readily accessible, no flight weight. • High weight penalty • Complicates flight TCM design
	Ground Data Transmission	• Analog downlink test data only • Digital Downlink Test Data Plus Selected Hardlines	• Large number of hardlines needed for required data capability. • Wideband A2A telephone pairs available (digital link) • Digital method preferred for transmission of data over long lengths involved from STC to PAD. • Selected hardlines used primarily for communication of critical signals and power control to LCC.
	Fault Isolation Concept	• Local (Pad) fault isolation and malfunction verification • Remote (control room) fault isolation and malfunction verification • Remote fault isolation plus local malfunction verification	• Interference with prelaunch operations • Centralized fault isolation in control room plus direct test point access (OSE connector) for verification of malfunctions which indicate capsule replacement.

Figure 10-1 (Continued)

SUMMARY OF MAJOR OSE TRADE STUDIES

TRADE STUDY	REMARKS
SSTS Automation Selective Automatic vs Manual Mode	• Minimum Test Time • Hi Speed Self Check and Alarm Monitor • Maximum Repeatability and Accuracy • Cost Effective for Selected Subsystems
STC Displays Digital Displays vs. Analog Meters vs. C RT Displays	• Minimum Operator Error • Hi Density Display Saves Space • Max Flexibility and Growth Potential
SSTS Automation Method Hard Wire Logic vs. Tape Reader vs. Desk Top Computer	• Cost Effective for Highly Repetitive Sequential Operations • Max Flexibility and Growth • Provides Independent Subsystem Test

Figure 10-2

OSE SELECTION CRITERIA AND FACTORS

PROGRAM CRITERIA	TYPICAL OSE SELECTION FACTORS
Probability of Mission Success	OSE reliability Affect on flight subsystems OSE redundancy and backup
OSE and Flight System Performance	Test quality Test time (operator, OSE, flight system) Test confidence Degree of self test Degree of fault isolation
Development and Schedule Risk	OSE operational availability (MTBF) Relative "state-of-art" OSE initial availability
Versatility (Flexibility)	Growth potential Choice of operating modes Potential common usage Adaptability to future missions
Cost	Test cost (operators time) OSE hardware cost OSE maintenance cost OSE development cost Software cost

Figure 10.1-1

numerical scale from .2 to 1.0 is used to rate the selection factors for each alternative in terms of its contribution to the VOYAGER project level selection criteria, as represented by the weighted totals shown in the detailed trade studies.

Cost factors are weighed carefully in the evaluation of alternative OSE approaches. The ratio of test effectiveness to total test cost is equated to determine cost-effectiveness. A major factor in ESP OSE effectiveness is its contribution to the probability of launch-on-time.

10.2 TRADE STUDIES. The major trade studies conducted during Phase B are as follows:

10.2.1 Trade Study-Subsystem Test Sets Automation Concept

10.2.1.1 Purpose and Scope - The objective of this trade study is to determine the optimum approach to controlling and monitoring support equipment for flight subsystems testing. Three alternatives were analyzed for compliance with the constraints and test plan: (1) manual control and monitor capability only, (2) selected subsystem test sets with automatic control and monitor and a manual backup mode, and (3) total automatic with manual backup.

10.2.1.2 Summary - Results of the study indicate that selected subsystem test sets should be automated if the types and number of tests, mechanization complexity, test time, and other related factors warrant or offset the costs. Manual (non-computer dependent) backup should be provided for the automated test sets.

10.2.1.3 Functional and Technical Requirements- Design of the subsystems test sets (SSTS) are constrained by several factors:

The SSTS must be capable of:

- o Manually controlling its subsystem to any operating mode and in any sequence, provided for by the normal subsystem test circuitry
- o Performing all required test routines expeditiously, correctly and repeatably.
- o Providing self-test capability without test interruption for isolation of problems to OSE or related ESP subsystem.
- o Interfacing with a general purpose computer for test sequence control or direction and data acquisition and display.

10.2.1.4 Approaches and Significant Selection Factors - Three basic approaches were considered initially: (1) manual only, (2) total automatic with manual backup, and (3) the automation of selected Subsystem Test Sets with a total manual capability. The second approach (total automatic with manual backup) was eliminated from further consideration since testing of some subsystems is best accomplished manually. The two remaining alternatives are presented with the significant factors affecting the baseline choice.

Selected SSTS Automated:

- o Maximum probability of mission success
- o Reduces total test time
- o Reduces possibility of operator-induced malfunctions
- o Reduces interpretation errors
- o Reduces operator fatigue due to automatic cycling of repetitive tests
- o Provides rapid malfunction verification
- o Facilitates test repeatability
- o Makes use of the constraint-required general purpose computer interface while in the autonomous subsystems test mode.
- o Maximum flexibility and growth potential for follow on missions.

Manual Mode Only:

- o Lowest in costs.
- o Retains the operator in the decision-making loop.
- o Higher OSE equipment reliability.

10.2.1.5 Recommended Approach - The results of the numerical evaluation (Figure 10.2-1) indicate that the optimum approach to SSTS control and monitor is to selectively automate the support equipment to the extent practical.

10.2.2 Trade Study - System Test Complex Display Techniques

10.2.2.1 Purpose and Scope - This trade study was conducted to determine the optimum data display method to be used for display of test parameters at the System Test Complex (STC).

10.2.2.2 Summary - The alpha numeric Cathode Ray Tube (AN/CRT) display is the optimum display method. The major factors contributing to its selection are high probability of mission success, flexibility and growth potential for follow on missions, and low development risk.

10.2.2.3 Functional & Technical Requirements - The display should readily convey the correct value of the measured parameter to the operator. Desirable features are ease of parameter identification, minimum read time, and ease of operator interpretation. For this study, the incoming data is assumed to be in digital form with parameter identification. Each measurement will be scaled to facilitate display in engineering units.

