This Ground Operations and Safety Plan is in accordance with the requirement of Action Item 384 of the ALSEP Array E Critical Design Review.

This document has been revised to incorporate those changes in hardware and operations that have occurred since the original release. All revisions and additions are highlighted by the use of revision bars on the right hand side of each page.

Changes to Revision A of this document have been incorporated prior to release of Revision B (1-12-72). Those changes occurred to page 57, Section 1.4.5 (E-5) Method of Detection and page 86, deletion of paragraph 6.5.2.3.1.

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LSP Experiment

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LSP GROUND OPERATIONS AND SAFETY PLAN

1.0 INTRODUCTION

1.1 Purpose

This document has been prepared in response to the requirement established in Action Item 384 at the LSP Critical Design Review on 16 June 1971. It identifies all conditions under which the explosive components of the LSP are manufactured, tested, transported, and stored while under the cognizance of the Bendix Corporation, Aerospace Systems Division (BxA). Sufficient background material has been included for this document to serve as a comprehensive reference to all safety matters related to the LSP.

1.2 Contents

This document is comprised mainly of material extracted from the following documents prepared under the LSP System Safety Plan:

Document No.	Title	Release Date
ALSEP-LS-10	LSP Safety Plan	4-6-71
2365390A	Safety Requirements - LSP Explosive Subassemblies	8-12-71
ATM-1049	LSP Detailed System Hazard Analysis	8-12-71
ATM-1053	LSP Operational Hazard Analysis	9-15-71
ALSEP-LS 11	LSP Field Test Safety Plan	9-15-71
Not Assigned	Array E Ground Safety Plan	12-1-71

This plan will be reviewed and updated as required to incorporate additional information which may be included in the final release of these documents.

1.3 Description of Lunar Seismic Profiling Experiment

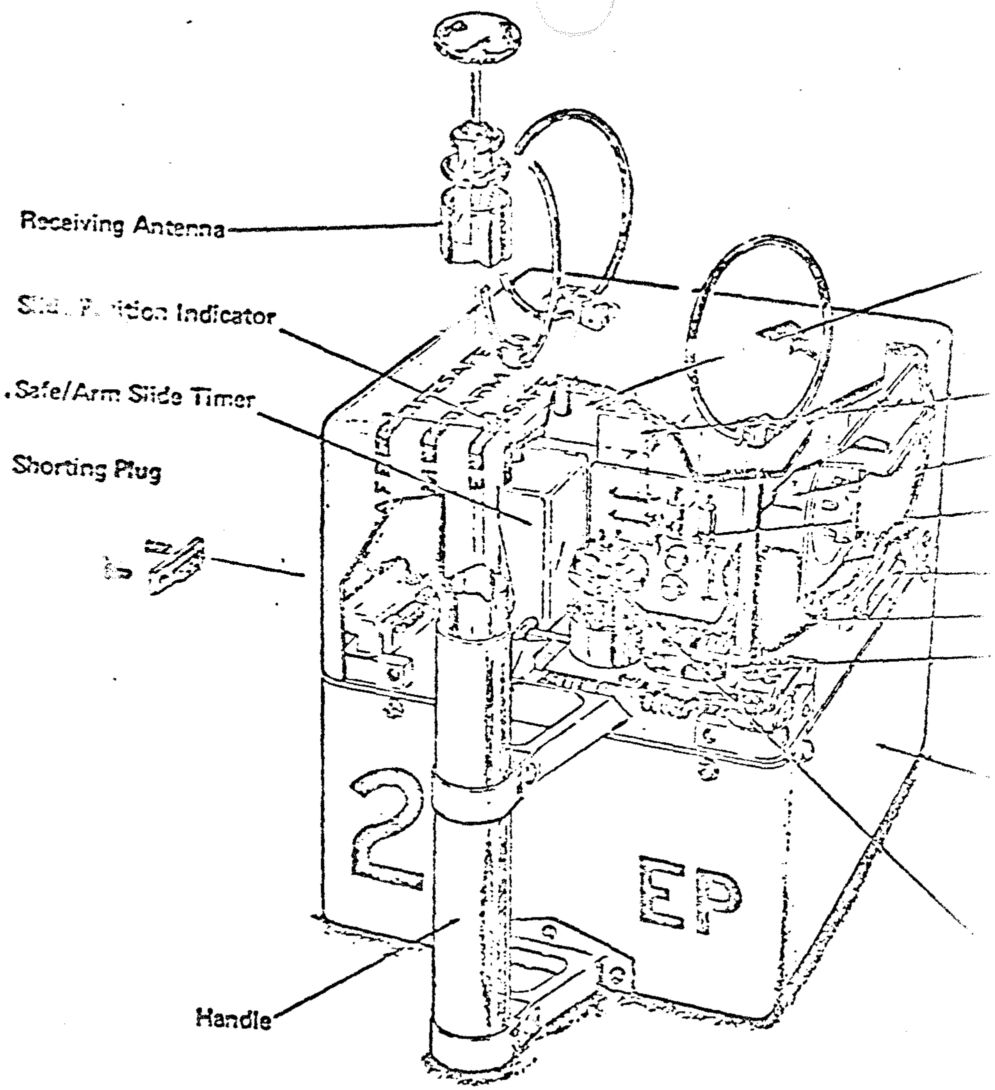
The LSP utilizes artifically induced seismic energy to investigate the physical characteristics of the lunar structure. It is scheduled to be transported to the Moon in the descent stage of the Lunar Module (LM) on the Apollo 17 Mission and set out on the lunar surface during the second and third periods of extra-vehicular activity.

The explosive materials in the Experiment are completely contained within eight explosive packages stored in Quadrant III of the LM descent stage during flight, and subsequently transferred to the Lunar Roving Vehicle (LRV) and deployed at distances from 500 feet up to 3.5 km from the ALSEP Central Station. The explosive charge weights vary from 1/8 lb up to 6 lb. and are approximately equivalent to TNT in energy per unit weight. The charges cannot be detonated until after departure of the crew from the lunar surface as two mechanical timers must first run out to establish firing conditions.

In addition to the explosive packages, the LSP contains a central electronics package housed within the ALSEP Central Station and an array of four geophones set out by the astronauts on the lunar surface.

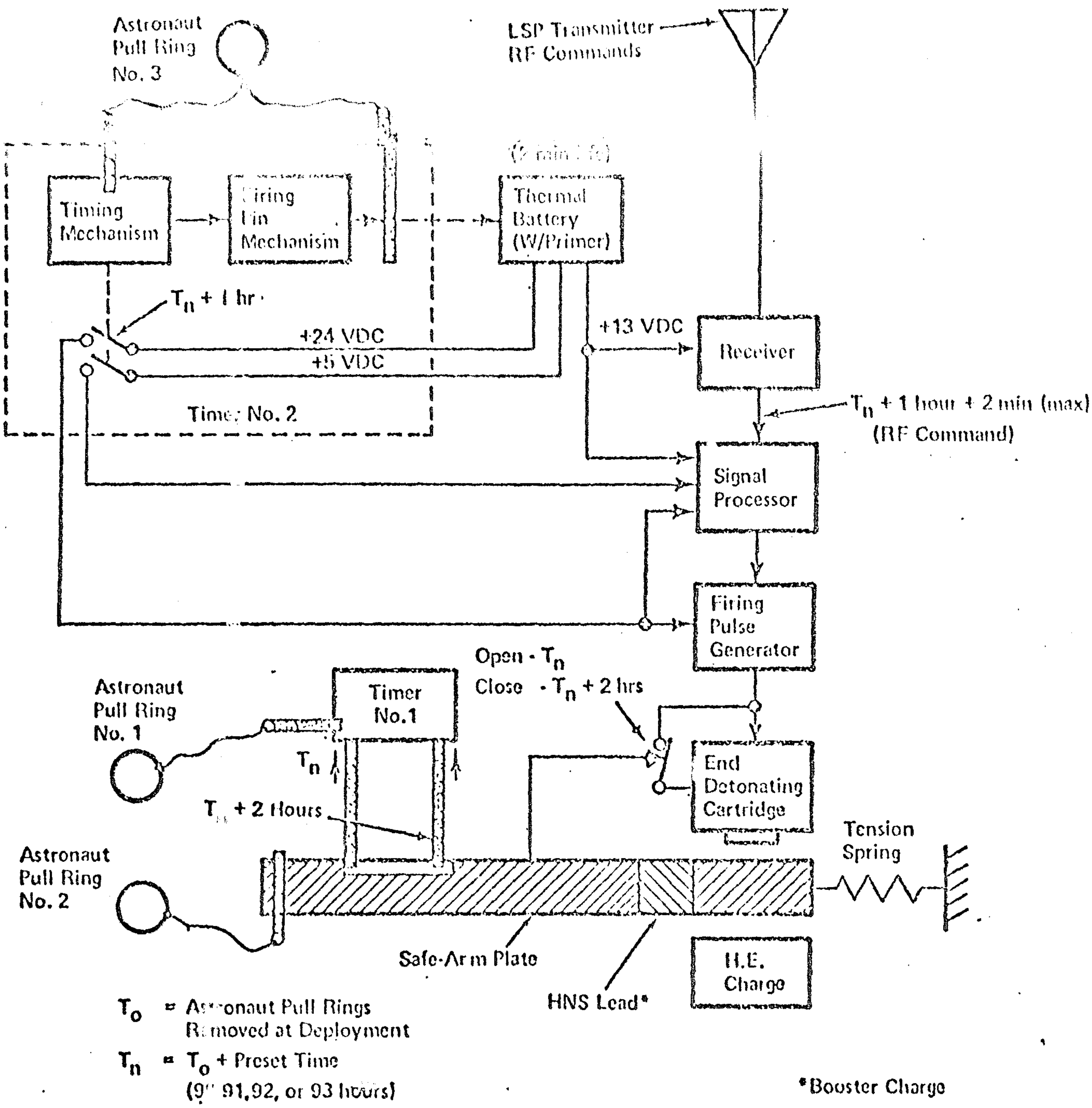
Seismic energy generated by detonation of the explosive packages are detected by the geophones and permit measurement of seismic velocities to a depth of 3-4 km. From the data obtained and known velocity-density relationships, pertinent information on the internal structure and composition of the lunar surface can be determined.

Figure 1.1 is an illustration of an LSP Explosive Package. Figure 1.2 is a functional block diagram. Each of the eight packages are identical except for the weight of the explosive charge and the preset runout time of the mechanical timers. The charge is contained within a nickel plated fiberglass housing which forms the bottom portion of the Explosive Package. The top portions, called the Electronics and Safe/Arm Assembly, consists of a magnesium baseplate upon which the following components are mounted; (1) End Detonating Cartridge (ELC), which is the first component of the explosive train; (2) a Safe/Arm Slide which contains an explosive "Lead", the second component of



Explosive Package

FIGURE I.1



BLOCK DIAGRAM OF EXPLOSIVE PACKAGE

FIGURE 1.2

the explosive train; (3) a mechanical Safe/Arm Slide Timer which moves the Lead into line with the EDC to complete, or "arm", the explosive train; (4) a Receiving Antenna, Receiver, Signal Processor, and Firing Pulse Generator which are used to receive a pulse-coded "fire" signal transmitted from the ALSEP Central Station; process this coded signal and provide a firing pulse to fuse a bridgewire in the EDC to actuate the explosive train; (5) a Thermal Battery to supply power to the above circuitry; (6) and a Thermal Battery timer to activate the battery via impact of a firing pin onto a percussion primer in the battery. These components will be maintained within the operating temperature range of 40°F to 170°F after deployment on the lunar surface through the use of passive thermal control techniques. Multilayer insulation inside a fiberglass top cover, plus white thermal paint on the exterior of the upper portion of the cover, minimizes solar input at high sun angles. The remaining exterior surfaces of the explosive package are painted black to allow rapid initial warm-up of the packages, since they will be deployed at low sun angles when temperatures are near the minimum operating limit of +40°F.

The two completely independent mechanical timers are started at the time of deployment by removal of separate pull-pins by the crew. Another pull-pin constrains the Safe/Arm Slide in its "safe" position, as a safety backup to the Safe/Arm Slide Timer. A fourth pull-pin contained within the Thermal Battery Timer constrains the firing pin from activating the battery and provides safety backup in the event the Thermal Battery Timer had prematurely functioned. Each pin is constrained such that it requires a defined minimum manual pull force for removal. In addition, the Safe/Arm pull-pin requires rotation and then pull to remove; each action is constrained by a retaining spring force. Each pull-pin incorporates fail safe locking features; each timer starting pin would be locked up and could not be removed if the timer had started to run preventing the timer drum from advancing; the Safe/Arm Slide pull-pin would be locked up and could not be removed if the slide was not being constrained in the "safe" position by the Safe/Arm Slide Timer preventing the Safe/Arm Slide from moving to the arm position; and the pull-pin constraining the firing pin within the Thermal Battery Timer would be locked up and could not be removed if the firing pin had been prematurely released by the timing mechanism preventing the firing pin from striking the thermal battery primer.

Referring to the block diagram, Figure 1.7, operation is as follows. At the time of deployment, the astronaut removes four pull-pins. This action starts both mechanical timers and removes pins which retain the Safe/Arm Slide in the "safe" position and lock the firing pin for the battery in a locked position, as safety constraints. The order of pull-pin removal is prescribed to maximize the safety inherent in the pull-pin locking features. The Safe/Arm Slide Timer is preset to function 90 hrs. after it is started. This period assures, with contingency, that the crew has left the lunar surface prior to the arming of any Explosive Package. At the end of the preset time, a pin constraining the spring loaded Safe/Arm Slide is retracted by the timer, allowing the slide to move to its "arm" position. Motion of the slide opens a microswitch which has previously shorted the electrical leads of the EDC. The Thermal Battery Timer is preset to function, independently 91 hours after it is activated which is one hour after the Safe/Arm Slide Timer operated to release the slide to its "arm" position. At that time a spring-loaded firing pin within the timer is released, striking a percussion primer within the battery and activating the battery. Two microswitches within the timer are also closed, connecting thermal battery output to the electrical circuits.

The signal transmitted by the LSP transmitter (located within the ALSEP Central Station) is a pulsed carrier with time characteristics as shown in Figure 1.3. A series of three pulses with the correct time spacing is required to provide a "fire" signal out of the Signal Processor within the Explosive Package. The LSP transmitter is turned "on" by ground command prior to the predetermined time of arming and powerup of the Explosive Package, preset by the timers. Once commanded "on" the transmitter continues to transmit the fire pulse set of three pulses once every 29.55 sec. In addition, AGC pulses are transmitted every 169.8 msec. The pulses have the effect of reducing the explosive package receiver gain and thereby eliminating the possibility of the packages being triggered by RF noise. Since the receiver gain is set by the LSP transmitter the gain is sufficient to receive firing pulses.

In the event the Explosive Package is not commanded to detonate or fails to detonate for any reason, after two hours the Safe/Arm Slide Timer mechanism retracts a second pin allowing the slide to move from the "Arm" to the "resafe" position. Position of the slide in "safe", "arm", or "resafe" is indicated to the crew via a linkage extending through the top cover of the Explosive Package and connected to the Safe/Arm Slide.

The numerous design safety features in the Explosive Package discussed above eliminate any possibility of danger to the crew (or ground handling personnel) by premature high explosive detonation. The locking features of the pull-pins plus the order of removal by the crew preclude output mechanical action of the timers in the event one or both timers had operated prematurely. Note that, once the pull-pins are removed, premature detonation could occur only if: (1) both timers time out prematurely, each within a "window" of hrs.; and (2) a pulse-coded spurious RF signal within the narrow (10 kHz) bandwidth of the Receiver is received during a three-minute maximum battery life "window".

TRANSMITTED PULSE FORMAT, THERMAL BATTERY VOLTAGE AND CONTROL OF RECEIVER GAIN DURING TURN-ON

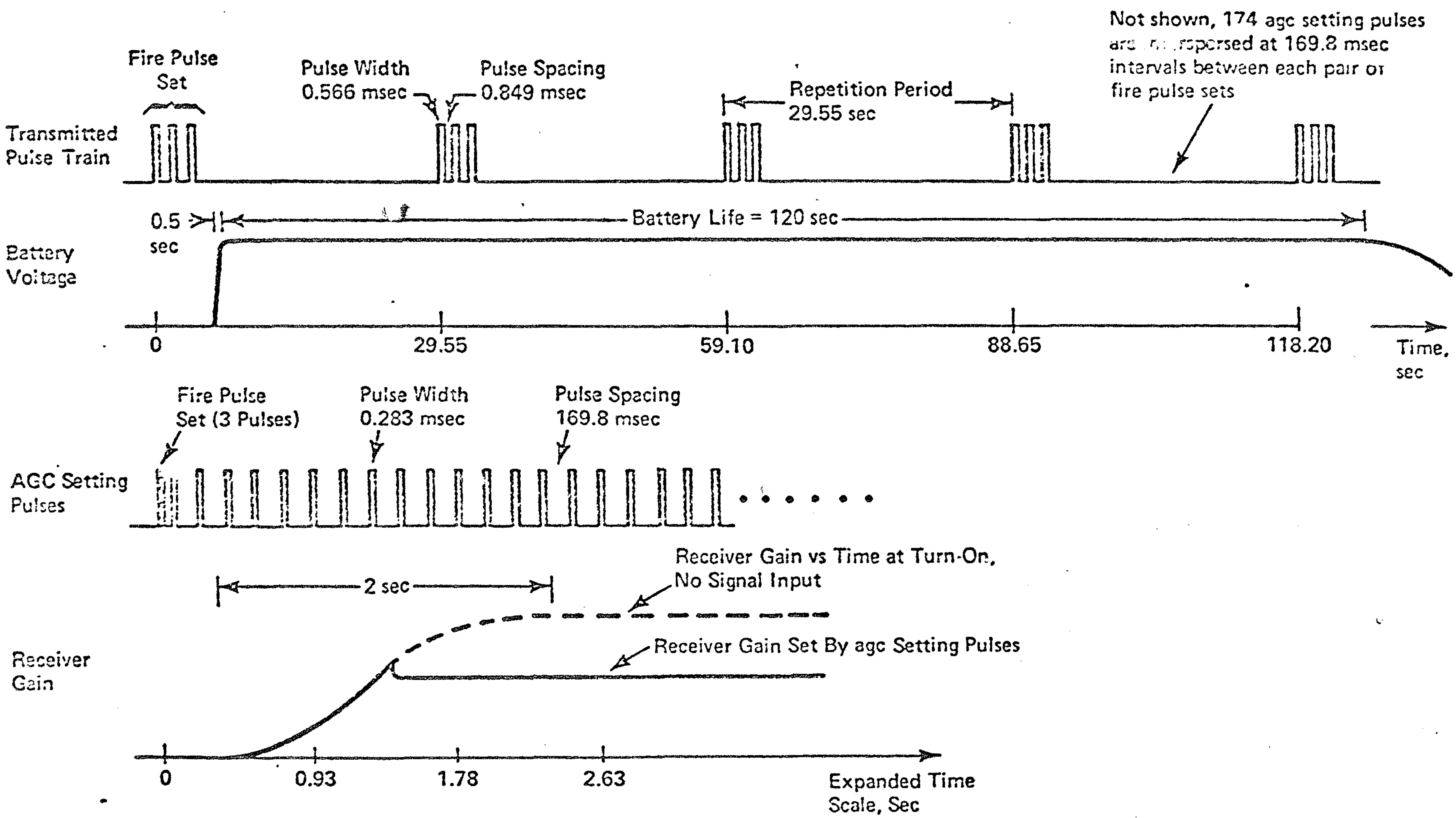


FIGURE 1.3

The Explosive Packages will be stowed in sets of four on two Transport Frame Assemblies, as shown in Figure 1.4. They will be carried to the Moon in Quad II of the Lunar Module. During the second ExtraVehicular Activity (EVA) a set of four with their Transport Frame Assembly will be placed on the LRV and then deployed, individually, at sites to be preselected prior to the mission. The second set of four will be deployed on the third EVA.

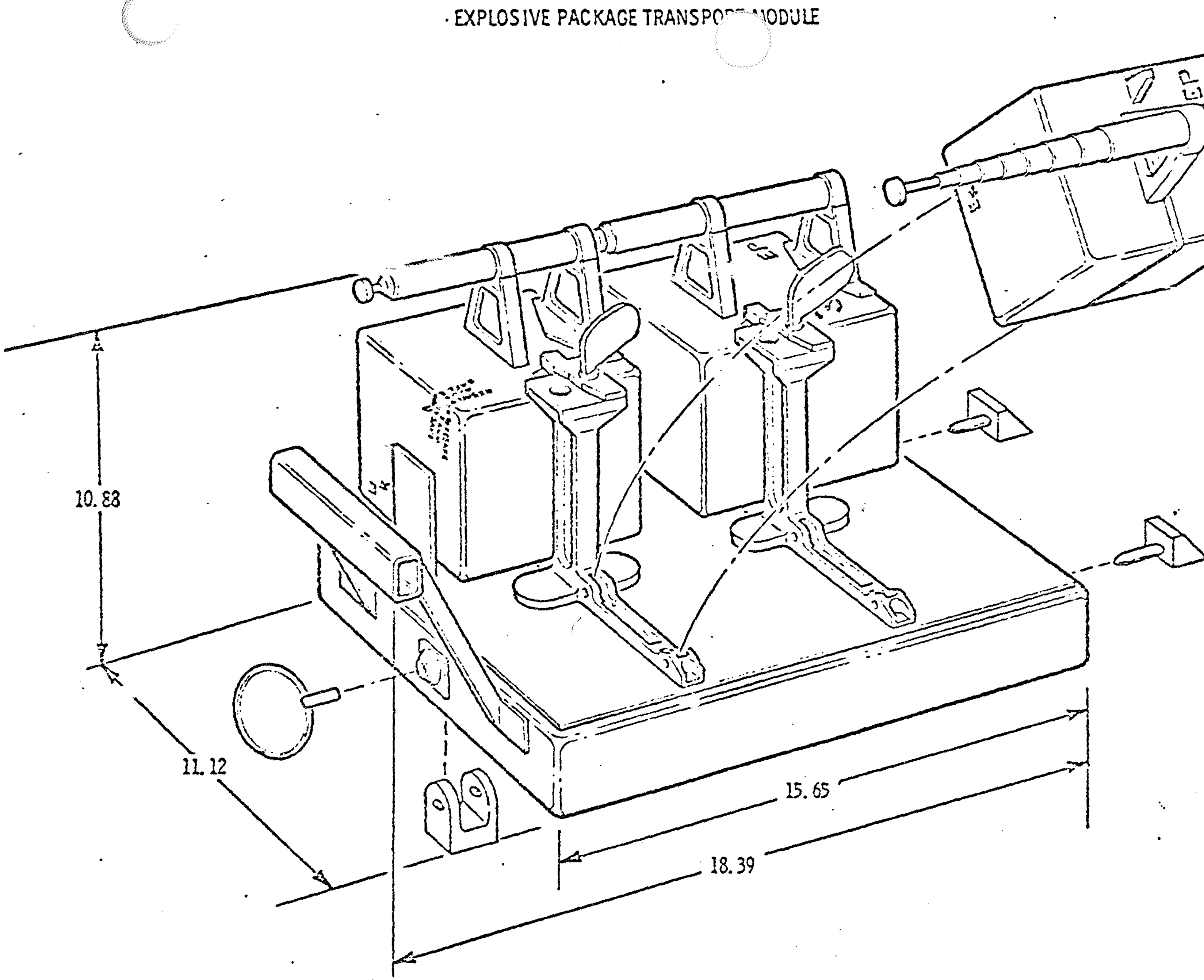
The timers in each of the Explosive Packages are preset to "arm", "activate" and "resafe" as follows: 90, 91, 92, 93 hrs; 91, 92, 93, 94 hrs.; 92, 93, 94, 95 hrs.. This spacing prevents overlap of package detonations in the event that any two packages are deployed and timers started within a time period less than the uncertainty in time-out of the timers. The second set of four has timers preset identical to the first set. However, the second set will be deployed much later than the first set, precluding overlap of detonations.

The photographic plan of deployed Geophones is as shown in Figure 1.5. The Universal Handling Tool (UHT), a common tool used by the astronauts for deploying most ALSEP hardware, will be used to carry this module to a site about 30 ft. from the ALSEP, for removal of the module cover, and then for individual pickup of each geophone and spool-out of the geophone cable which is wound on a ball bearing supported reel.

A block diagram of the LSP Central Electronics is shown in Figure 1.6.

A monopole type transmitting antenna will be stowed on the ALSEP Sunshield, erected by the crew and attached to the discarded pallet used to carry the Heat Flow Experiment on ALSEP.

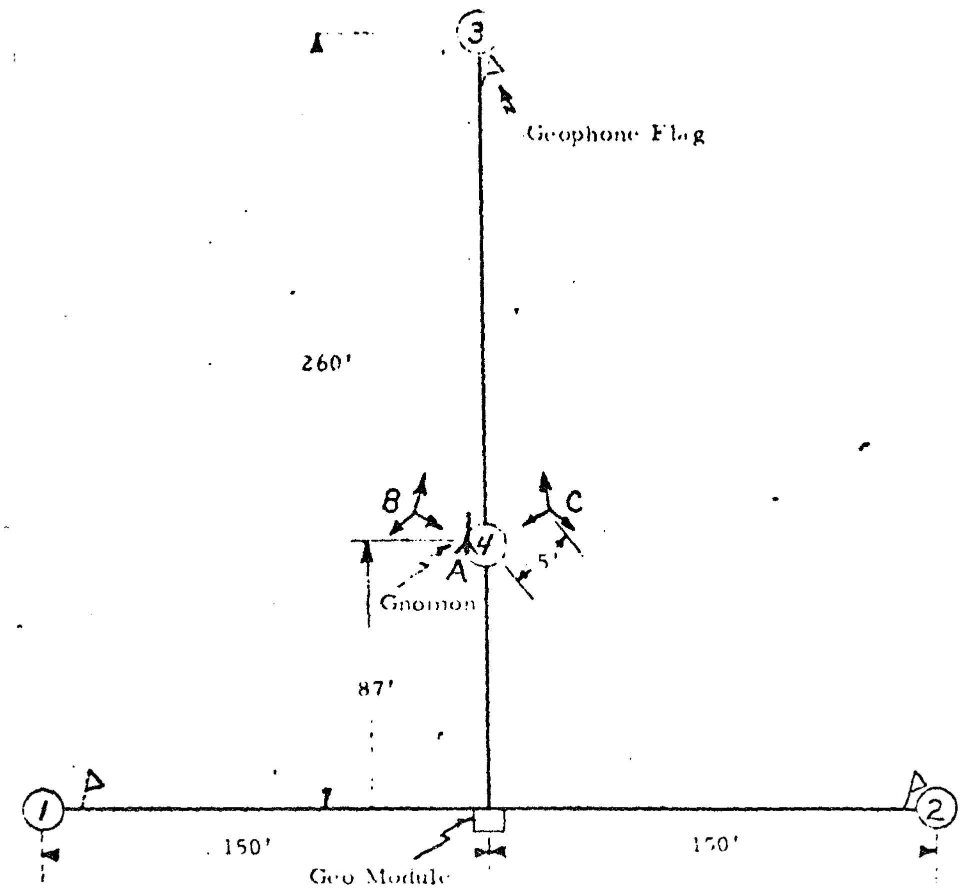
The mechanical timers are illustrated schematically in Figures 1.7 and 1.8. Figure 1.7 shows the general arrangement of the Safe Arm Slide Timer. It consists of a housing from which two slide stops extend. A timing mechanism, in the housing controlled by a wrist watch movement, withdraws one stop and then the other at precisely timed instants. The withdrawal of the first stop (the Arming Pin) allows the slide to move from a safe position to an armed position. The withdrawal of the second stop (the Safing Pin) allows the slide to move to a second safe position. The timing mechanism is self-powered, thereby eliminating loading or drag on the watch movement.



EXPLOSIVE PACKAGE TRANSPORT MODULE
10.88
11.12
15.65
18.39
EP
2

FIGURE 1.4

PHOTOGRAPHIC PLAN [illegible] DEPLOYED GEOPHONE ARRAY



Position	Photo Task	No. of Photos
A	Take panoramic photos of Array	5
B	Take one photo of Geophone #1, one photo of Geophone #2 with Geophone #4 and gnomon in view; and one photo of Geophone #3.	3
C	Take one photo of Geophone #1 with gnomon and Geophone #4 in view; one photo of Geophone #2, and one photo of Geophone #3.	3