10.2.2.4 Design Approaches and Significant Characteristics - Five methods were studied:

Alpha Numeric Cathode Ray Tube (AN/CRT) - Displays (in English language and engineering units) the parameter identification, range, value, and limits for a virtually unlimited quantity of measurements. Also capable of displaying a wide range and format of statements and graphical data. This method requires considerable logic for character generation and formatting.

Decimal digits with the scaling performed by the computer - Displays the parameter in digits with the engineering units mechanically attached to the front panel adjacent to the display. The only logic is that required to store the scaled value between computer updates.

Decimal digits with local scaling - Uses the same display as the previous one but receives unscaled data. A digital multiplication scheme is required for each group of displays, but the incoming data can originate from any digitized source.

Analog Meters with computer performed digital to analog conversion (DAC) - Performs scaling mechanically by selecting a meter scale which is graduated in appropriate engineering units.

Analog Meters with DAC's located in the display panel - Accepts digital data from any source and performs digital to analog conversion locally. The scaling is performed as in the previous method.

10.2.2.5 Evaluation - The trade study results are summarized in Figure 10.2-2. The selection factors used were chosen to emphasize the approach differences, i.e., factors which are equally favorable or unfavorable to all concepts are not mentioned. Pertinent factors affecting the baseline choice are shown below.

AN/CRT

- High reliability and readability
- Flexibility and growth potential to support follow on missions.
- Low development risk (units are developed and off-the-shelf)

Decimal

- Average flexibility for expansion
- Will not accommodate special formats
- High hardware costs

Meters

- Low readability
- Low accuracy
- Average flexibility for expansion
- Will not accommodate special formats

10.2.2.6 Recommended Design Approach - The AN/CRT is the best display technique. The computer scaled decimal display is second. The flexibility of the AN/CRT to support expanded or changing display requirements is the major factor contributing to its selection.

10.2.3 Trade Study-Technique for Automating Subsystem Test Sets

10.2.3.1 Purpose and Scope - The purpose of this evaluation is to determine the optimum means of implementing automatic test sequence control and monitor for selected ESP subsystem test sets (SSTS).

Five approaches are considered: (1) hard-wired logic within each SSTS; (2) a central general purpose computer; (3) a "satellite" or small, individual automatic processor for each SSTS to be automated; (4) a punched-tape reader; and (5) a magnetic tape reader. The characteristics of each candidate, with required peripheral equipment, were evaluated for possible SSTS utilization at the subsystem vendor's plant, for systems integration and checkout at the contractors plant and for contingency checkout at KSC.

10.2.3.2 Summary - The method for automating selected subsystem test sets as determined by this trade study, is to utilize a small general purpose digital computer as the automatic processor.

10.2.3.3 Functional and Technical Requirements - Several VOYAGER project and test implementation constraints were considered:

The SSTS must be capable of:

- o Performing all required test routines expeditiously, correctly and repeatably.
- o Providing self-test capability without test interruption for isolation of problems to OSE or related ESP subsystem.
- o Interfacing with a general purpose computer for test sequence control or direction and data acquisition and display.

10.2.3.4 Approaches and Significant Characteristics - Each of the five methods of automating the SSTS test sequence control and monitoring are listed with a brief explanation and the significant factors affecting the baseline choice.

Hard-wired Logic - The controller provides a fixed program implemented by solid state, integrated circuits, electro-mechanical devices, or a hybrid design.

The significant factors are:

- o Lack of flexibility to changes in program.
- o Considerable engineering costs for circuit design.
- o Rapid test sequencing (except for electro-mechanical if included in the

design).

Central Computer - Each automated SSTS time shares a common general purpose digital computer. Computer memory (size), speed, and instruction repertoire were the major constraints in the consideration of computer costs and performance characteristics. The significant factors are:

- o Excellent performance and ability.
- o Reasonable hardware costs.
- o Software more complex due to integrating all routines into one program.
- o Does not provide automated SSTS operation when the subsystem test equipment and control computers are not in close physical proximity.
- o Self-tests are easily implemented.

Satellite Computer - Each automated SSTS has, integral to the subsystem test set, a small digital computer for test sequence control and monitoring. The significant factors are:

- o Flexibility for independent SSTS operation.
- o Relatively low costs.
- o Slower memory cycle and execution speed than larger computers, but adequate for application.
- o Permits simpler programming than required for a central computer.
- o Self-tests easily implemented due to random access memory.

Punched Tape Reader - A tape reader as an integral part of the SSTS to provide control and monitoring functions automatically. Both optical and mechanical tape readers have been considered. The significant factors are:

- o Lowest cost of the five methods considered.
- o Lowest reliability.
- o Most applicable to fixed sequence programs rather than random sequences.
- o Comparatively slower and noisier than other approaches.

Magnetic Tape Reader- Each SSTS contains its own magnetic tape reader for test automation. The significant factors are:

- o Speed is adequate for SSTS application.
- o Flexible for independent SSTS operation.
- o Overall performance is about average.
- o Moderately expensive.

10.2.3.5 Recommended Approach - A satellite computer for each automated SSTS is the recommended approach for automating test sequence control and monitoring. Figure 10.2-3 summarizes the study results.

SUBSYSTEM TEST SET AUTOMATION CONCEPTS

PROGRAM LEVEL CRITERIA AND VALUE →

OSE SELECTION FACTORS →

CANDIDATES	PROBABILITY OF MISSION SUCCESS (P_s) (FACTOR = .35)						SYSTEM PERFORMANCE (FACTOR = .20)						DEVELOPMENT RISKS (FACTOR = .20)			FLEXIBILITY (FACTOR = .15)	COSTS (FACTOR = .10)						
	Test Time	Autonomous SSTE	Fault Isolation Time	OSE Reliability	Reaction Time	Weighted Total	Operation Time	Fault Isolation Ability & Time	Operator Induced Malfunctions	OSE Verification & Calibration	Test Repeatability	Weighted Total	Hardware	Software	Weighted Total	Program Growth	Operational	Hardware	Maintenance	Development	Software	Weighted Total	Grand Total
1. Manual	0.2	1.0	0.4	1.0	0.4	0.210	0.2	0.2	0.2	0.4	0.6	0.064	1.0	1.0	0.200	0.075	0.4	1.0	0.4	1.0	1.0	0.076	0.625
2. Selected SSTE Automatic with Manual Backup	0.8	0.8	1.0	0.8	1.0	0.308	1.0	0.8	0.8	1.0	1.0	0.184	0.9	0.8	0.170	0.090	1.0	0.4	0.5	0.8	0.8	0.070	0.822

Figure 10.2–1

SYSTEM TEST COMPLEX DISPLAY TECHNIQUES

PROGRAM LEVEL CRITERIA AND VALUE →

PROBABILITY OF MISSION SUCCESS (P_s) (FACTOR = .35)	SYSTEM PERFORMANCE (FACTOR = .20)	DEVELOPMENT RISK (FACTOR = .20)	FLEXIBILITY (FACTOR = .15)	COST (FACTOR = .10)

Figure 10.2-

10-11-1

1, 10.2–2, 10.2–3

OSE SELECTION FACTORS →

CANDIDATES	Reliability	Readability	Repairability	Operator Error Factor	Weighted Total	Accuracy (Overall)	Self Test Ease	Calibration	Computer Load	Weighted Total	Off Shelf	New Technology	Program Effect	Weighted Total	Expansion	Special Formats	Change Parameters	Major Data Format Change	Weighted Total	Basic Hardware	Expansion	Addition to	Weighted Total	Grand Total
Alpha Numeric CRT	.8	1.0	.6	1.0	.3	1.0	.8	1.0	.8	.18	1.0	1.0	1.0	.2	1.0	1.0	1.0	1.0	.15	.2	1.0	.6	.06	.89
Decimal (Computer Drive)	.8	1.0	.8	.8	.3	1.0	.8	1.0	.8	.18	.8	1.0	1.0	.19	.8	0	1.0	.8	.1	.8	.8	.8	.08	.85
Decimal (Local Scale)	.8	1.0	.6	.8	.28	1.0	1.0	1.0	1.0	.2	.6	1.0	1.0	.17	.6	0	.8	.6	.08	.6	.6	.1	.07	.80
Meters (Computer DAC)	.8	.6	.1	.8	.28	.6	.8	.6	.8	.14	1.0	1.0	1.0	.2	.8	0	1.0	1.0	.1	.1	.8	.8	.09	.81
Meters (Local DAC)	.8	.6	.8	.8	.26	.6	1.0	.6	1.0	.16	.8	1.0	1.0	.19	.6	0	.8	.8	.08	.8	.6	1.0	.08	.77

Figure 10.2–2

SUBSYSTEM TEST SET AUTOMATION TECHNIQUE

PROGRAM LEVEL CRITERIA AND VALUE →

OSE SELECTION FACTORS →

CANDIDATES	SYSTEM PERFORMANCE (FACTOR = .50)							FLEXIBILITY (FACTOR = .20)					COSTS (FACTOR = .20)						DEVELOPMENT RISKS (FACTOR = .10)			
	Reliability	Test Time	Test Repeatability	Fault Isolation Ability	OSE Verification & Calibration	Operator Induced Malfunctions	Weighted Total	Independent SSTE Operation	Hardware Modifications	Program Growth	Development Changes	Weighted Total	Engineering	Hardware	Software	Modifications (Hdwe & Software)	Operational	Weighted Total	Hardware	Software	Weighted Total	Grand Total
Hardwired Logic	0.8	1.0	–	0.8	0.9	–	0.437	1.0	0.2	0.6	0.2	0.100	0.2	1.0	1.0	0.2	0.5	0.112	0.6	1.0	0.080	0.729
Central Computer	1.0	1.0	–	1.0	1.0	–	0.500	0.2	0.9	1.0	0.9	0.150	0.9	0.4	0.4	0.6	1.0	0.132	1.0	0.6	0.080	0.862
Satellite Computer	0.9	0.9	–	1.0	1.0	–	0.475	1.0	1.0	1.0	1.0	0.200	1.0	0.7	0.8	0.8	0.8	0.164	1.0	0.8	0.090	0.929
Punched Tape Reader	0.4	0.6	–	0.8	0.9	–	0.337	1.0	1.0	1.0	1.0	0.200	0.9	0.8	0.8	1.0	0.6	0.164	1.0	0.8	0.180	0.881
Magnetic Tape Reader	0.8	0.9	–	0.9	0.9	–	0.437	1.0	1.0	1.0	1.0	0.200	0.9	0.6	0.8	0.9	0.7	0.156	1.0	0.8	0.090	0.883

Figure 10.2–3

Specific performance details, capacity, costs and availability of small computers are the subject of an intensive study to be conducted during Phase C prior to final hardware selection.

10.3 ALTERNATIVE INTEGRATION CONCEPT - The baseline integration approach used in the preceding selections of Part D, has isolated the support requirements for each system and established a point of reference for objective integration of OSE functions when the systems configuration and allocation of technical responsibility is firmly established. In order to provide a preliminary insight into the ultimate effect of OSE integration upon Entry Science Package OSE, we have included the following study of an alternative integration concept that is based on sharing of common OSE functions by the CBS, SLS, and ESP contractors.

10.3.1 Summary - The alternative integration approach (maximum OSE sharing) can result in a total equipment and space reduction of approximately 25% in the System Test Complex (STC) and 20% in the Subsystem Test Area.

10.3.2 Identification of Shared and Common OSE - Based on the similarity of test and OSE functions, the primary candidates for equipment sharing are identified below.

- Telemetry & Command Processor (TCP) - The TCP computer used in the STC is identical to those used in the Deep Space Network (DSN). If it is decided to replace the DSN computer with third generation computers, containing multisystem time sharing programming capabilities, a single TCP computer will be capable of telemetry processing for the CBS, SLS, and ESP. A reduction from three computers to one can be realized.
- System Test Complex (STC) - The Test Director Console, Voice Communications System, Timing Distribution System, Recording Groups, and Ground data Transmission System (GDTS) generate similar requirements for all three contractors in support of integrated systems tests at the factory and KSC. The recording group shows a possible 50% reduction in requirements by using a common central recording group for the integrated CBS/SLS/ESP. Of the remaining STC equipment, a major savings can be realized by common (CB/SL/EP) use of the GDTS in which a 65% reduction in data lines and 25% reduction in test command equipment is possible. The other STC equipment requirements would reduce by approximately 10%.