9270-51

FIGURE 1.5

LSP CENTRAL ELECTRONI[illegible] FUNCTIONAL BLOCK DIAGRAM

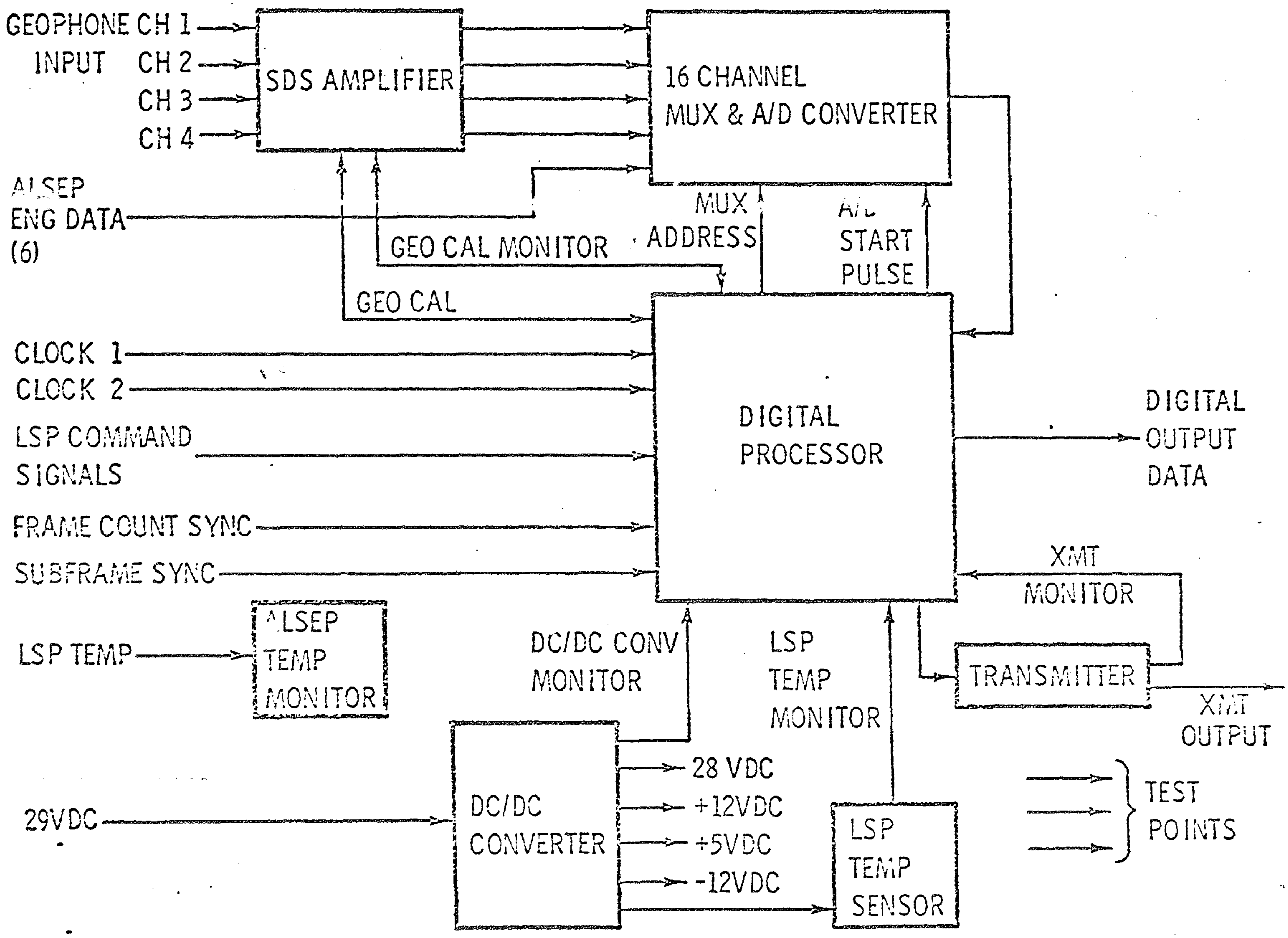
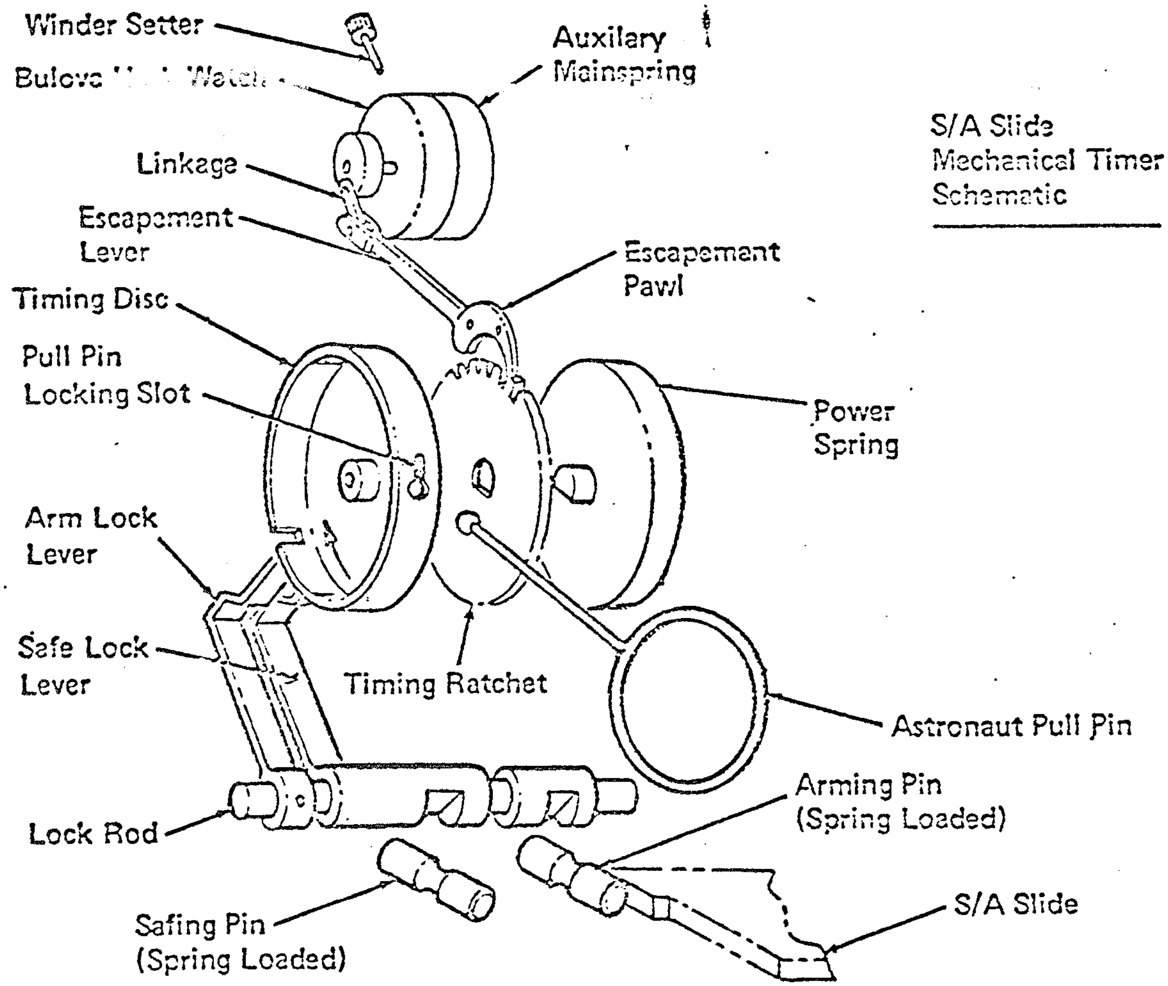
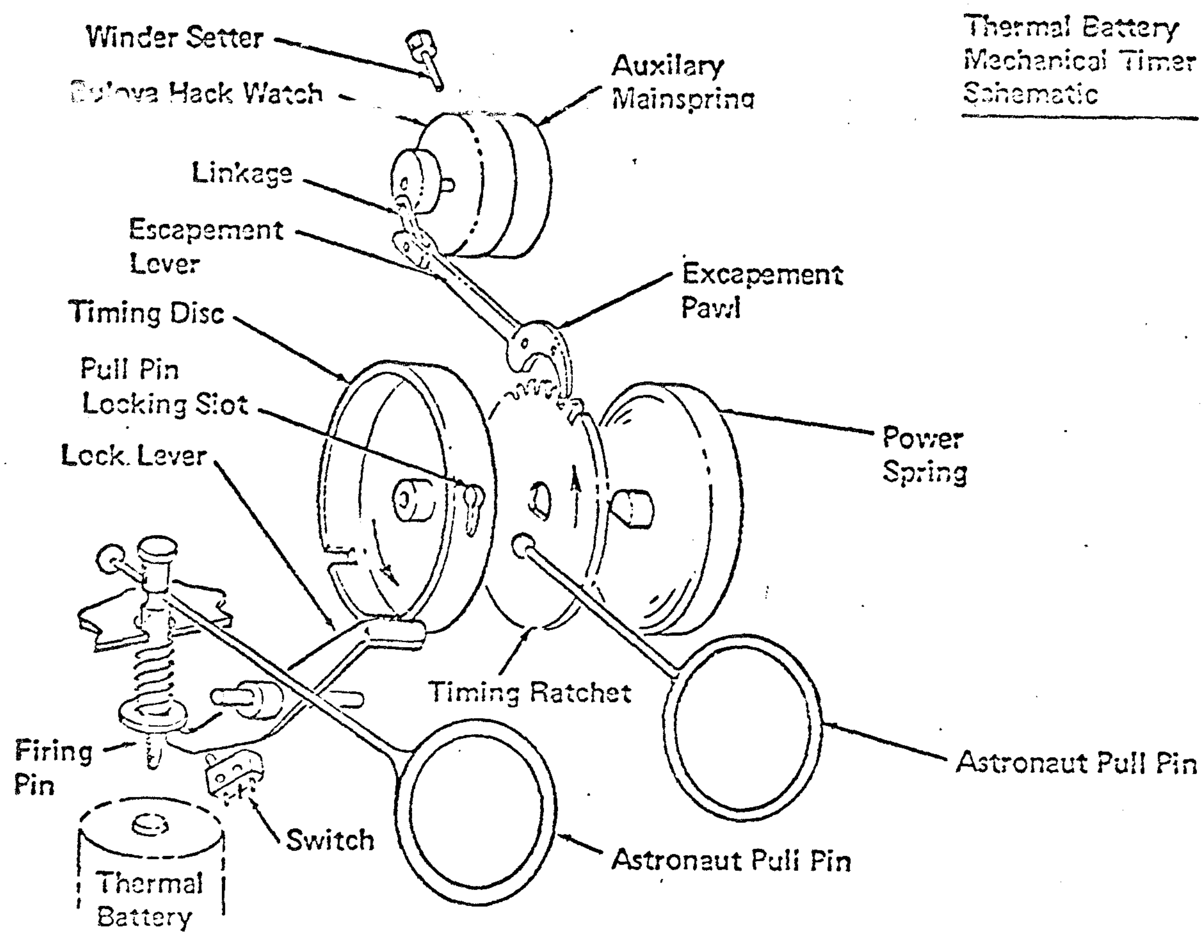


FIGURE 1.6



SAFE/ARM TIMER

FIGURE 1.7



BATTERY TIMER

FIGURE 1.8

The Arming and Safing Pins consist of two rods protruding from the timing assembly. The rods are spring loaded inward and restrained by locks which are secured to two independent sections of the Lock Shaft. The levers on the other end of the locks ride on the periphery of the Timing Drum. Rotation of the timing drum by the timing mechanism presents a timing slot through which the Arm Lock Lever drops at the correct time, thus releasing the Arming Pin which is spring retracted. Continued timing drum rotation allows a second safe lock level to drop, releasing the Safing Pin.

The timing mechanism consists of the timing drum mounted on the timing shaft, a ratchet to control rotation of the drum and an escapement pawl to provide controlled release of the ratchet, one tooth at a time. The time drum is driven by a mainspring concentric to the shaft.

The motion of the escapement pawl is controlled through an arm and linkage to the center output shaft of a wrist watch movement. This shaft rotates once per hour producing an oscillating motion of the pawl, which alternately holds the timing ratchet by the "nose" and the "tail" of the pawl, allowing the timing drum to advance through the angular distance of one ratchet tooth per hour.

The Thermal Battery Timer, Figure 1.8, is similar to the safe-arm slide timer. It differs in operation from the safe-arm time in that a single lever, retained by a latch, releases a firing pin when the lever drops through the timing slot in the drum. The firing pin is then driven by a firing pin spring to actuate the thermal battery primer. Two microswitches are closed at the same time the firing pin is released.

The design incorporates the largest watch movement that space and weight restrictions will allow. This movement is the Bulova military hack watch, which is produced in large numbers for use in military wrist watches and conforms to MIL-W-3818 (superseded by Federal Specification GG-W-113A). It has a jewelled pallet, detach lever, mechanical escapement movement and an overcoiled hairspring. It is ruggedized for military service, but is otherwise typical of high quality horological practice. The term "hack watch" derives from the design feature which stops the movement when the winding stem is pulled out and started again when the stem is depressed. This feature is utilized in the timer application by allowing the watch to be started by pulling a pull-pin. The motion of the pull-pin through a yoke arrangement depresses the stem, starting the watch.

It was necessary to modify the 24 hour watch mechanism to provide at least 95 hours running time, with suitable margin. This was accomplished by incorporating an auxiliary mainspring and mainspring barrel in series with the normal watch mainspring and a slightly revised framework to house the parts. This arrangement leaves the basic watch movement unchanged, thereby not degrading its normal high reliability.

The watch movement and the remainder of the control assembly are sealed and backfilled to a slight overpressure with dry nitrogen, plus helium as a tracer for leak rate testing. This is required for several reasons. One is to provide an inert environment for the watch lubricant to prevent oxidation or gumming during long storage periods. The other reasons are to prevent possible evaporation of the lubricant in the lunar environment, and to prevent the effects of low pressure from changing the balance wheel amplitude. Sealing of the units is accomplished by gasket o-ring seals on the control housing, the winding/setting shaft and the shaft to the escapement pawl.

2.0 MANUFACTURING AND TEST

2.1 Hazardous Test Procedures

The manufacturing and test flow for the electronic and safe/arm assemblies is presented in Figure 2.1, 2.2, and 2.3. The flow charts identify the manufacturing and test operations which may contain tasks hazardous to personnel and equipment. Work Order Operation Sheets (WO/OS's) pertaining to manufacture of explosive assemblies are reviewed to eliminate hazardous operations, to insure the inclusion of caution and warning notes, and for signature approval of the LSP system safety engineer.

The test procedures outlined by the hardware flows are also reviewed as part of the system safety program plan activities. Those procedures are identified in Figure 2.4.

The packaging and transportation flow diagram is shown in Figure 2.5.

2.2 Identification of Hazards in Test Procedures

All identified hazards in test procedures and Work Order/Operations Sheets are listed in the front of the document by specific hazard type and again within the procedure at a point prior to each occurrence, using caution or warning captions as appropriate.

CAUTION - Used prior to any operation that could result in damage to equipment if not followed.

WARNING -Used prior to any operation that could result in injury or death to personnel if not followed.

The cover sheets of multi-page bound or stapled documents are stamped or otherwise marked prominently with the following:

WARNING

This procedure contains sequences hazardous to personnel and/or material.

When this technique is not appropriate to the document containing the hazardous sequence, the above expression is written into the instructions prominently on the first page.

LSP EXPLOSIVE PACKAGE PROTOTYPE HARDWARE FLOW

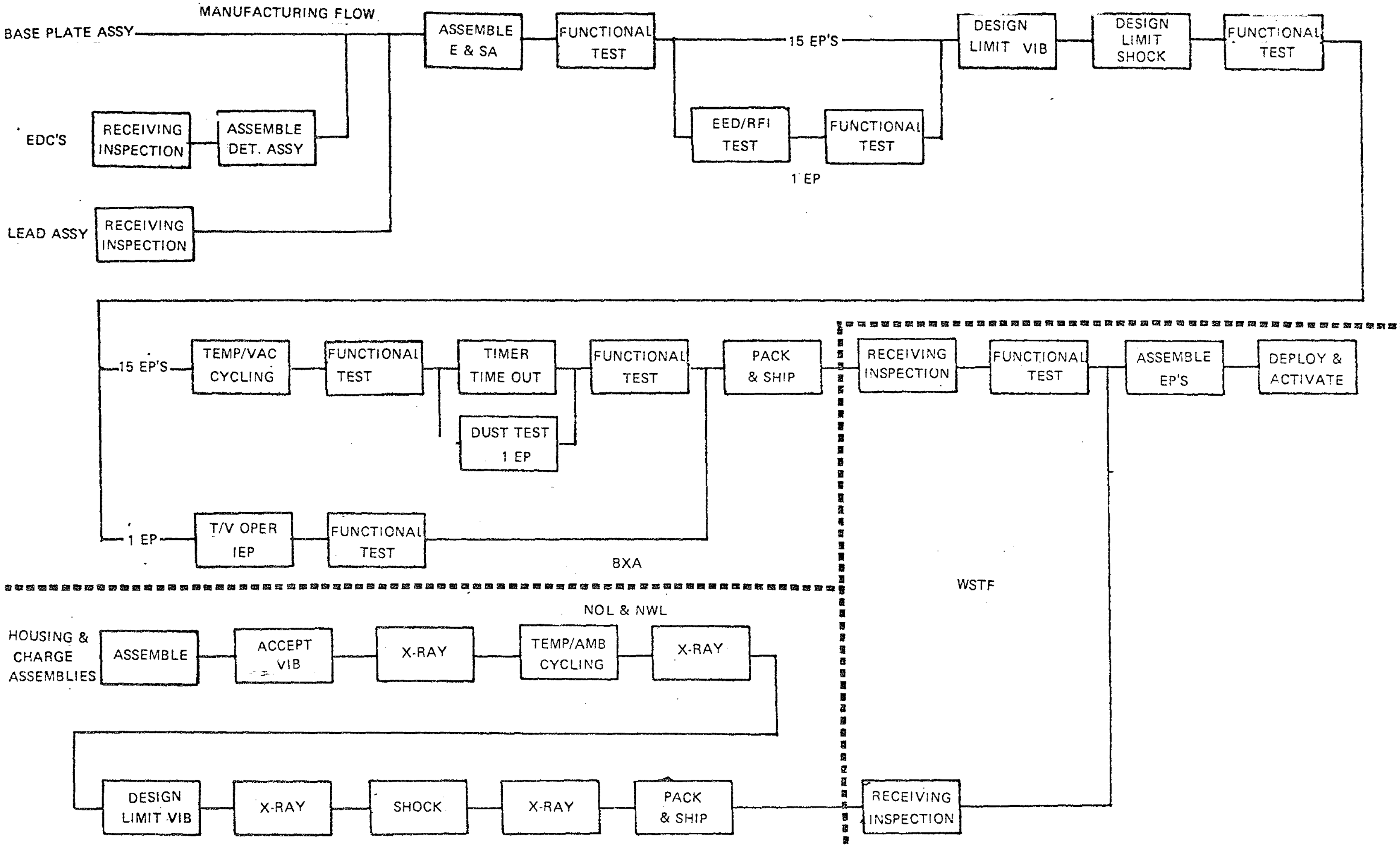


Figure 2.1

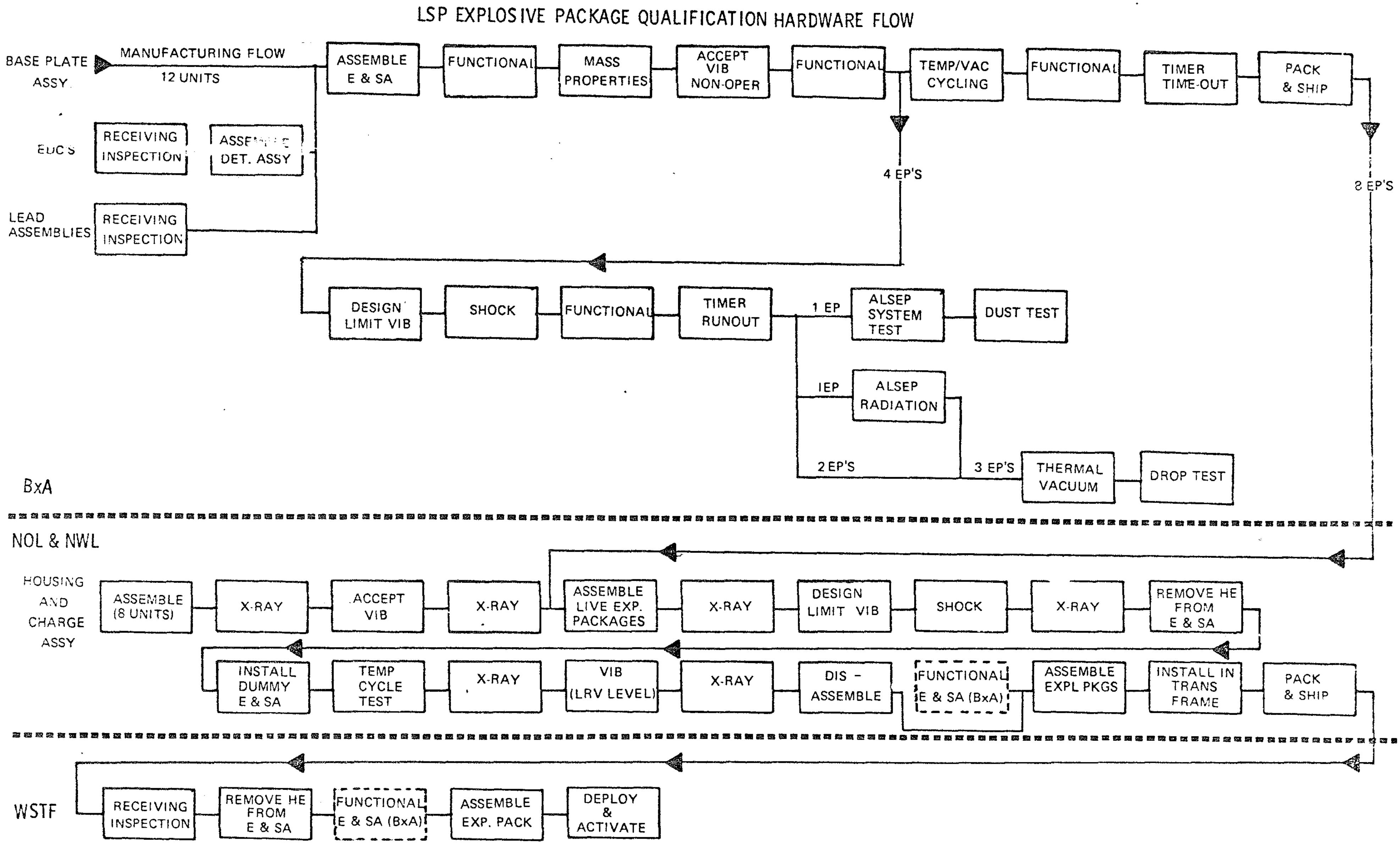

LSP EXPLOSIVE PACKAGE QUALIFICATION HARDWARE FLOW
BASE PLATE ASSY
MANUFACTURING FLOW
12 UNITS
ASSEMBLE E & SA
FUNCTIONAL
MASS PROPERTIES
ACCEPT VIB NON-OPER
FUNCTIONAL
TEMP/VAC CYCLING
FUNCTIONAL
TIMER TIME-OUT
PACK & SHIP
EDC'S
RECEIVING INSPECTION
DET. ASSY
4 EP'S
8 EP'S
LEAD ASSEMBLIES
RECEIVING INSPECTION
DESIGN LIMIT VIB
SHOCK
FUNCTIONAL
TIMER RUNOUT
1 EP
ALSEP SYSTEM TEST
DUST TEST
IEP
ALSEP RADIATION
2 EP'S
3 EP'S
THERMAL VACUUM
DROP TEST
BxA
NOL & NWL
HOUSING AND CHARGE ASSY
ASSEMBLE (8 UNITS)
X-RAY
ACCEPT VIB
X-RAY
ASSEMBLE LIVE EXP. PACKAGES
X-RAY
DESIGN LIMIT VIB
SHOCK
X-RAY
REMOVE HE FROM E & SA
INSTALL DUMMY E & SA
TEMP CYCLE TEST
X-RAY
VIB (LRV LEVEL)
X-RAY
DIS - ASSEMBLE
FUNCTIONAL E & SA (BxA)
ASSEMBLE EXPL PKGS
INSTALL IN TRANS FRAME
PACK & SHIP
WSTF
RECEIVING INSPECTION
REMOVE HE FROM E & SA
FUNCTIONAL E & SA (BxA)
ASSEMBLE EXP. PACK
DEPLOY & ACTIVATE