- <u>Subsystem Test Equipment (SSTE)</u> - A reduction in quantities of subsystem test set (SSTS) equipment can be realized if the ESP requirements are combined with either the CBS or SLS contractor requirements. The ESP/CBS combination is recommended because of the commonality of their telecommunication (TCM) subsystems. The following equipment savings are possible with this approach: Power SSTS - 35%, Sequencer - 35%, TCM - 20%, Thermal Control - 35%, and Pyrotechnic - 35%. This represents a total reduction of approximately 11 racks of SSTS and two automatic processors associated with the sequencer and TCM SSTS's.

PART K

INTERFACE ALTERNATIVES

Paragraph 3.2.2 of the VOYAGER Capsule Systems Constraints and Requirements Document states that "...to the extent practicable, the Capsule Bus, Surface Laboratory and Entry Science Package shall be mutually independent, separable and self supporting". This philosophy has been followed in our design. However, where it is deemed practical to increase the probability of mission success, the boundaries between these elements have been crossed. This is particularly true for the Capsule Bus/Entry Science Package interfaces.

The above quoted paragraph also states that "The management and technical interfaces of the Entry Science Package may rest with either the Capsule Bus System or Surface Laboratory System." It is the purpose of this part of the Report to evaluate these two interface alternatives, using the selected design Entry Science Package interfaces as a basis.

SECTION 1

SYSTEM INTERFACES

The proper perspective for the interface alternative evaluation requires the definition of the total interface between the Entry Science Package (ESP) and other systems. These interfaces are defined as inter system (or area) interfaces where relationships exist between two or more systems hardware, procedures, operational support equipment, or operations. Figure 1-1 illustrates these typical inter system interfaces.

Our interface design approach, tailored by our experience in conducting other major space programs and VOYAGER program desires of standardization for future missions, is based on the following considerations:

a. Simplicity - To provide maximum ESP independency and to increase the proability of mission success.

b. Accommodation - To provide accommodation compatible with performance and other requirements.

c. Access - To provide for checkout of physical interfaces.

d. Precise Definition - To establish easily recognizable lines of responsibility for each interface.

e. Documentation - To make responsibilities easily visible, and the lines of responsibility readily available to the cognizant authority.

f. Control - To assure follow up of responsibilities and mutual understanding of overall program objectives.

1.1 SYSTEM INTERFACE EVOLUTION - ESP interfaces evolve, as shown by Figure 1-2, out of the NASA VOYAGER Program Plans. These interfaces occur because (1) each of the VOYAGER systems may be awarded to a separate contractor, and (2) separate NASA centers or JPL are assigned responsibility for each system.

System interface requirements first appear during the customer's preliminary study and definition of the VOYAGER Systems. Once system interfaces are identified, interface control is needed for coordination among the system contractors. This control enables each contractor to design and test his system before integrating it with the next level of assembly, and also facilitates installation, checkout, and operation after integration.

For the VOYAGER Program, McDonnell has written an Interface Control Plan (presented in Volume VI, Part C, Section 9). The main elements of this plan are as

TYPICAL SYSTEMS INTERFACES

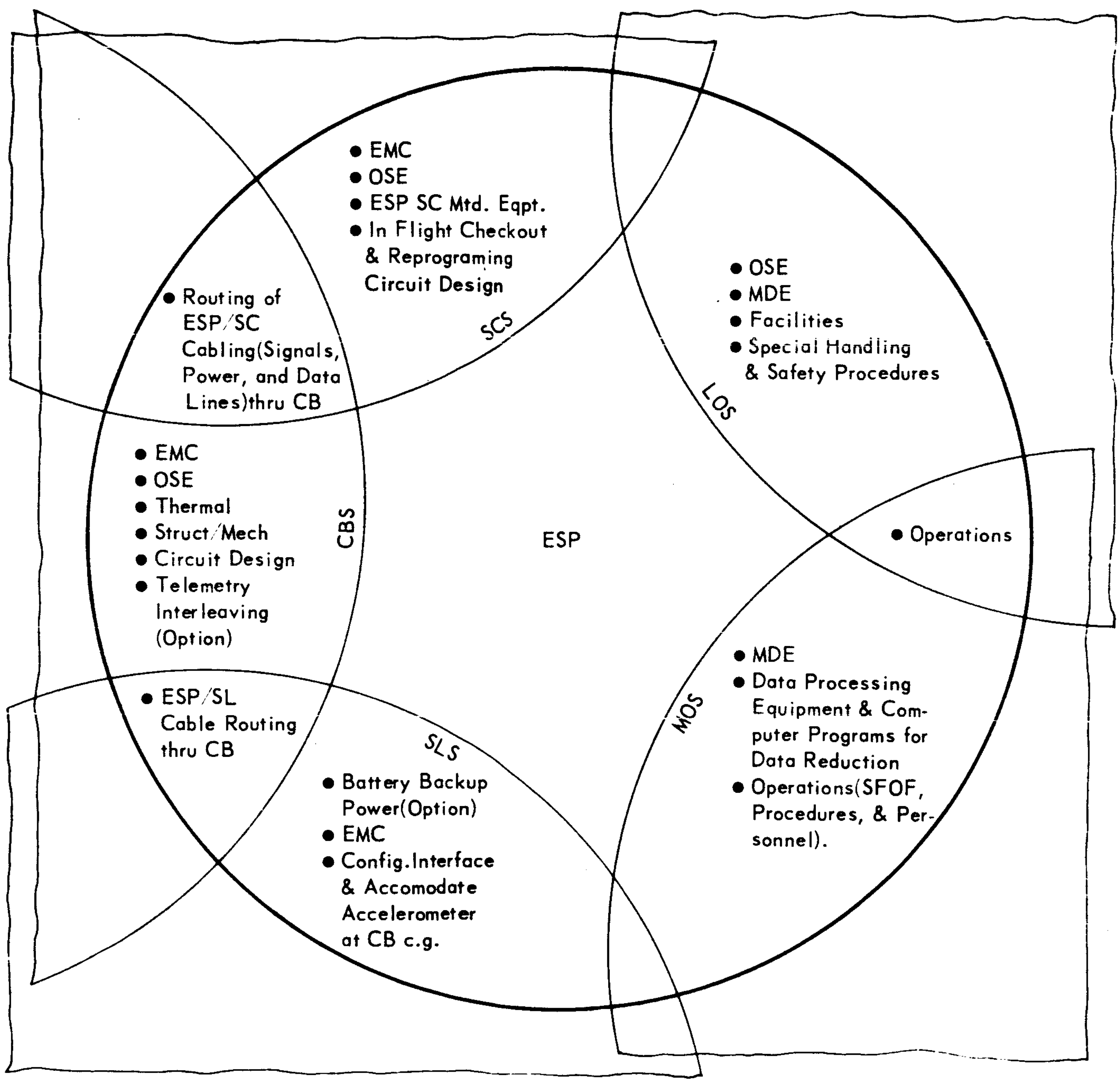


Figure 1-1

INTERFACE EVOLUTION
ENTRY SCIENCE PACKAGE

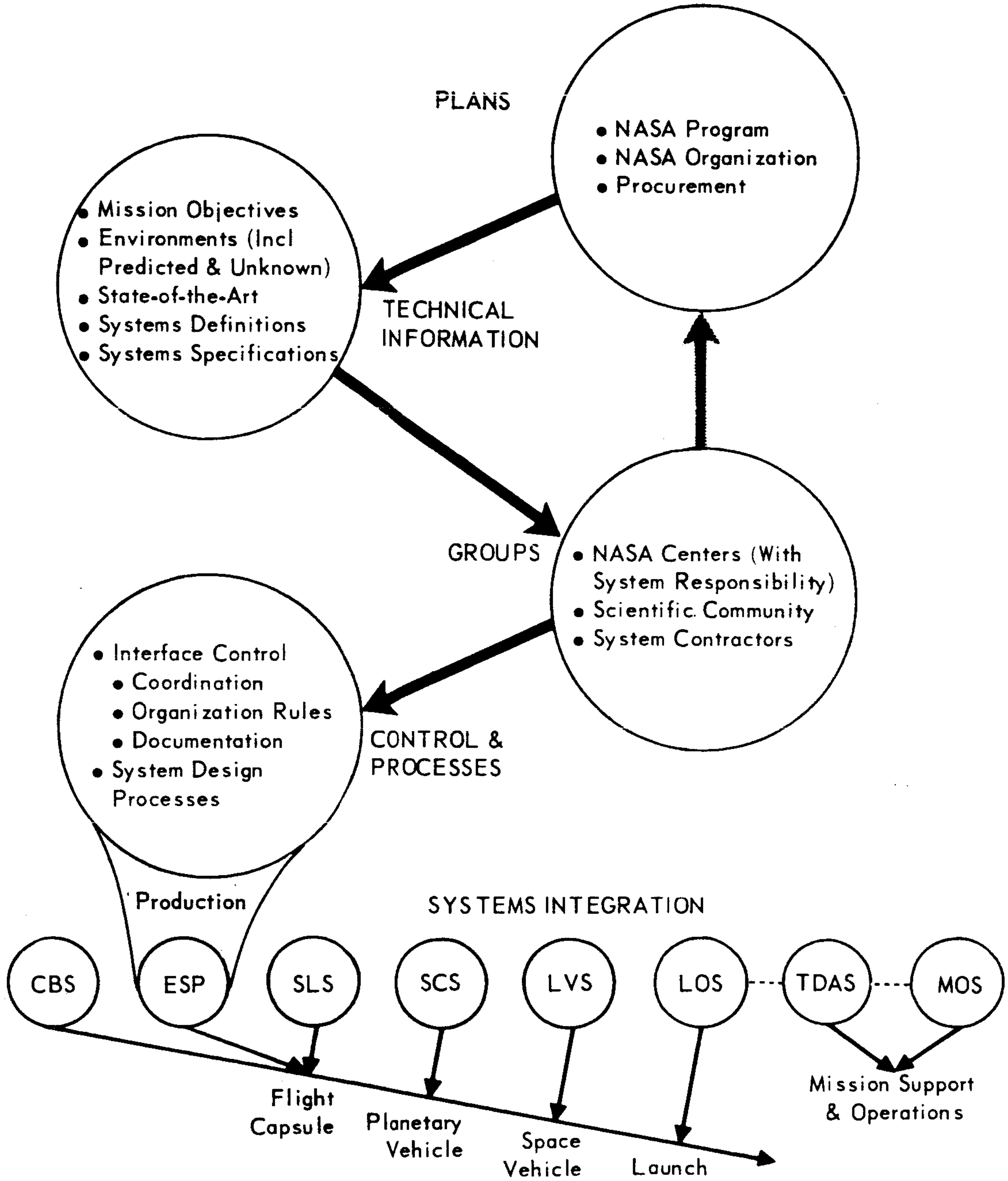


Figure 1–2

follows:

a. Interface Control will be under the direction of NASA (NASA Project Office)

b. An Interface Control Working Group (ICWG) organization will be founded with members from each System Contractor, JPL, each NASA Center with system responsibility, and the NASA Project Office.

c. Control documents (Interface Specifications, Interface Control Drawings, and change documentation) will be used throughout the program.

d. Formal meetings will be held, namely (1) Interface Control Meetings - NASA Project Office - will provide top management policy and decisions for each System Contractor, JPL and NASA Center having system responsibility, and (2) the ICWG Meetings will provide coordination of technical agreements, and documentation between system contractors.

e. Informal meetings (e.g., telecons, visits) will provide day to day communications between system contractors.