Figure 2.2

LSP EXPLOSIVE PACKAGE FLIGHT HARDWARE FLOW

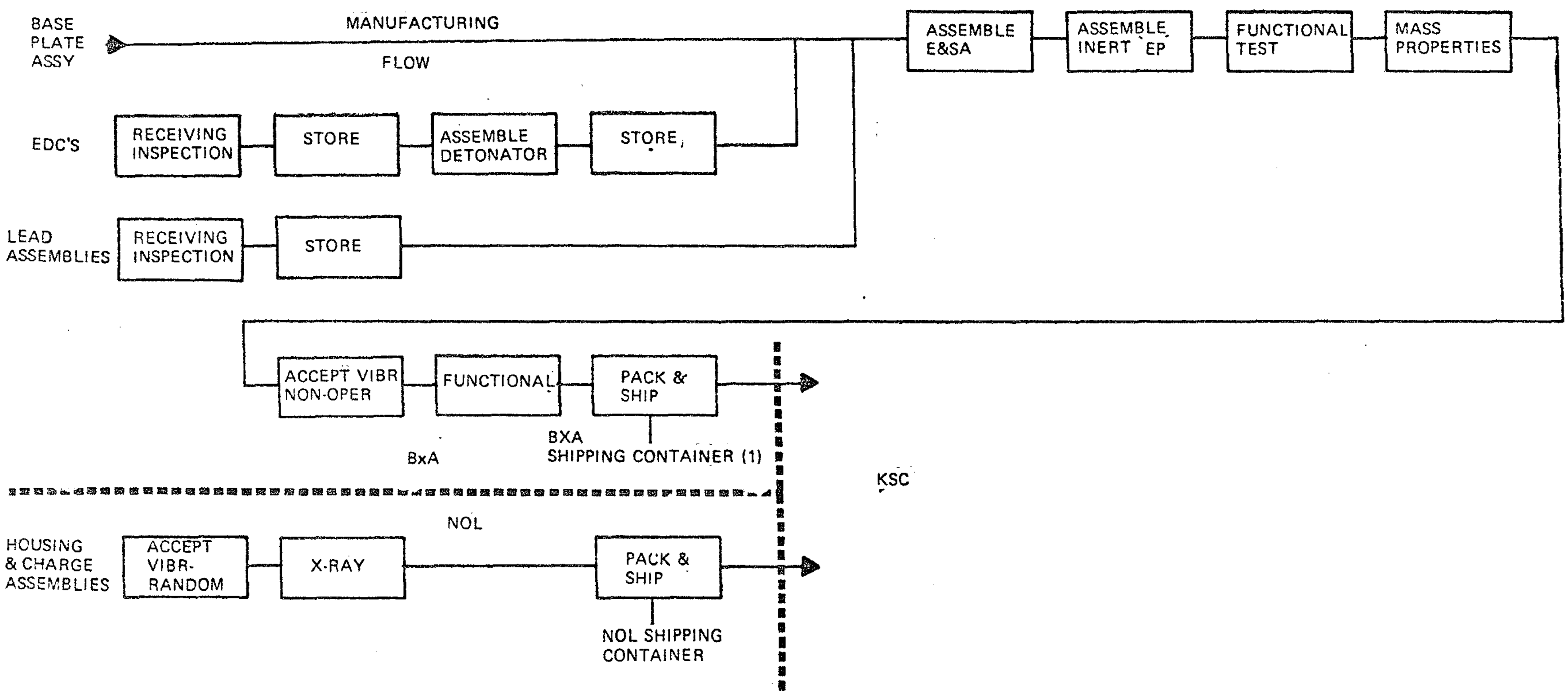


Figure 2.3

LSP MANUFACTURING AND TEST

Procedures subject to SAFETY review

TP NUMBER	TITLE	PROTO	QUAL	FLT
TP 2365360	Electronic and Safe Arm Assembly Functional Test No. 1	X	X	X
TP 2365365	Electronic and Safe Arm Assembly Functional Test No. 2	X	X	X
TP 2365370	Design Limit Vibration, Transport Frame Assembly	X	X	
TP 2365371	Shock, Transport Frame Assembly	X	X	
TP 2365372	Thermal Vacuum	X	X	
TP 2365373	Temperature, Vacuum	X	X	
TP 2365375	Explosive Package Handling	X	X	X
TP 2365377 thru TP 2365380	Field Test Procedures	X	X	
TP [illegible]5384	Mass Properties		X	X
TP 2365387	Acceptance Vibration Random		X	X
TP 2365399	Explosive Package Drop Test		X	
	LSP unique sections to ALSEP qual model procedures		X	
TP 2365721	Experiment Fit Check			X
TP 2365367	Timer and Amplitude Measurement	X	X	X
TP 2365388	EDC Bridgewire Measurement	X	X	X

Figure 2.4

ALSEP ARRAY E - LSP EXPLOSIVES

PACKAGING AND TRANSPORTATION - SUPPLIER, BxA, KSC AND WSTF

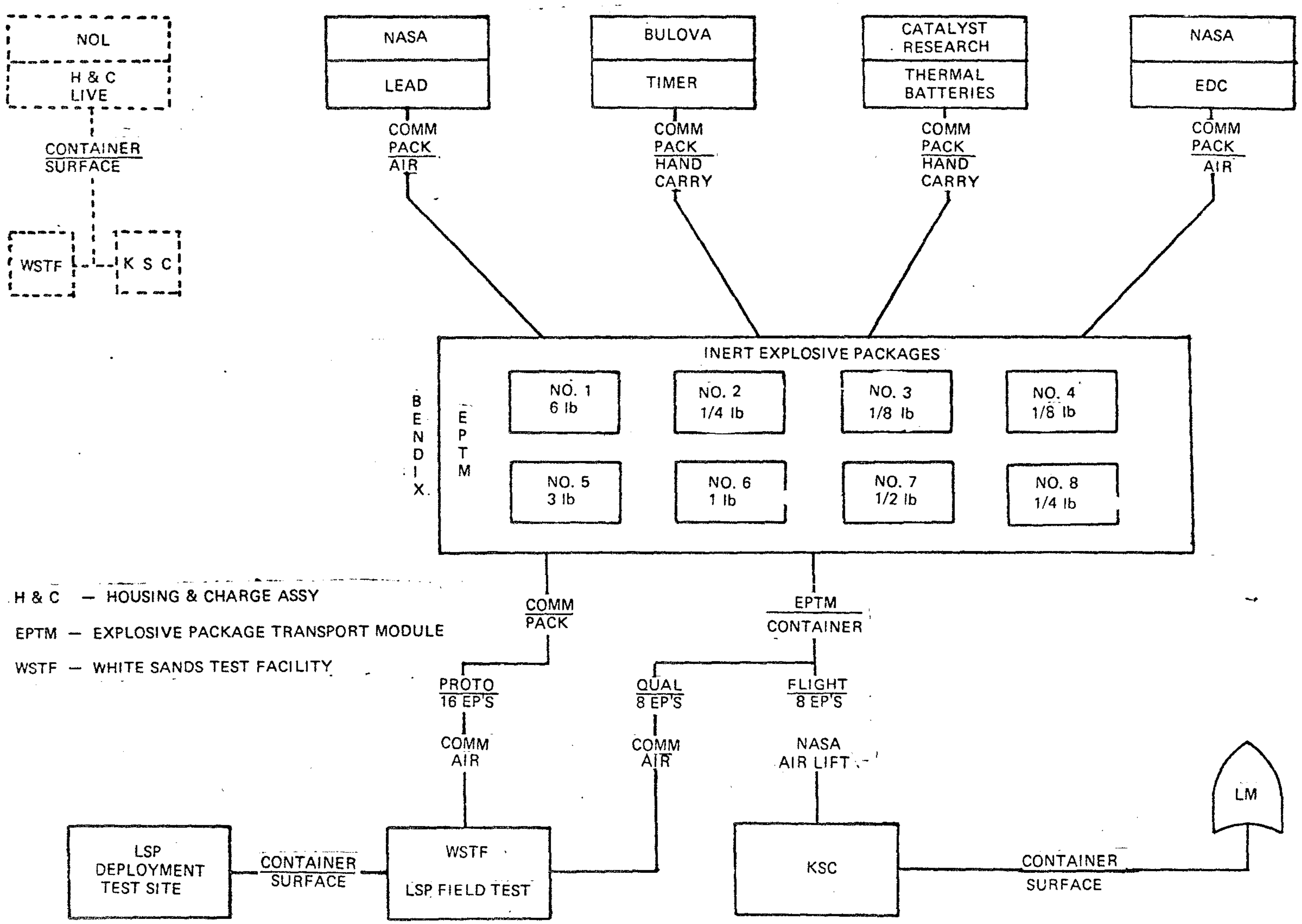


FIGURE 2.5

Prior to the specific step that introduces a hazardous operation, a warning or caution note is inserted similar to the following:

WARNING

HAZARDOUS STEP(S) FOLLOW

At the completion of the hazardous operation step(s), the following note is inserted:

NOTE

HAZARDOUS STEP(S) COMPLETED

2.3 Implementation of Safety Requirements

A safety requirement procedure 2365390A, "Safety Requirements - Lunar Seismic Profile (LSP) Experiment Explosive Subassemblies" has been written outlining general safety and handling requirements to be followed in manufacturing and test of the LSP experiment explosive subassemblies. This procedure formally established the requirements outlined above for all LSP manufacturing and test procedures.

3.0 FIELD TESTS AT WHITE SANDS TEST FACILITY (WSTF)

3.1 Transportation of Explosives to WSTF

The prototype E&SA's will be packed in accordance with best commercial packaging procedures and transported to WSTF by escorted air freight. The E&SA's are classified as Class "C" Explosives as they contain an end detonating cartridge (EDC).

The qualification E&SA's will be attached to EPTM's and transported to WSTF in one ALSEP shipping container by escorted air freight. In addition to the EDC, qualification units will contain a Class "C" explosive lead assembly.

The live H&C's are classified Class "A" Explosives and are supplied and transported to site by Naval Ordnance Laboratory (NOL) in NOL shipping containers. B×A coordinates the delivery of the H&C's with NOL to assure schedules are not constrained, and that cognizant site safety personnel are notified of the arrival of the explosive shipment. As noted in Figure 3.1, all movement of live H&C's at WSTF are controlled by WSTF approved test preparation sheets (TPS).

LSP - EXPLOSIVE TEST PACKAGE FLOW - WSTF

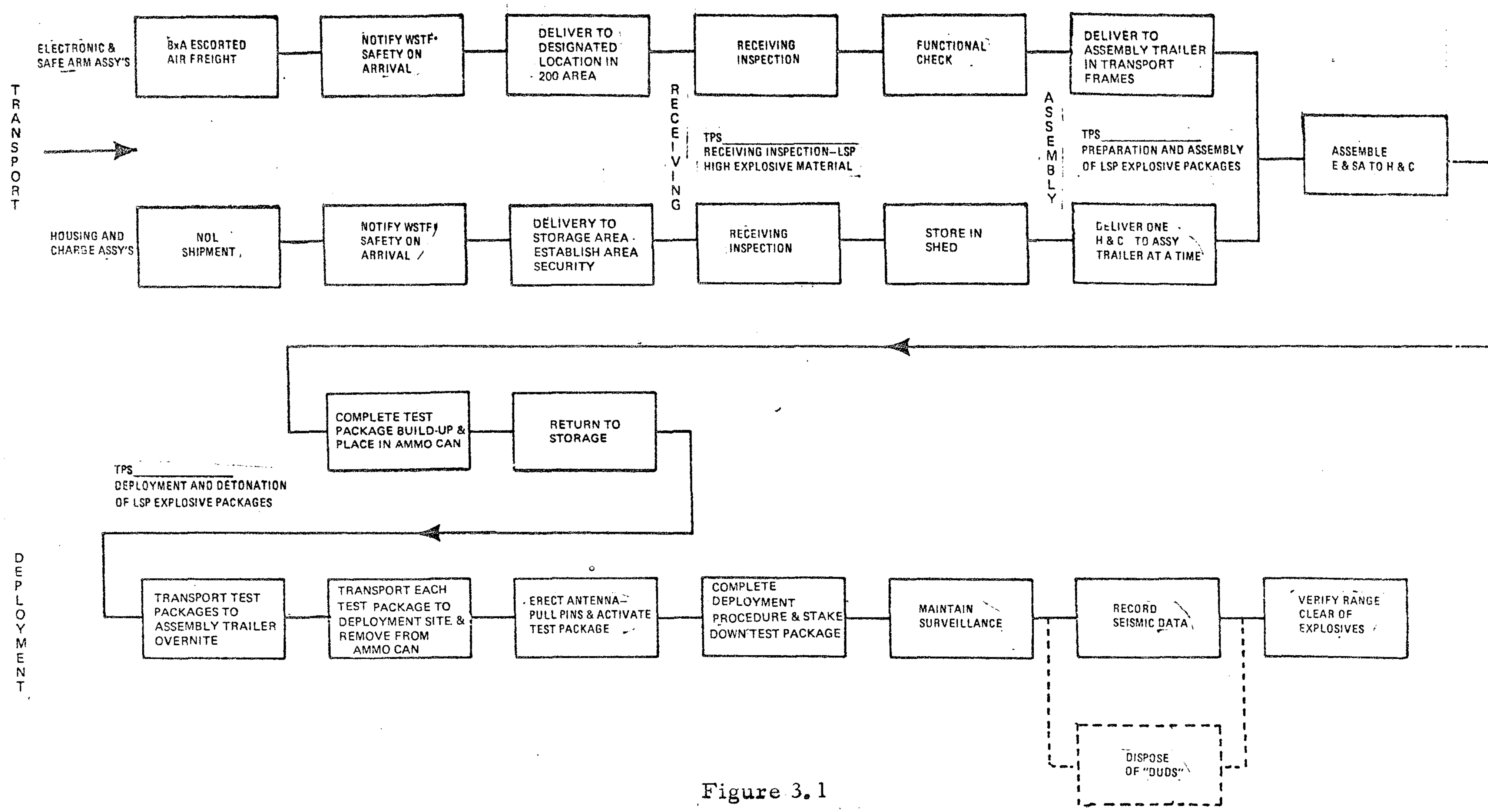


Figure 3.1

3.2 Receiving Inspection

Receiving Inspection of the E&SA's will be performed by BxA personnel in accordance with Bendix procedures. The inspection will consist of the following:

a. Visually inspect outside of container for damage during shipment.

b. Open container and visually inspect contents for obvious damage and assure item quantities match shipping document.

c. Remove E&SA's and perform a functional test.

d. Restow in shipping container, close container and store.

Receiving Inspection of the H&C's will be performed by NOL personnel and signed off by BxA. The inspection will consist of the following:

a. Visually inspect outside of container for damage during shipment.

b. Open container and visually inspect contents for obvious damage and assure item quantities match shipping document.

c. Close container and store in explosive storage structure.