Out of iterations of the systems engineering process come ESP interface design and its hardware verification. This process is summarized in Figure 1-3.

1.2 INTERFACE AREAS - The VOYAGER systems functionally interface as shown in Figure 1-4. Technical, operational and software interfaces are shown later in Figure 2-1. The following paragraphs briefly discuss the ESP interfaces with other systems.

1.2.1 ESP-to-CBS - For the ESP and the Capsule Bus System (CBS), physical, signal and thermal interfaces exist as a result of the ESP being integrated with the CB. This interface area also includes OSE compatibility, operations, and software.

1.2.2 ESP-to-SLS - This is not a major interface, but does include an electrical relationship, in that, the Surface Laboratory (SL) provides the ESP backup battery power.

1.2.3 ESP-to-SCS - This interface consists of data flow for inflight monitoring and checkout during cruise and Martian orbit and an rf relay during Martian entry. The hardware interface is between the Spacecraft (SC) and SC mounted support equipment which provides data to the SC and requires direct and backup commands and power from the SC. Other interfaces entail software, such as operational procedures.

1.2.4 ESP-to-LOS - This interface area involves Launch Operations Systems (LOS) functional support essential to integrated launch preparations and launch pad operations. These entail OSE environmental control and ground power, and software such as special handling and checkout procedures.

SYSTEMS ENGINEERING EVENTS AFFECTING INTERFACES

ACTIVITY	INTERFACE CONSIDERATION
System Trade Studies	Study of all practical approaches to interface.
System Analysis	Analysis of approaches for most practical and best selection (based on state-of-the-art, constraints, etc.)
Design Milestones	
• Preliminary Design	Selection of preliminary concept with alternatives
• Concept Freeze	Selection of preferred concept
• Specification Control Drawings (SCD's) Completion	Inclusion of system interfaces
• System Specification	Definition or interface criteria constraints
• Part I Contract End Item (CEI) Specification	Inclusion of interface requirements
• Preliminary Design Review (PDR)	Verification of interface requirements
• SCD's Release	Documentation of system interface provisions on drawings
• Interface Specification and Interface Control Drawings Release	Documentation of system interface provisions on drawings
• Design Release	Documentation of system interface provisions on drawings
• Critical Design Review (CDR)	Verification of interface requirements designed
• Part II CEI Specs	Inclusion of system interface requirements
• First Article Configuration Inspection (FACI)	Verification that interface requirements were complied with

Figure 1–3

VOYAGER SYSTEMS FUNCTIONAL BLOCK DIAGRAM

(——▶ FUNCTIONAL AND SOFTWARE INTERFACE)
(— ▶SOFTWARE INTERFACE)

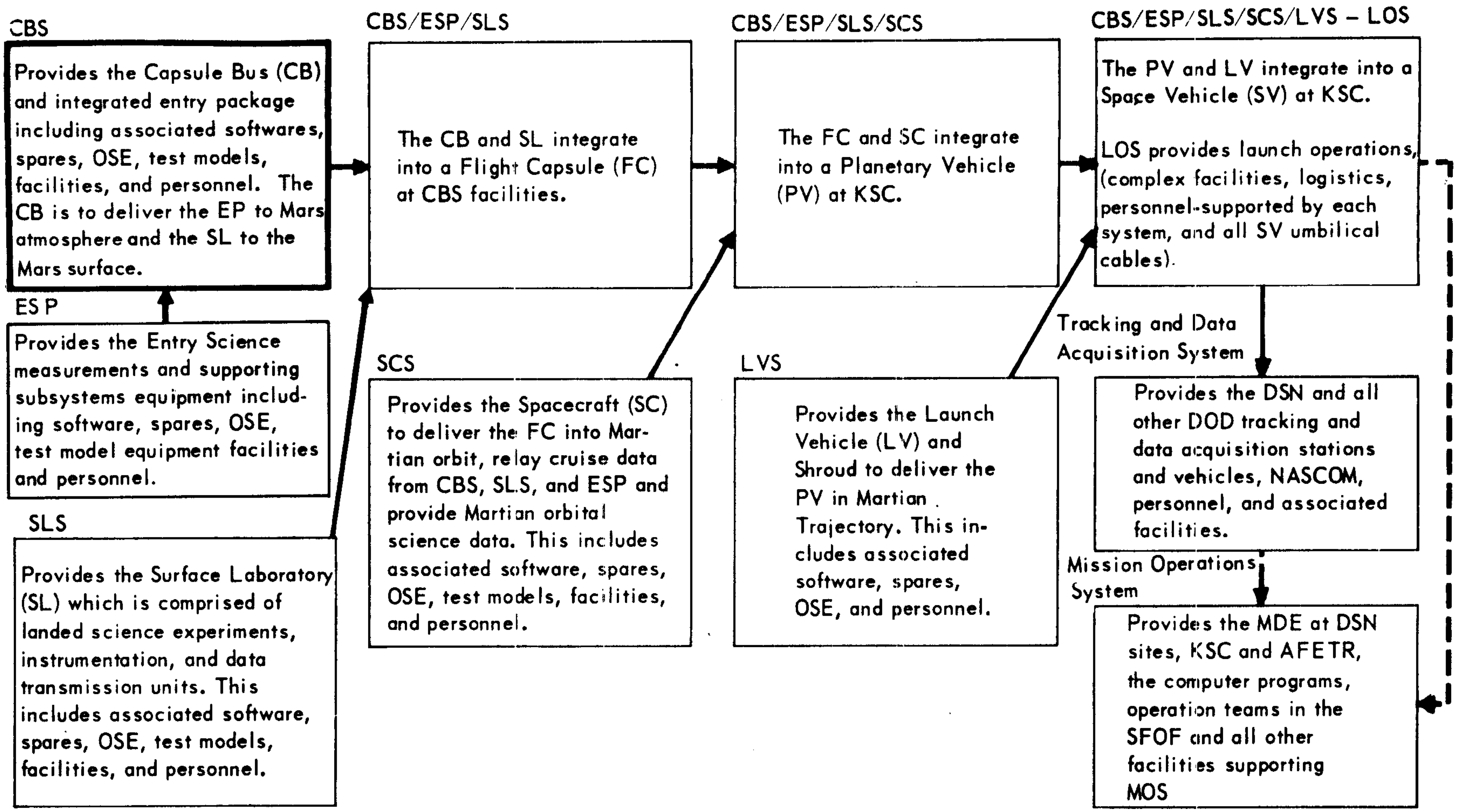


Figure 1–4

1.2.5 ESP-to-TDAS - The Tracking and Data Acquisition System (TDAS) provides telemetry data acquisition, tracking, command, and data handling support during the mission.

1.2.6 ESP-to-MOS - This is a software interface area. Mission Operations Systems (MOS) conducts mission operations from Planetary Vehicle injection. Environmental, engineering, and science data are relayed to the Space Flight Operations Facility of the MOS for analysis. Computer programs are utilized for data reduction and analysis. Critical data or indication of anomalies may require reaction by MOS to effect corrective procedures.

SECTION 2

SELECTED ESP DESIGN TECHNICAL INTERFACES

A detailed breakdown of the ESP to CB and ESP to SL technical interfaces are presented in Figure 2-1 for the preferred designs. The ESP technical interfaces are defined as the analysis and design, hardware, operations and software interfaces.

The analysis and design interfaces concern those activities associated with simultaneously insuring proper performance of the ESP scientific mission and the mission of the interfacing system. Most of the ESP analysis and design interfaces are with the CB since the CB is an intimate part of the ESP scientific measurement technique.

Hardware interfaces concern the physical contact between the ESP and other system elements. These interfaces include such items as wires, mounting brackets, power and signals.

Operations interfaces concern the areas where the ESP support activities interact with the support activities for other system elements. This includes operation procedures such as those for post-launch decisions.

Software interfaces involve documentation such as test plans, design specifications/drawings, and hardware integration schedules.

SELECTED DESIGN ESP TECHNICAL INTERFACE SUMMARY

TECHNICAL INTERFACE	INTERFACES WITH CAPSULE BUS (CB)	INTERFACES WITH SURFACE LABORATORY (SL)
1. Analysis and Design		
a) Aeroshell		
– Structure	• Imaging Window Design for ESP Performance and CB Integrity • Structure Design to Damp Vibration Coupling to Accelerometers	
– Heat Protection System	• Design for Minimum Deposition of Products on Window While Providing CB Heat Protection • Analysis and Design to Minimize Contaminate Deposition in Instrument and Measurement Pertubations • Nose Cap Design for ESP Performance and CB Heat Protection, Integrity and Weight Efficiency	
– Aerodynamics	• Aerodynamic and Flow Field Analysis for Capsule Performance as Bus and as Instrument for Relating Acceleration to Density and Measured Total Temperature and Pressure to Ambient Quantities	
– Engineering Data	• Analysis for Complimenting ESP Data With CB Engineering Data (Heat Shield – Structural Temperatures, Strain/Stress Measurements, Etc.)	
b) Attitude Control and Inertial Sensors		
– Pre Entry	• Analyze De-orbit Monitoring Requirements for Both CB & ESP Mission • Analysis of Requirements for Entry Angle of Attack and Pointing to Improve ESP Performance (Atmosphere Determination and Imaging) and for CB Integrity	
– Entry and Descent	• Analysis and Design for Solutions to Limiting Angle of Attack Excursions, Angular Rates and Frequency for Improved Performance and Simple Correction of Accelerometers, Pressure and Temperature Sensor Outputs, Simple Imaging Equipment Design and for Performance of CB Mission • Determine Inertial Sensor Sample Rate and Accuracy Compatible With Determining CB Performance and Aiding ESP Data Analysis	
c) Capsule Mission Sequencing	• Analysis of CB Sequence of Events (Parachute Deploy, Aeroshell Separation, Terminal Thrust Ignition, Etc.) to Satisfy CB Mission and Optimize ESP Data	
d) Data Handling	• Analysis of Feasibility of Using Capsule Landing Phase for ESP Science Operations (Brief Post Touchdown Atmospheric Measurements and Imagery) and Interaction With CB • Analysis and Design of Data Interleaving (CB & ESP)	• Analysis of Possibility of Using ESP UHF Equipment for Relay of SL Data
e) Radar	• Analyze Use of Higher Altitude CB Radar to Aid ESP Atmosphere Determinction • Determine Radar Performance Including Data Rate to Satisfy CB Mission and Support ESP Measurements	
g) Power	• Analyze "Fail–Safe" Mechanisms for Backup Power	• Analyze "Fail–Safe" Mechanisms for Backup