3.3 Assembly Operations

Assembly of the E&SA's to the H&C's will be performed in a van type trailer specifically designated for this purpose. During assembly, the below listed steps are safety requirements:

a. Assure all necessary earth grounds are installed and verified to provide less than 5 ohm impedance to ground.

b. No more than one H& C or live EP may be in the assembly trailer at a time while assembly operations are being performed.

c. The maximum number of personnel allowed in the assembly trailer at any one time is limited to three.

d. Following assembly of each E&SA and H&C into an EP, the EP shall be installed in a 30 caliber ammunition can and returned to the storage structure prior to delivering another H&C to the trailer for assembly.

NOTE: No more than four EP's may be moved back into the assembly trailer the night before they are scheduled to be deployed to keep them from cold soaking below lunar minimum temperatures.

3.4 Deployment of Explosive Packages

General steps during deployment and detonation are as follows:

a. Remove EP's from the storage structure and transport to the preselected test deployment site.

b. Erect each EP antenna individually and set the EP on the ground.

c. Connect the heater battery.

d. Assure the EP is relatively level on the ground and pull the pull-rings to start sequence.

e. Install the styrofoam test cover tops and stake the EP to the ground.

f. Install fragmentation dome, if applicable.

g. The maximum number of personnel allowed in the deployment area at this time is limited to three

Surveillance must be maintained until detonation of all explosive packages. The seismic data will be recorded during detonation of each EP.

Due to the adverse temperatures at WSTF it is necessary to use heater strips to maintain the explosive packages within their operating environment. The use of heaters has been investigated for inherent safety and they do not present a hazard during field test.

3.5 Recovery of Duds

In the event an EP does not detonate, the systematic backout logic will be as shown in Figure 3.2. Although it will be highly desireable to recover Duds for failure analysis, a determination must be made that the EDC did not fire and that the slide is in the "resafe" position before the EP can be considered safe to handle. If this cannot be verified, the EP must be destroyed in-place as the high explosive material may have been subjected to conditions (heat, shock, impingement by foreign matter) which would render it unstable and unsafe to handle.

3.6 Field Test Safety

A comprehensive field test safety plan (ALSEP-LS-11), covering all contingencies which may develop during the field tests, will be utilized to control hazardous operations. The backout procedure outline from this plan is presented herein as Table 3.1.

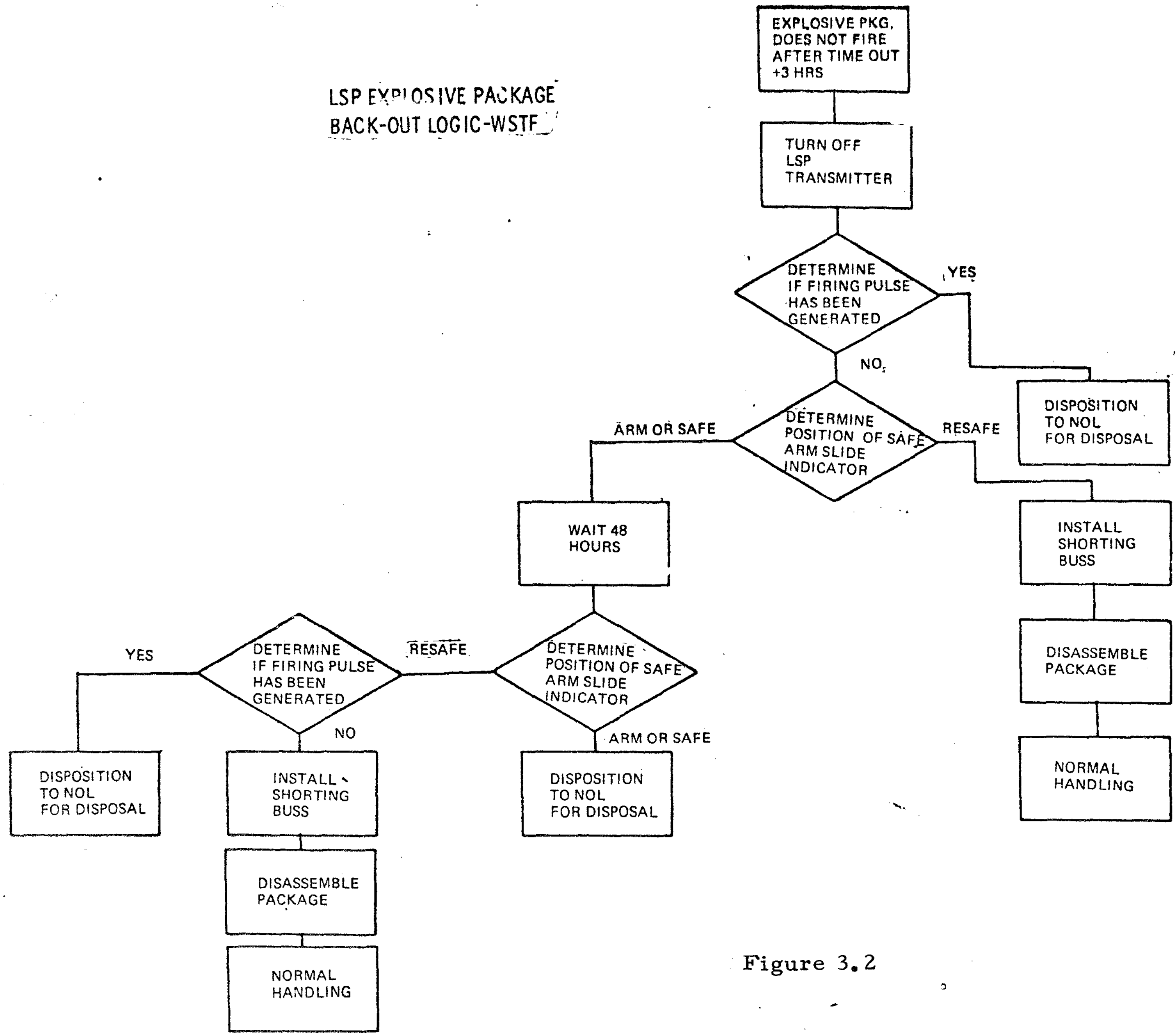

LSP EXPLOSIVE PACKAGE
BACK-OUT LOGIC-WSTF
EXPLOSIVE PKG. DOES NOT FIRE AFTER TIME OUT +3 HRS
TURN OFF LSP TRANSMITTER
DETERMINE IF FIRING PULSE HAS BEEN GENERATED
YES
NO
DISPOSITION TO NOL FOR DISPOSAL
DETERMINE POSITION OF SAFE ARM SLIDE INDICATOR
ARM OR SAFE
RESAFE
INSTALL SHORTING BUSS
DISASSEMBLE PACKAGE
NORMAL HANDLING
WAIT 48 HOURS
DETERMINE POSITION OF SAFE ARM SLIDE INDICATOR
RESAFE
ARM OR SAFE
DISPOSITION TO NOL FOR DISPOSAL
DETERMINE IF FIRING PULSE HAS BEEN GENERATED
YES
NO
DISPOSITION TO NOL FOR DISPOSAL
INSTALL SHORTING BUSS
DISASSEMBLE PACKAGE
NORMAL HANDLING

Figure 3.2

LSP FIELD TEST BACKOUT PROCEDURES

ACTIVITY	PROBLEM	RESPONSE
A. Receiving Inspection of Electronics and Safe Arm Assembly	1. Safe Arm Slide has moved to arm position	1. a. Clear area of extraneous personnel b. Do not expose personnel to the bottom face of the E&SA c. Verify transportation buss installed d. Isolate in secure area pending disposition of DR
	2. Transportation Buss not Installed	2. Transportation Buss Available a. Install transportation buss b. Provide normal handling Transportation Buss Not Available a. Clear area b. Install a wire short from Pin 5 to Pin 11 on Connector J2 c. Isolate in secure area pending disposition of DR
	3. Detonator Assembly Fires	3. a. Clear area b. Remove E&SA Assembly to secure area pending disposition of DR
	4. Lead Assembly Detonates	4. See Corrective Action No. 3
B. E&SA Functional Check	5. Safe Arm Slide moves to arm position	5. See Corrective Action No. 1
	6. Detonator Assembly Fires	6. a. Clear area b. Secure area and maintain test configuration exactly as when accident occurred pending disposition of DR

Table 3.1

ACTIVITY	PROBLEM	RESPONSE
	7. Lead Assembly Fires	7. See Corrective Action No. 6
C. Receiving Inspection of	8. Physical Damage	8. a. Clear area b. NOL to disposition DR
D. Assembly of Explosive Packages	9. Safe/Arm Slide moves to arm position	9. a. Clear area b. Secure area pending disposition of DR
	10. Detonator Fires	10. a. Clear area b. Secure area pending disposition of DR
E. Deployment	11. Safe Arm Slide moves to arm position	11. a. Clear area b. Secure area pending disposition of DR
	12. EDC fires or flash bulb fires	12. a. Clear area b. Secure area pending disposition of DR
	13. One Timer Pin shears during pin pulling	13. a. Install or verify installation of Safe Arm Slide safing pin b. Disposition DR
F. Detonation	14. Explosive Package Duds	14. a. See Figure 4 for backout logic b. Maintain security pending disposition of DR
	15. Premature detonation of Explosive Package	15. a. Verify LSP central station transmitter "Off" b. Secure, but do not approach, all other deployed or stored high explosives pending disposition of DR

Table 3.1 (Continued)

4.0 KSC OPERATIONS

4.1 General

The LSP flight EPTM will be transported from BxA to KSC in one ALSEP experiment container. LSP components to be confidence verified at KSC will be shipped in the same container; i.e., Thermal Battery Detonator (assembled into a thermal battery selected from the flight lot), Detonator Assembly, and Lead. The packaging, handling, and transportation will be conducted in accordance with BxA Procedure TP-2368916. The flow of LSP Explosive Package components is shown in Figure 4.1. The schedule of procedures to be written to implement this flow is shown in Figure 4.2.

4.2 Receiving Inspection

4.2.1 Explosive Package Transport Module

Receiving inspection of the EPTM KSC will be conducted in accordance with TCP 2368934 in the BxA facility in hangar S, and will be limited to a visual inspection for handling damage, reading of environmental recorders, and verification of the data package. The EPTM will remain in hangar S until required at the O&C building for fit checks to the LM pallet.

4.2.2 Housing and Charge Assemblies

The live H&C's are supplied as GFC and will be shipped by NOL directly to KSC. BxA will coordinate schedules and transportation with NOL and KSC. Receiving inspection will be in accordance with TCP 2368931 in the Flight Ordnance Test Laboratory (FOTL). A minimum receiving inspection, similar to the EPTM, will be performed. There are no requirements for radiographic inspection. The H&C's will be stored by NASA until required for mating with the E&SA's in the FOTL.

ALSEP ARRAY E - LSP FLOW - KSC

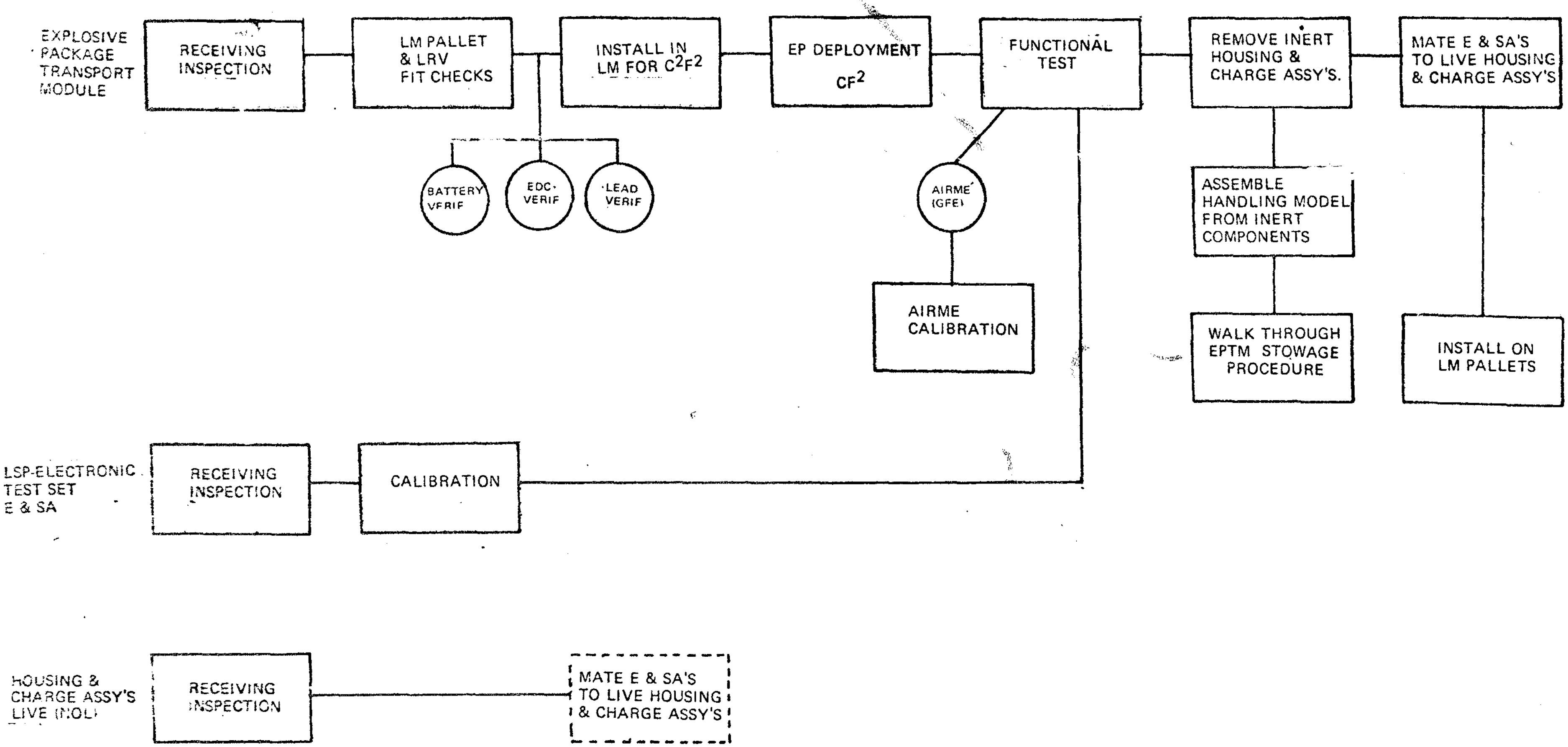


Figure 4.1

TIER 4

Bendix Aerospace Systems Division

MASTER SCHEDULE

Title: SYSTEM SUPPORT
KSC DOCUMENTATION — ARRAY E (APOLLO 17)

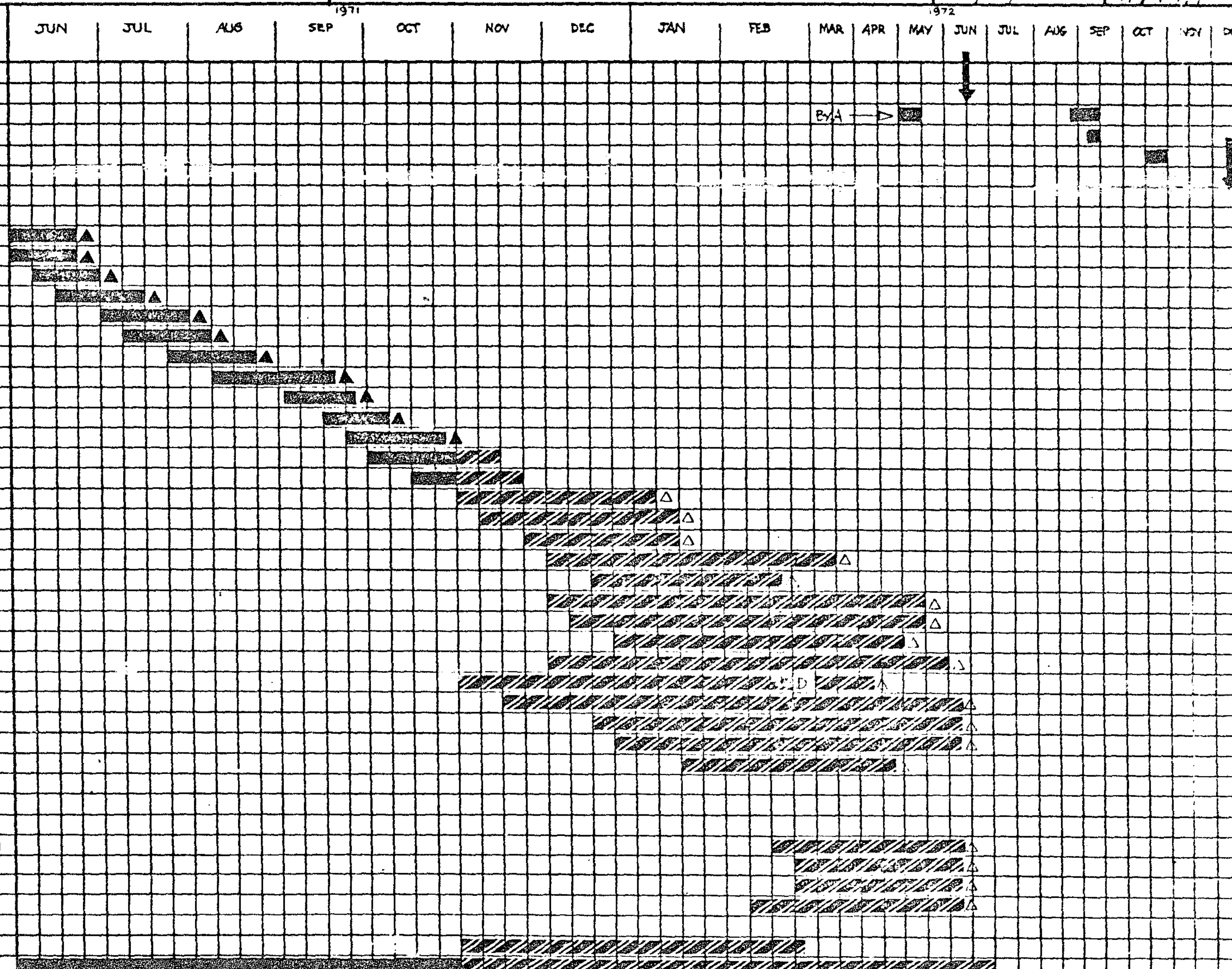
No:

Issued On: 1/14/71

Revision No: 13

Updated On: 11/1/71

Line	Item
1	MAJOR EVENTS - KSC (PLANNING)
2	DELIVERY TO KSC
3	CF² & RESTOWAGE
4	SIT
5	S/P INSTALLATION IN LM
6	LAUNCH (APOLLO 17)
7	
8	KSC PROCEDURES (TCPs)
9	2335975 SPEC. BOYD BOLT INSTALLATION
10	2337001 STS RECEIVING INSPECTION
11	2337009 PSE PRESSURE CHECK
12	2337056 S/Ps FIT CHECK TO LM
13	2337075 ACA INSTALLATION ON LM
14	2337076 ACA REMOVAL FROM LM
15	2337086 SUBPACKAGES HANDLING
16	2337090 FC/BAND ASSY. + FIT CHECK TO CG FIXTURE
17	2337169 PRESS SHIPPING CONTAINERS
18	2341443 CASK TILT DEMONSTRATION
19	2345113 S/P INSTL. IN GSE, MOVE TO LP
20	2345116 S/P INSTALLATION IN LM
21	2365345 RTG LEAK + RESISTANCE TEST
22	2368909 S/P 1 RECEIVING INSPECTION
23	2368910 S/P 2 RECEIVING INSPECTION
24	2368930 ARRAY E GSE RECEIVING INSPECTION
25	2368931 LSPE ORDNANCE RECEIVING INSP.
26	2368920 E+SA TEST SET RECEIVING INSP.
27	2368932 E+SA TEST SET CHECKOUT
28	2368933 E+SA TEST SET CALIBRATION
29	2368934 EPTM RECEIVING INSPECTION
30	2368935 E+SA FUNCTIONAL TEST
31	2365344 ARRAY E CF² + RESTOWAGE
32	2368936 EPTM CF² + RESTOWAGE
33	2368937 ARRAY E PREP. FOR FLIGHT
34	2368938 EPTM/ORD. ASSY. INSTL ON GAC PALLET
35	2368939 EPTM/LM/LRV FITCHECK
36	
37	
38	
39	2368940 STS CHECKOUT (SIT)
40	2368906 ALSEP/MSFN TURN ON + VERIFY (SIT)
41	2368908 ALSEP + STS TURN OFF (SIT)
42	2368907 GMIL/ALSEP INTERFACE TEST (SIT)
43	
44	TRSD
45	MAINTENANCE OF TCPs



Remarks: ▬▲ COMPLETED
▨ SCHEDULED WORK

Other	Test	Mfg Dept	Mfg Prog	Engr	Prog Cont	Next Higher Schedule No	Page 1 of 1

970-28C

FIGURE 4.2

4.2.3 E&S/A Test Set

The E&SA Test Set, P/N 2365992, will be commercially packed and transported from BxA to KSC. Receiving inspection of the Test Set will be conducted in Hangar S in accordance with TCP 2368920. The Test Set will be retained in hangar S for the duration of the program.

4.3 E&SA Test Set Functional Checkout

Functional checkout of the E&SA Test Set will be accomplished in hangar S in accordance with TCP 2368932. The test set will be used during functional test of the E&SA's in conjunction with the AIRME.

4.4 Test Set Calibration

4.4.1 E&SA Test Set

A complete calibration procedure for the E&SA's Test Set will be provided in TCP 2368932. Selected portions of this procedure will be performed as required to keep the test set in calibration.

4.4.2 AIRME

The AIRME is provided by NASA as GFE and is maintained in calibration by NASA.

4.5 Lot Verification Tests

4.5.1 End Detonating Cartridge

The EDC is a GFE item and will be forwarded to FOTL for lot verification testing per NASA requirements. No additional BxA support is required.

4.5.2 Lead

The lead is a GFE item and will be forwarded to FOTL for lot verification testing per NASA requirements. No additional BxA support is required.

4.5.3 Thermal Battery Primer

The M42G Primer is the only component of the thermal battery which requires lot verification testing. However, an assembled battery from the flight lot is provided for ease of traceability and to assure identification of the test specimen with the flight hardware. If required, BxA will provide FOTL with a residual battery timer and instructions for using it as a test fixture for firing the battery. No additional BxA support is required.

4.6 Fit Check to LM Pallets

The EPTM is stowed on one pallet in the LM Quadrent III and transferred on the lunar surface to a second pallet which has previously installed on the LRV. Thus, the fit check requirements are pallet to pallet with neither the LM nor the LRV being directly involved. Fit checks will be accomplished to verify the mating of the EPTM to each pallet and will assure proper design fit prior to the LM C^2F^2. The fit checks will be conducted in accordance with TCP 2365339. The fit checks may be performed in the Grumman (GAC) Bond Room in the O&C Building prior to the installation of the pallets in the LM, or as otherwise directed for schedule convenience.

4.7 Install in LM for C^2F^2

The transfer of the transport frames from the LM pallet to the LRV pallet is presumed to be part of the LRV deployment sequence in the LM C^2F^2. The necessary steps for installing the EPTM and removing one frame at a time for installation on the LRV will be included in TCP 2365336.

4.8 EPTM Crew Fit and Functional (CF^2)

The EPTM CF^2, involving removal of the explosive packages from the transport frames and simulation of the deployment procedures to be performed on the lunar surface, may be performed as a continuation of the LM C^2F^2, or, if more convenient may be performed independently as a seperate CF^2 in the GAC Bond Room. TCP 2365336 shall be written so as to maintain this option.

Two flight crew operational constraints are imposed on the E&SA's during CF^2:

a. LSP E&SA pull pins should not be removed. Replacement of the pins in time to avoid the requirement to reset the timers cannot be guaranteed under real time CF^2 conditions.

b. The EVA procedure of lowering the explosive packages to the ground by use of the extended receiver antenna should not be attempted as the antenna is not stressed to accept the earth weight of the packages.

4.9 E&SA Functional Tests

Functional test of the E&SA's will be conducted following the EPTM CF^2 and prior to mating with the H&C's, utilizing the E&SA test set and the AIRME, per TCP 2368935. Two sequences of tests will be performed.

4.9.1 Electronics Subassembly Checkout

The electronics subsystem, including the receiver, decoder, firing circuit, and the capacitor charging circuit, will be checked out.

4.9.2 EDC Bridgewire Resistance Measurement

The transportation buss will be removed and the bridgewire resistance will be checked to determine if within tolerance using the AIRME. The flight buss will be inserted at this time so that continuity checks can be made prior to mating with the H&C.

4.10 Removal of Inert H&C's

Separation of inert H&C's from the live E&SA's will be accomplished in accordance with TCP 2368938 at FOTL. The inert H&C's are a part of the handling model used in the walk through of the procedure to stow the LM pallet.

4.11 Assembly of Live EP's

The live H&C's will be separated from the structural E&SA's at FOTL and assembled into live EP's. The EP's will be then mounted on a transport frame to become the Explosive Package Transport Module (Flight). The necessary steps for assembly will be included in TCP 2368938.

4.12 Assembly of Handling Model EPTM

The hardware discarded in assembly of the flight model EPTM will be assembled into a handling model EPTM for use in walking through the procedure for installation in LM pallet and installation of the pallet in the LM. The handling model EPTM will be constructed from the NOL transport frames, 8 NOL structural E&SA assemblies and 8 BxA inert H&C's.

4.13 Walk Thru of EPTM Stowage Procedure

The handling model will be used to perform a walk thru of the EPTM stowage procedure. This simulation of EPTM stowage will be used to debug the TPS and to locate problems associated with clearances and access. By using the handling model, requirements to handle the live EPTM will be minimized.

4.14 Stowage of EPTM on LM Pallet

Stowage of the flight EPTM will be performed in accordance with a Grumman procedure TCP 2368938, EPTM/ordnance assembly installation on GAC pallet. The installation will be performed at FOTL.

5. 0 Safety Data Package

5. 1 EXPLOSIVE DEVICES AND INERT EQUIVALENTS

5. 1. 1 Detonator Assembly

A. 1. Nomenclature: Detonator Assembly

2. BxA P/N:

a. Prototype 2348421-1

b. Qual/Flight 2348421-101

3. Source/Vendor: GFE from MSC

NOTE: Modified NASA/MSC Apollo-qualified detonator Part No. LSC-320315-15. Modification consists of removing the connector outer shell and installing a twisted, shielded, jacketed pair cable.

4. Next Assembly:

a. Prototype - Base Plate Assembly P/N 2348552-1 thru -4.

b. Qualification/Flight - Base Plate Assembly P/N 2348552-201 thru 208

5. End Item:

a. Prototype - Explosive Package Transport Module P/N 2348320-1, 2

b. Qualification/Flight - Explosive Package Transport Module, P/N 2348320-601, 602

6. Quantity per End Item: 8

7. Use and Description of Operation: To initiate detonation Lead Assembly to detonate explosive package.

8. Hazard Classification:

   Q-D Class: per AFM 127-100

   Compatibility Group: B per AFM 127-100

   ICC Class: C per T. C. G. Tariff 15

9. Size of Components: 1.25" x 1.0" x 1.0" (plus 12" lead wire)

10. Weight of Components (less pkg.): Less than one lb.

11. Formulation:

Lead Azide	100 mg
HNS I	100 mg

12. Electrical Characteristics:

    a. Maximum number fire rating:

       1 amp 1 watt 5 minutes time

    b. Minimum all fire rating:

       5 amp 5 watts .005 sec. time

    c. Bridge wire resistance: 0.90 - 1.20 ohms

    d. Ordnance Component Connector Pin Data:

Pin	Resistance
A-B	0.90 - 1.20 ohms

13. Physical Characteristics:

    a. Shelf Life: 4 years

    b. Temperature Limits: greater than 600°F

c. Humidity limits: N/A

d. Auto ignition temperature: greater than 600°F

e. Safing method: Shorting Pins A & B to case

14. Proper method of Detonation:

Detonated by a current of not less than 5 amps

B. 1. Nomenclature: Detonator Assembly

2. BxA P/N

a. Prototype 2348421-2

b. Qualification/Flight - 2348421-102

Not Safety Critical - Contains no explosive and is color coded red in accordance with MSC Design and Procedural Standard No. 103, dated 6 March 1970.

C. 1. Nomenclature: Detonator Assembly EED

2 BxA P/N: 2364718

Not Safety Critical - Contains a bridge wire but no ex plosive and is color coded blue in accordance with MSC Design and Procedural Standard No. 103, dated 6 March 1970.

5.1.2 Lead Assemblies

A. 1. Nomenclature: Lead, Live

2. BxA P/N 2364734

3. Source/Vendor: GFE from MSC

4. Next Assembly:

a. Prototype - Base Plate Assembly, P/N 2348552-1 thru -4.

b. Qualification/Flight - Base Plate Assembly, P/N 2348552-201 thru -208

5. End Item:

   a. Prototype - Explosive Package Transport Module P/N 2348320-1, 2

   b. Qualification/Flight - Explosive Package Transport Module P/N 2348320-601, 602

6. Quantity per End Item: 8

7. Use and Description of Operation:

   To act as a booster in explosive package explosive train

8. Hazard Classification:

   Q-D Class: per AFM 127-100

   Compatibility Group: B per AFM 127-100

   ICC Class: C per T. C. G. Tariff 15

9. Size of Components: .425" x .425" x .284"

10. Weight of components: less than 1 lb

11. Formulation: HNS II - less than 200 mg.

12. Electrical Characteristics: Not Applicable

13. Physical Characteristics:

    a. Shelf Life: None specified

    b. Temperature Limits: greater than 600°F

    c. Humidity Limits: N/A

    d. Auto ignition temperature: greater than 600°F

    e. Safing method: Packaging to reduce shock

14. Proper method of detonation: Detonated by explosive impact from Detonator Assembly

B. 1. Nomenclature: Lead, Inert

2. BxA P/N: 2364735

Not Safety Critical - Contains no explosives and is color coded red in accordance with MSC Design and Procedural Standard No. 103, dated 6 March 1970.

5.1.3 Housing and Charge Assembly

A. 1. Nomenclature: Housing and Charge Assembly

2. BxA P/N:

Prototype	Qual/Flight
2348555-1	2348555-401
2348555-2	2348555-402
2348555-3	2348555-403
2348555-4	2348555-404
2348555-5	2348555-405
2348555-6	2348555-406
2348555-7	2348555-407
2348559-1	2348559-301

Not Safety Critical - (Inert) contains no explosive charge

B. 1. Nomenclature: Housing and Charge Assembly

2. BxA P/N:

Prototype	Qual/Flight
2348555-8	2348555-408
2348555-9	2348555-409
2348555-10	2348555-410
2348555-11	2348555-411
2348555-12	2348555-412
2348555-13	2348555-413
2348555-14	2348555-414
2348559-2	2348559-302

3. Source/Vendor: GFE from MSC

4. Next Assembly:

a. Prototype: Explosive Package Assembly, P/N 2364701-1 thru -8

b. Qualification/Flight - Explosive Package Assembly, P/N 2364701-501 thru -508

5 End Item:

a. Prototype - Explosive Package Transport Module, P/N 2348320-1, 2

b. Qualification/Flight - Explosive Package Transport Module, P/N 2348320-601, 602

6. Quantity per End Item: 8

7. Use and Description of Operation:

Supplies Seismic Energy by detonation

8. Hazard Classification:

Q-D Class: 4 per AFM 127-100

Compatibility Group: 1 per AFM 127-100

ICC Class: A per T. C. G. Tariff 15

9. Size of Components:

Part Number	Dimensions
2348555-408 & -8	4. 900" x 4. 900" x 2. 360"
2348555-409 & -9	4. 900" x 4. 900" x 2. 360"
2348555-410 & -10	4. 900" x 4. 900" x 2. 360"
2348555-411 & -11	4. 900" x 4. 900" x 2. 920"
2348555-412 & -12	4. 900" x 4. 900" x 4. 140"
2348555-413 & -13	4 900" x 4. 900" x 2. 360"
2348555-414 & -14	4. 900" x 4. 900" x 2. 360"
2348559-302 & -2	4. 900" x 4. 900" x 4. 490"

10. Weight of Components:

Part Number	Weight (lbs)
2348555-408 & -8	.402
2348555-409 & -9	.525
2348555-410 & -10	.910
2348555-411 & -11	1.451
2348555-412 & -12	3.525
2348555-413 & -13	.402
2348555-414 & -14	.525
2348559-302 & -2	6.528

11. Formulation:

Part Number	Type Charge	Quantity
2348555-408 & -8	HNS-II	.125 lb
2348555-409 & -9	HNS-II	.250 lb.
2348555-410 & -10	HNS-II	.50 lb.
2348555-411 & -11	HNS-II	1.00 lbs.
2348555-412 & -12	HNS-II	3.00 lbs.
2348555-413 & -13	HNS-II	.125 lb.
2348555-414 & -14	HNS-II	.250 lb.
2348559-302 & -2	HNS-II	6.00 lbs.

12. Electrical Characteristics: Not Applicable

13. Physical Characteristics:

    a. Shelf Life: none specified

    b. Temperature Limits: greater than 600°F

    c. Humidity Limits: N/A

    d. Auto Ignition Temperature: greater than 600°F

    e. Safing Method: Packing to protect from shock

14. Proper Method of Detonation: Detonated by live lead Assembly

5.2 Functional Diagrams of E&SA and Interfacing Test Sets

A complete set of functional diagrams of the E&SA interfaced with the E&SA Test Set, the AIRME, and the Modified ALINCO Tester (or equivalent) is to be provided in Figures 5-1 through 5-3.