Figure 2–1

	Switching	Power Switching
h) Thermal Control	• CB Thermal Control Design Attention to Camera Heating Through Window, Stagnation Point Sensor Heating, Base Region Sensor Heating and ESP Package Thermal Environment	
i) Science		• Analysis and Methods for Use of ESP Descent Imaging and Atmospheric Properties Determination Data in Supplementing SL Science Data • Analyze Use of Capsule Landing Phase Science Operations to Improve SL Mission
2. Hardware		
a) Telecommunications	• CB Provides Telemetry Sync, Word Sync, Frame Sync and Clock Signals to ESP • ESP Cruise Data is Through CB Cruise Commutator • CB Distributes ESP Checkout Data and Data Sync to Spacecraft (SC) • ESP Parasitic Antenna Test Signal Through CB to SC • CB Engineering Data and ESP Low Rate Data Cross Strapped Between CB and ESP Telemetry	
b) Sequencing & Command	• CB Sequencer Controls ESP Power Turn On and Turn Off • SC Commands (Switch to Internal Power, Turn On Cruise Commutator, and Switch to SC Power) Routed Through CB • CB Provides Aerodecelerator Deployment Sequence and Initiate Signal to ESP • CB Provides Terminate Terminal Thrust Command to ESP • CB Provides Checkout Data Sync and Control Commands to ESP	
c) Electrical Power	• CB Distributes SC Regulated Power to ESP • CB Distributes SC Power for ESP Heaters • CB Distributes SL Backup Power to ESP	• SL Provides ESP Battery Backup Power (via CB)
d) Structural/ Mechanical	• CB Provides Thermal Protection for ESP During Cruise • CB Provides for Mounting and Alignment of ESP Enclosure and Following: Accelerometers, Stagnation Sensors, Descent TV Cameras, TV Window, UHF Antenna, Stagnation Vent Tube, Cabling and Separation Devices	
3. OSE	• Stimulus and Monitor Signals for Integrated Testing (Between CBS and ESP OSE) • ESP OSE Physical Interface With CB Systems Test Complex • ESP to CB Ground Station RF Data Link • ESP and CB Simulators for Pre-mate Testing	
4. Operations/Software		
a) Procedures	• OSE Maintenance and Test Procedures • OSE Integration Schedules • Special ESP Handling/Operation • Post-Launch Decisions	• Science Coordination
b) Plans	• ESP–CBS Integrated Test Program • Interface Control Plan	
c) Documentation	• CBS and ESP Integration Schedules • Operational Sequencers • Design Requirements Coordination (EMC, Environments, Isolation, Etc.) • Logic Drawings • Interface Specifications (IFS's), Interface Control Drawings (ICD's) and Interface Change Notices (ICN's)	• Logic Drawings (Backup Battery Power)

SECTION 3

COMPARISON OF ESP MANAGEMENT AND TECHNICAL INTERFACE ALTERNATIVES

As can be seen from Figure 2-1, the bulk of the ESP technical interfaces are with the CB. This fact alone argues strongly for placing responsibility for the ESP with the CB. However, a total evaluation of the interface alternatives must consider interactions through all phases of the VOYAGER program. Such an evaluation for the technical and management interfaces is presented in Figure 3-1. The outstanding points developed in the figure are:

a. The first consideration in deciding the assignment of the ESP should be to maximize the probability of success of obtaining meaningful entry data. Since the CB is an integral part of the ESP measurement technique, assigning the ESP to the CB should facilitate obtaining this success with design proceeding closely in parallel and problem solving directed toward simultaneously optimizing CB and ESP.

b. Assigning ESP responsibility to the SLS results in ESP/CBS interface control resorting to committee (ICWG); i.e. this interface would be treated as an inter-system interface. If on the other hand, the ESP is a responsibility of the CBS, the ESP/CB interface will be treated as an intra-system interface, thus allowing the majority of the ESP interfaces to be under more direct control.

c. Due to the intimate relationship of ESP and CB missions and equipment, many of the analysis, design, development and qualification activities required for both the CB and ESP can be combined, resulting in reduced program cost.

d. The flexibility for change of the ESP mission, since it is dependent on the CB design, will be maximized if the ESP responsibility is with the CB. The CB contractor can more readily evaluate the feasibility of change, its effects on the CB and take action on required changes.

e. Two major advantages are obtained with assignment of ESP responsibility with the SLS. These are: 1) the possibility of using the ESP UHF relay during post touchdown operations (requiring some functional integration and hardware modification), and 2) the synergistic benefits of combining SLS and ESP science integration through a single systems contractor.

Although certain advantages exist for combining the ESP and SL programs;

COMPARISON OF ESP MANAGEMENT AND TECHNICAL INTERFACE ALTERNATIVES

PROGRAM PHASES	ESP RESPONSIBILITY WITH CAPSULE BUS	ESP RESPONSIBILITY WITH SURFACE LABORATORY
Analysis and Design	Advantages ● Facilitates the identification of technical interface problems and solution for optimization of both CB and ESP missions. ● Results in greatest flexibility for ESP mission changes/options, assures ready evaluation of and action on change. ● Since CB is integral part of ESP measurement technique, proper formulation of science measurements facilitated. ● ESP/CB subsystem similarities permits partial combination of subsystem design and analysis for improved efficiency. ● Permits evaluation of areas of possible functional integration to improve ESP and CB effectiveness/cost. ● Analysis activities associated with CB performance and ESP instrument design can be combined. Disadvantages ● VOYAGER science activities less integrated.	Advantages ● Provides for ready evaluation of methods for using ESP equipment and data to supplement S.L. mission. Disadvantages ● Massive interface specifications (IFS) link between contractors required. ● Technical interfaces controlled by committee between two contractors, the interface control working group (ICWG). Tends toward slow identification of problems, massive documentation and general inefficiency with result that problem solutions may optimize neither CB nor ESP mission. ● Flexibility for mission change/options reduced since committee resolution of problems required.
Development	Advantages ● Similar technical requirements of ESP and CB batteries and ESP and CB telecommunications equipment(data storage units and transmitting antennas identical) permits combination of development programs and single source procurement to reduce cost and scheduling. ● Flexibility for change remains at a maximum with combined development programs. ● Equipment similarities create possibility of integration of OSE and STE requirements. ● Intimate knowledge of CB data characteristics provides for most efficient development of ESP software, and possible integration of CB/ESP data reduction software. Disadvantages –	Advantages – Disadvantages ● Dissimilar technical requirements for ESP and SL batteries and telecommunications equipment require separate development programs.
Qualification & Testing	Advantages ● Due to equipment operational similarities, some common qualification and test programs possible. Program costs and schedule decrease correspondingly. Disadvantages –	Advantages -- Disadvantages ● ESP and S.L. equipment differences require separate qualification and test programs.
Mission Operations Planning & Support	Advantages ● Changes in CB operations effect ESP mission, contigency planning simplified. ● Supporting CB data can be more readily integrated with ESP data Disadvantages	Advantages -- Disadvantages ● Coordination required to obtain CB data for ESP data reduction

Figure 3–1

to optimize the probability of success of the ESP mission, to minimize cost of the ESP, and to retain the greatest flexibility for change, it is recommended that responsibility for the ESP be assigned to the CB program.