E&SA Schematic Diagram

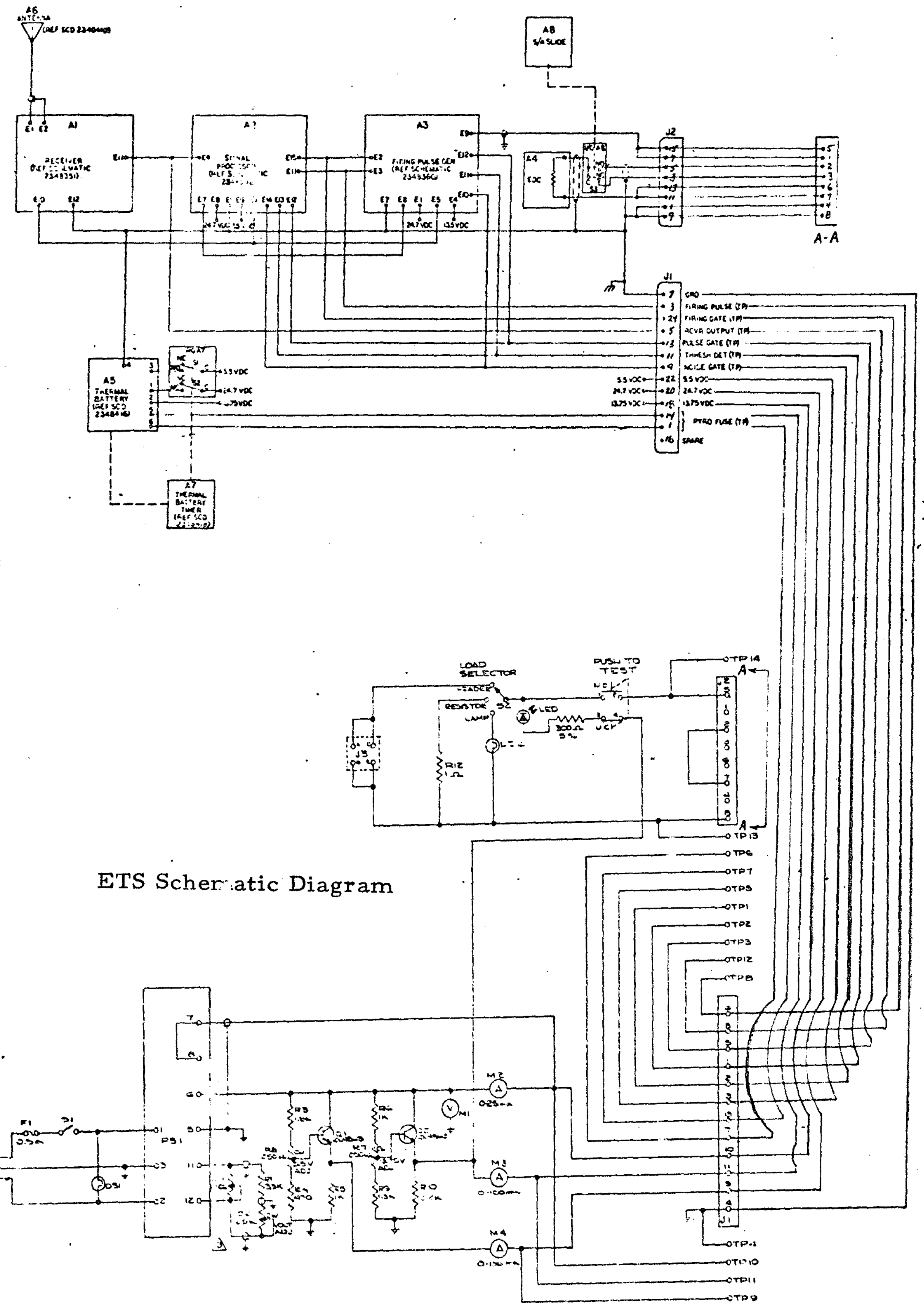
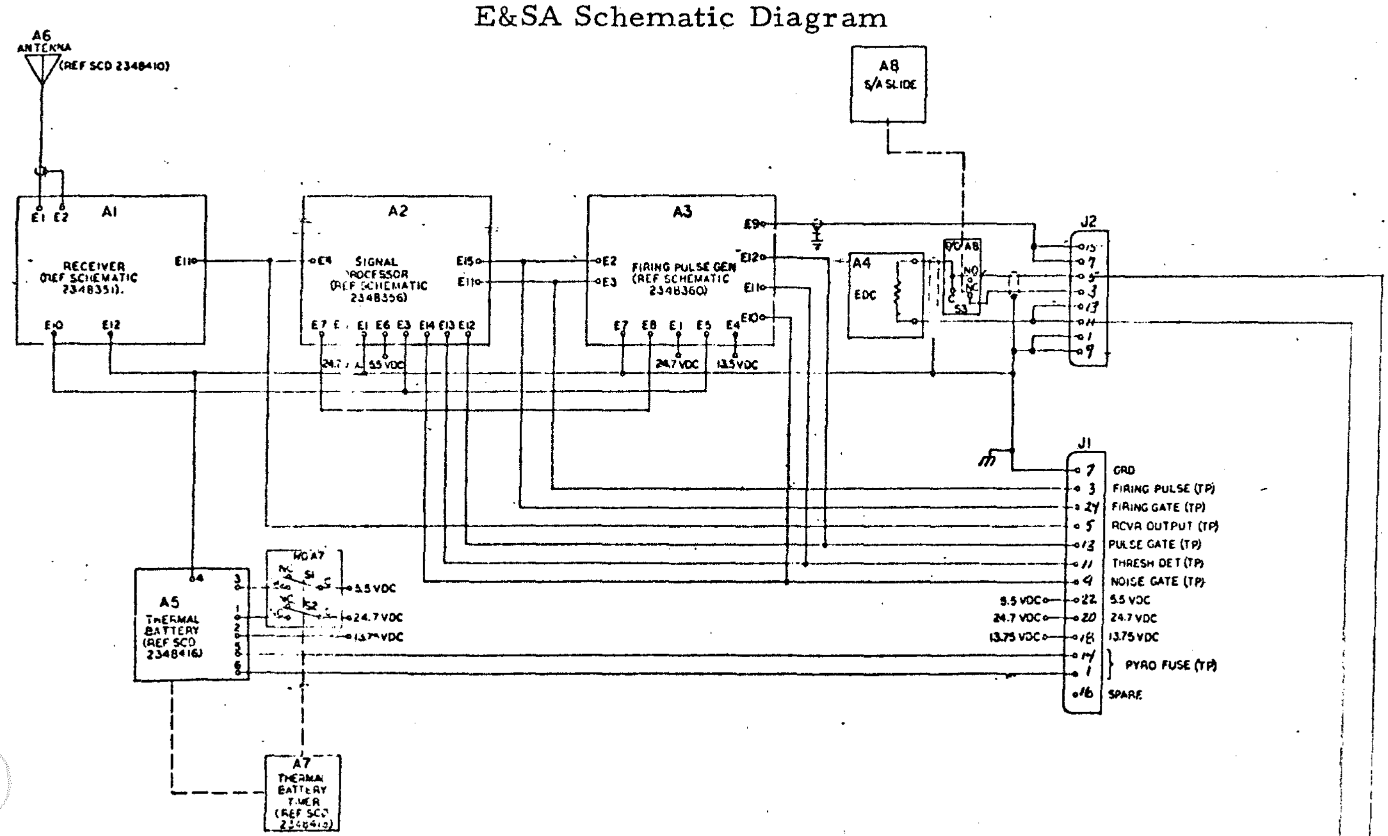


Figure 5.1 E&SA/ETS Connection

E&SA Schematic Diagram



AIRME Schematic Diagram

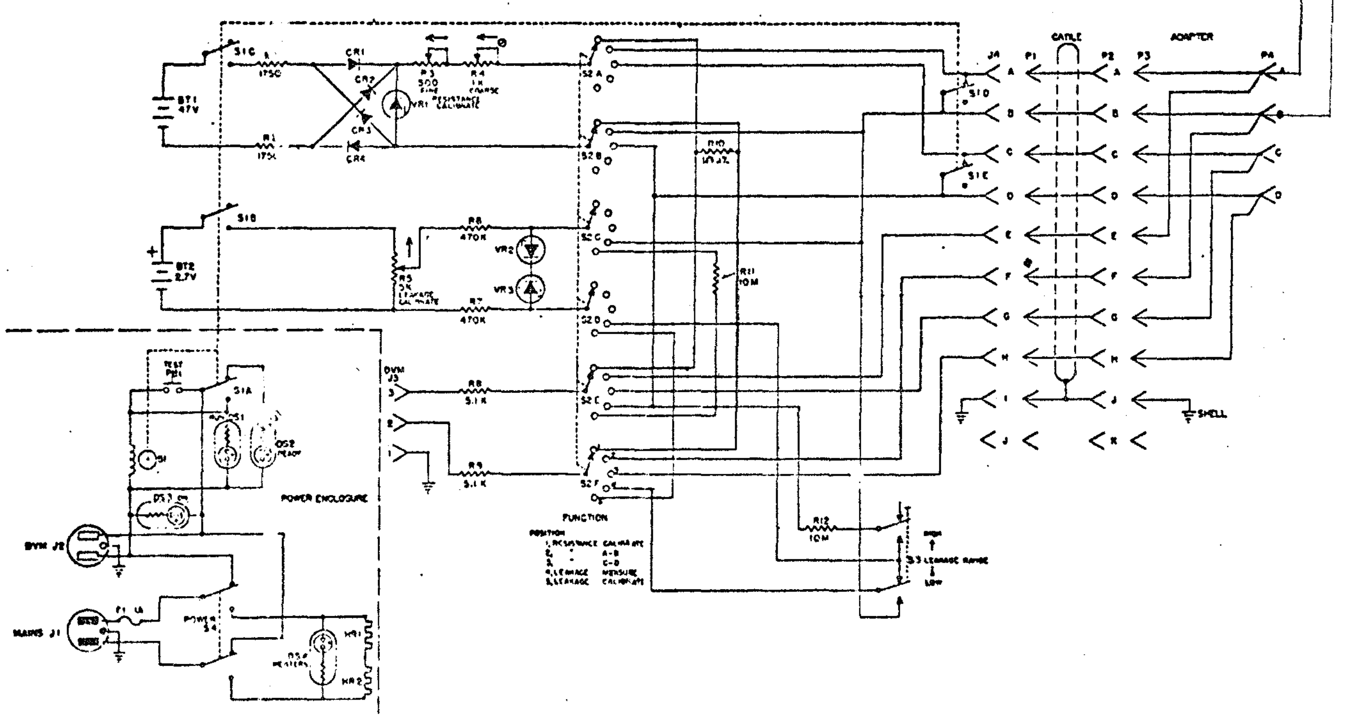


Figure 5.2 E&SA/AIRME Connection

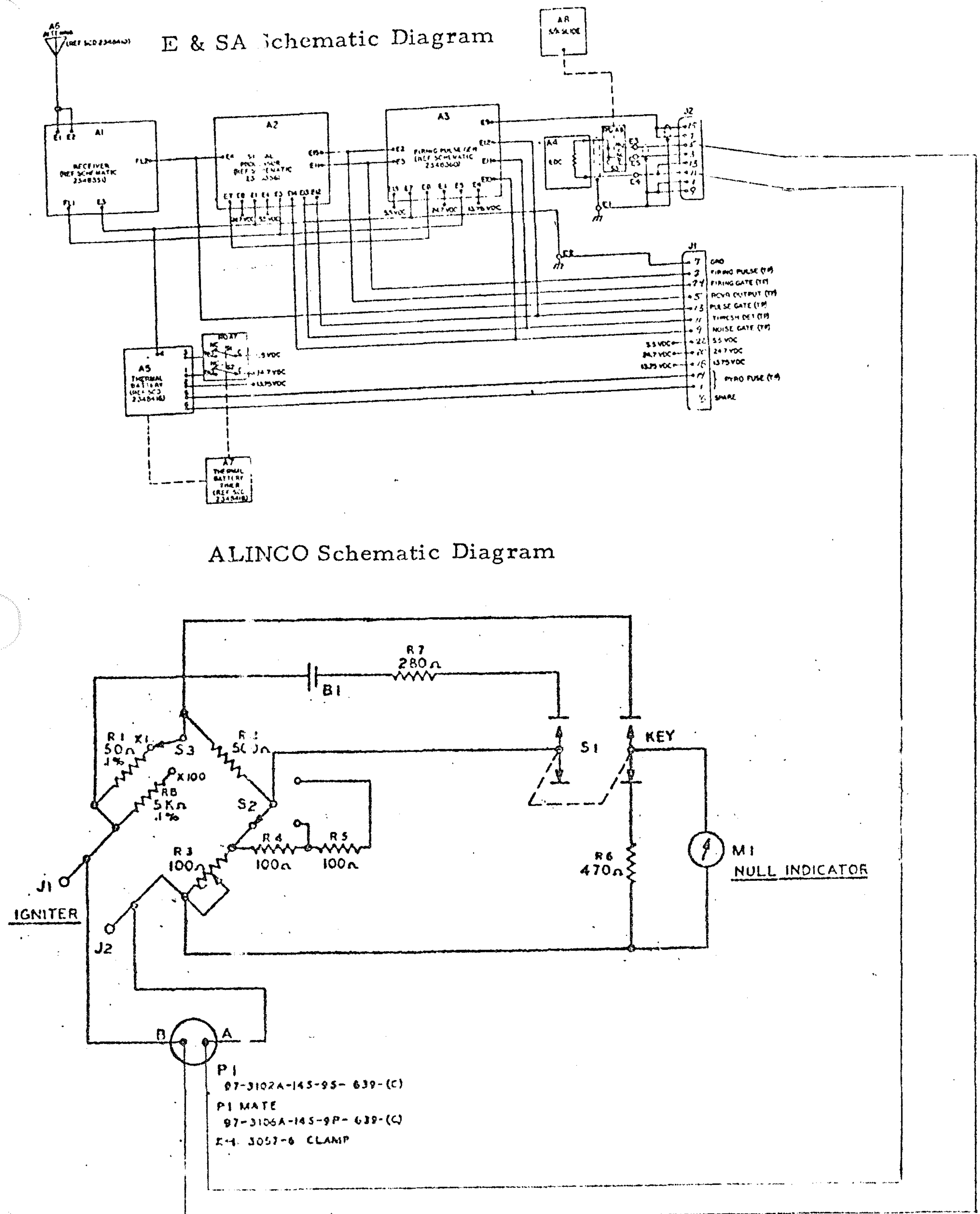


Figure 5.3 - E & SA/ALINCO Connection

6.0 SYSTEM SAFETY ANALYSIS

6.1 Introduction and Scope

This System Safety Analysis is provided in three sections; (1) A Fault Hazard Analysis (paragraph 6.3) which details the hazardous effects for component failure modes during the various phases of the mission, (2) The LSP-ETS Electronics and S/A Assembly Secondary Fault Hazard Analysis (paragraph 6.4) which details the LSP hazard effect for component failure modes within the Test Set during BxA in-house, WSTF, and KSC testing, and (3) The Operational Hazard Analysis (paragraph 6.5) which details all known hazards throughout the life cycle of the LSP Experiment. Figures 2.1, 2.2, 2.3, 3.1, and 4.1 are provided to clarify the hardware flow.

6.2 Summary and Conclusion

The Fault Hazard Analysis (ATM 1049) reveals three single point failure modes which are considered catastrophic or critical as defined in paragraph 6.3. These modes of failures are all related to premature or uncontrolled detonation of the main explosive charges. The probability of occurrence of such an event is extremely minute due to the nature of the HNS explosive.

The Secondary Fault Hazard Analysis has exposed one single-point failure mode which could result is a marginal hazard; this failure mode is an open circuit in the EDC grounding connection at the J2 connector. The hazard can be minimized through proper test set checkout procedures or eliminated with the use of an indicator which will allow the test conductor to be aware of the open circuit.

The Operational Hazard Analysis (ATM 1053) has exposed eleven hazards involved during; Manufacturing and Assembly, Handling and Transportation, Storage, Maintenance, Test and Lunar phases of the LSP Experiment.

6.3 Fault Hazard Analysis

Philosophy

The Fault Hazard Analysis is a systematic, hazard-identifying, analytical tool which requires a detailed investigation of the system to determine component failure modes, various causes of failures, and resultant effects or the safety of the system. The analysis is primarily a continuation and upgrade, from a safety standpoint, of the Reliability Failure Modes, Effects, and Criticality Analysis. The information provided in this analysis, when completed and properly associated with the system logic, serves as the basic fault input to the Fault Tree Analysis of Section 6.3.1.

Fault Hazard Analysis Form Explanation

- Item No. - Code number for the assembly, subassembly and components.
- (FMECA No.) - Code number of the related Failure Mode, Effects and Criticality Analysis.
- Part/Component - Nomenclature of the part, subassembly, or assembly.
- Failure Mode & Effect - Possible ways in which the item may fail and the effect of the failure on the system.
- Hazard Effect - A brief description of the safety hazards associated with the failure mode.
- Method of Detection - Means in which the failure mode may be detected in order to correct the failure and avoid the hazard.
- Corrective Action - Measure which can be taken in order to counteract or control the hazard.

- Crew Reaction Time - The time period beginning with initiation of the hazard and ending with removal of the hazard from the system. In this analysis N/A considers that no hazard exists for the failure mode.

- Hazard Classification

  Safety Catastrophic - Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction will cause death or injuries to personnel.

  Safety Critical - Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem or component malfunction will cause a hazard which requires immediate corrective action to avoid loss of or injury to personnel.

  Safety Marginal - Condition(s) such that environment, personnel error, design characteristics, procedural deficiencies, or subsystem failure or component malfunction will degrade system performance but which can be counteracted or controlled without major damage or any injury to personnel.

  Safety Negligible - Condition(s) such that personnel error, design characteristics, procedural deficiencies, subsystem failure, or component malfunction will not result in major systems degradations, and all not produce system functional damage or personnel injury.

- Mission Phase -

  A) Installation - The period ot time beginning with the equipment leaving KSC storage and ending after LM installation.

  B) Launch - The period of time beginning LM installation completion and ending with escape tower separation.

MISSION PHASE – A - INSTALLATION, B - LAUNCH, C - FLIGHT, D - LUNAR STAY

ALSEP ARRAY E

FAULT HAZARD ANALYSIS SHEET

DATE 8-16-71

PAGE ______

ITEM NO. [FMECA No.]	PART/COMPONENT	FAILURE MODE AND EFFECT	HAZARD EFFECT	METHOD OF DETECTION	CORRECTIVE ACTION	CREW REACTION TIME (τ)	HAZARD CLASSIFICATION
1.	Safe Arm Slide Timer Assy. (Timer No. 1)						
1.1	Watch Movement Subassembly						
1.1.1(A1)	"O"-Ring	N_2 leakage resulting in timer beat rate increase	A)B)C) None; Pull pins are not removed and watch movements do not operate during these phases. D) None; This condition is not considered critical as beat rate increase is insufficient to result in a safety problem during the lunar stay (see Bendix Report ATM-1038).	A)B)C) None D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.1.2(B1)	1st Pinion	Gear Tooth strippage resulting in loss of energy to the watch main spring.	A)B)C)D) None; the failure mode relates to winding of the watch movement which must be successfully accomplished prior to A).	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.1.3(B2)	Wheel Crown	Gear Tooth strippage resulting in loss of energy to the main spring.	A)B)C)D) None; Same as 1.1.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.1.4(B3)	First Wheel	Gear Teeth strippage resulting in loss of energy to the main spring.	A)B)C)D) None; Same as 1.1.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.1.5(B4)	Watch Mainspring	Structural failure resulting in loss of capability to store energy.	A)B)C)D) None; Same as 1.1.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible

MISSION PHASE –
A - INSTALLATION
B - LAUNCH
C - FLIGHT
D - LUNAR STAY

ALSEP ARRAY E

FAULT HAZARD ANALYSIS SHEET

DATE 8-16-71
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ITEM NO. (FMECA #)	PART/COMPONENT	FAILURE MODE AND EFFECT	HAZARD EFFECT	METHOD OF DETECTION	CORRECTIVE ACTION	CREW REACTION TIME (τ)	HAZARD CLASSIFICATION
1.1.6(B5)	Winding Wheel	Teeth strippage resulting in loss of energy transmission to the mainspring.	A)B)C)D) None; same as 1.1.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.2(C)	Control Subassembly						
1.2.1(C1)	O-Rings	Leakage allows oil (Synta-Viscolube) to evaporate which provides increased friction in the escapement resulting in timer stoppage.	A)B)C)D) None; fail-safe	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.2.2(C2)	Pawl	Tooth shear resulting in rapid drum movement speed-up.	A)B)C) None; Same as 1.1.1 D) None; Rapid timer movement will allow safe arm plate to travel to the resafe position prior to the activation of the thermal battery.	A)B)C) None D) Condition may be observed on the Safe/Arm indicator.	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.2.3(C3)	Link	Breakage resulting in timer stoppage	A)B)C) None; Same as 1.1.1 D) None; Timer stoppage results in a fail-safe condition.	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.2.4(C4)	Coupling Drive	Breakage resulting in timer stoppage	A)B)C) None; Same as 1.1.1 D) None; Same as 1.2.3	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.2.5(C5)	Actuator Clock	Shear or binding resulting in timer unable to start	A)B)C) None; Same as 1.1.2 D) None; Same as 1.2.3	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.2.6(C6)	Stem Control	Binding resulting in timer unable to start	A)B)C) None; Same as 1.1.2 D) None, Same as 1.2.3	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible

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1.3(D)	Timer Subassembly						
1.3.1(D1)	Timing Gear	Teeth strippage resulting in rapid movement of drum	A)B)C) None; Same as 1.1.1 D) None; Worst case rapid timer movement will cause the Safe Arm Plate to travel to the resafe position prior to the activation of the thermal battery.	A)B)C)D) None	A)B)C) D) None required	N/A	A)B)C)D) Negligible
1.3.2(D2)	Drum Mainspring	Structural failure resulting in energy loss and timer stoppage	A)B)C) None; Same as 1.1.1 D) None; Same as 1.2.3	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.3.3(D3)	Pull Ring No. 1 Retainer	Structural failure resulting in possible inadvertent loss of pull ring #1 and premature starting of timer	A)B)C) None; Premature starting of timer would release the Arming Pin; however, Safe Arm Plate would be held in the safe position with the Pull Ring No. 2. D) None; Premature time out & release of arming pin as described above would cause Safe/Arm Slide to lock up Pin #2 and prevent its removal	A) Visual B)C) None D) Inability to remove Pin #2	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.3.4	Escapement Wheel Shaft (Note: Added by BxA System Safety)	Structural failure resulting in timer speed-up	A)B)C) None; Same as 1.1.1 D) None; Worst case rapid movement will cause the Safe Arm Plate to travel to the resafe position prior to the activation of the thermal battery	A)B)C)D) None	A)B)C)D) None Required	N/A	A)B)C)D) Neglibible

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ITEM NO.	PART/COMPONENT	FAILURE MODE	HAZARD EFFECT	METHOD OF DETECTION	CORRECTIVE ACTION	CREW REACTION TIME (τ)	HAZARD CLASSIFI CATION
1.4(E)	Base Mounting (Arming and Safing Pin) Subassembly						
1.4.1(E1)	Arming Pin	Structural failure resulting in lock-up of arming pin	A)B)C)D1) None; Safe/Arm Plate is held in the safe position with Pull Ring Pin No. 2 D2) Negligible; Although the slide can move to the armed position, the charging circuit will remain inactive and encoded signal will neither be transmitted nor capable of being received	A)B)C) None D1) Pull Ring Pin #2 cannot be removed D2) Visual	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.4.2(E2)	Safing Pin	Structural failure resulting in premature movement of the Safe Arm Plate to the resafe position	A)B)C) None; Same as 1.1.1 D) None; Safe Arm Plate could never be in the armed position	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.4.3(E3)	Arming Pin Lock	Structural failure resulting in the Arming Pin to retract	A)B)C)D) None; Same as 1.4.1	A)B)C) None D) Pull Ring Pin #2 cannot be removed	A)B)C) None required D) Same as 1.4.1	N/A	A)B)C)D) Negligible
1.4.4(E4)	Safing Pin Lock	Structural failure resulting in premature movement of the Safe Arm Plate to the resafe position	A)B)C) None; Same as 1.1.1 D) None; Same as 1.4.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.4.5(E5)	Arm Lock Lever	Structural failure resulting in the Arming Pin to retract	A)B)C)D) None; Same as 1.4.1	A)B)C) None D-1) Pull Ring Pin #2 cannot be removed D-2) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.4.6(E6)	Arming Pin Latch	Structural failure resulting in the Arming Pin to retract	A)B)C)D) None; Same as 1.4.1	A)B)C) None D-1) Pull Ring Pin #2 cannot be removed D-2) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible

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1.4.7(E7)	Safing Pin Latch	Structural failure resulting in premature movement of the Safe Arm Plate to the resafe position	A)B)C) None; Same as 1.1.2 D) None; Same as 1.4.2	A)B)C)D) None	A)B)C) D) None required	N/A	A)B)C) D) Negligible
1.5(F)	Pull Ring No. 1 Pin Subassembly						
1.5.1(F1)	Pull Pin	Structural failure results in the inability to start timer	A)B)C) None; Same as 1.1.2 D) None; Safe Arm Plate cannot move to the armed position	A)B)C) None D) Visual examination of the Pull Pin Subassembly	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.5.2(F2)	Sleeve	Binding resulting in the inability to start timer	A)B)C) None; Same as 1.1.2 D) None; Safe Arm Plate cannot move to the armed position	A)B)C) None D) Visual examination of the Pull Pin Subassembly	A)B)C)D) None required	N/A	A)B)C)D) Negligible
1.5.3(F3)	Shear Pin (#24 AWG Buss Wire)	Shear pin fails after Pull (Safety) Pin has pulled clear of the drum	A)B)C) None; Same as 1.1.2 D) None; Timer is allowed to start although unknown to crew member. Crew member may decide not to remove Pull Pins No. 2 & 3 on an operative system.	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
2.0	Safe Arm Slide Assembly						
2.1	Pull Ring Pin No. 2	Structural failure resulting in an inoperative slide (Note: Inadvertent loss of pin has not been considered as a failure mode and left out due to the added safety feature of the 70°CCW turn in order to enable pin removal.)	A)B)C) None; Pull Ring Pins are not removed during these D) None; Safe Arm Plate cannot move to the armed position	A)B)C) None D) Visual inspection of Pull Ring Pin	A)B)C)D) None required	N/A	A)B)C)D) Negligible

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2.2	Safe Arm Plate	Binding resulting in the loss of capability of the slide to move to the armed position	A)B)C) None; Same as 1.1.1 D) None; Safe Arm plate will not move to the armed position	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
2.3	Booster Charge	Premature Detonation (Note: Although the nature of HNS-1 is extremely insensitive and the probability of a premature detonation is very remote, this failure mode is being considered from an analytical viewpoint. The failure mechanisms which could cause the failure mode are unknown at this time).	A) Booster will detonate the H. E. charge, resulting in probable fatality to personnel and sever damage to adjacent major subsystems B)C) Booster will detonate the H. E. charge resulting in probable catastrophic damage to the LM D) Booster will detonate the H. E. charge & expose LM & crew to a potentially catastrophic hazard	A) None B)C) Possible sensing from I. U. or during visual inspection of the LM D) None	A) None available B)C) Mission abort D) None available	A) Zero B)C) Worst Case would be prior to lunar landing and could be <1 minute D) Zero	A) Catastrophic B)C) Critical D) Catastrophic
2.4	Slide Spring	Structural failure resulting in the loss of capability of the slide to move to the armed position	A)B)C)D) None; Same as 2.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.0	Thermal Battery Timer Assembly (Timer No. 2)						

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3.1(A&B)	Watch Movement Subassembly						
3.1.1(A1)	O-Ring	Leakage resulting in timer beat rate speed-up	A)B)C) None; Pull pins are not removed and watch movements do not operate during these phases. D) None; This condition is not considered critical as beat rate increase is insufficient to result in a safety problem during the lunar stay (see Bendix Report ATM-1038).	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.1.2(B1)	First Pinion	Gear tooth strippage resulting in loss of energy to the watch mainspring	A)B)C)D) None; Same as 1.1.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.1.3(B2)	Crown Wheel	Gear tooth strippage resulting in loss of energy to the main-spring	A)B)C)D) None; Same as 1.1.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.1.4(B3)	First Wheel	Gear teeth strippage resulting in loss of energy to the main-spring	A)B)C)D) None; Same as 1.1.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.1.5(B4)	Watch Mainspring	Structural failure resulting in loss of capability to store energy	A)B)C)D) None; Same as 1.1.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.1.6(B5)	Winding Wheel	Teeth strippage resulting in loss of energy transmission to the mainspring	A)B)C)D) None; Same as 1.1.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible

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3.2(C)	Control Subassembly						
3.2.1(C1)	O-Rings	Leakage allows oil (Synta-Viscolube) to evaporate which provides increased friction in the escapement resulting in timer stoppage	A)B)C)D) None; Same as 1.1.2	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.2.2(C2)	Pawl	Tooth shear resulting in rapid drum movement speed-up	A)B)C) None; Same as 1.1.2 D) None; Rapid timer movement will allow premature Thermal battery activation; however, Timer No. 1 would not allow the Safe Arm Plate to be in the armed position prematurely and EDC will not have received a firing pulse prematurely.	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.2.3(C3)	Link	Breakage resulting in timer stoppage	A)B)C) None; Same as 1.1.2 D) None; Same as 1.2.3	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.2.4(C4)	Coupling Drive	Breakage resulting in timer stoppage	A)B)C) None; Same as 1.1.2 D) None; Same as 1.2.3	A)B)C)D) None	A)B)C)D) None required	N/A	A)BC)D) Negligible
3.2.5(C5)	Actuator Clock	Shear or Binding resulting in timer unable to start	A)B)C) None; Same as 1.1.2 D) None; Same as 1.2.3	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.2.6(C6)	Stem Control	Binding resulting in timer unable to start	A)B)C) None; Same as 1.1.2 D) None; Same as 1.2.3	A)B)C)D) None	A)B) C)D) None required	N/A	A)B)C)D) Negligible

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ITEM NO. (FMECA #)	PART/COMPONENT	FAILURE MODE AND EFFECT	HAZARD EFFECT	METHOD OF DETECTION	CORRECTIVE ACTION	CREW REACTION TIME (r)	HAZARD CLASSIFICATION
3.3(D)	Timer Subassembly						
3.3.1(D1)	Timing Gear	Teeth strippage resulting in rapid movement of the drum	A)B)C) None; Same as 1.1.1 D) None; Same as 1.3.1	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C) D) Negligible
3.3.2(D2)	Drum Mainspring	Structural failure resulting in energy loss and timer stoppage	A)B)C) None; Same as 1.1.2 D) None; Same as 1.2.3	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.3.3(D3)	Pull Ring No. 3 Retainer Spring Clip	Structural failure resulting in possible inadvertent loss of the timer No. 2 Pull Pin and prematurely starting the timer	A)B)C) None; Premature starting of the timer would allow the Thermal Battery Firing Pin Mechanism to be activated. However, the Safety Pin between the Firing Pin Mechanism and the Thermal Battery would not allow activation of the Thermal Battery. D) None; Firing Pin would lock-up on its pull pin resulting in the inability to release the complete Pull Ring No. 3 Subassembly	A) Visual B)C) None D) Visual	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.4(E)	Base Mounting (Firing Pin Mechanism Subassembly)						
3.4.1(E1)	Firing Pin Body	Binding resulting in the inability to activate the Thermal Battery	A)B)C) None; Pull Ring Pin #3 is not pulled during these phases and firing pin is not allowed to activate Thermal Battery D) None; Thermal Battery cannot be activated	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible

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3.4.2(E2)	Firing Pin Tip	Structural failure resulting in the inability to activate the Thermal Battery	A)B)C)D) None; Same as 3.4.1	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.4.3(E3)	Firing Pin Spring	Structural failure resulting in loss of spring force and the inability to activate the thermal battery	A)B)C)D) None; Same as 3.4.1	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.4.4(E4)	Thermal Battery Switch	A) Open failure resulting in the inability of the Thermal Battery to charge the Signal Processor and Firing Pulse Generator	A)B)C) None; Same as 3.4.1 D) None; EDC cannot be detonated	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
		B) Closed failure resulting in the ability of the Battery to charge the Signal Processor and Firing Pulse Generator	A)B)C)D) None; Thermal Battery cannot be activated until the Firing Pin Mechanism has been fired. This would result in multiple failures for this condition to be a hazard	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.4.5(E5)	Switch Actuator	Bending resulting in the inability to allow the Thermal Battery Switch to close	A)B)C)D) None; Same as 3.4.4A	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.4.6(E6)	Switch Actuator Pin	Structural failure resulting in the inability to allow the Thermal Battery Switch to close	A)B)C)D) None; Same as 3.4.4A	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible

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3.4.7(E7)	Firing Pin Lock	Structural failure resulting in lock-up of the Pull Ring Pin No. 3	A)B)C)D) None; Pull Ring Pin No. 3 is not removed during these phases and Firing Pin will be locked up on the firing pin safety pin	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
		Structural Failure after Pull Ring has been removed	A)B)C)D1)None - D2) Negligible; Thermal Battery will fire and charge firing circuit. Safe/Arm Slide remains in "safe" position and encoded signal will not be transmitted.	A)B)C)D1)D2) None	A)B)C)D1)D2) None required	N/A	A)B)C)D1) D2) Negligible
3.4.8(E8)	Firing Pin Latch	Structural failure resulting in premature release of the Firing Pin	A)B)C)D) None; Same as 3.4.7	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.4.9(E9)	Latch Shaft Dowel Pin	Structural failure resulting in premature release of the Firing Pin	A)B)C)D) None; Same as 3.4.7	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.5(F)	Pull Ring Pin (Timer) No. 3 Subassembly						
3.5.1(F1)	Pull Pin (Timer Mechanism)	Structural failure resulting in the inability to start the Thermal Battery Timer	A)B)C) None; Same as 1.1.2 D) None; Timer cannot operate resulting in a fail-safe condition	A)B)C) None D) Visual examination of the Pull Pin Assembly	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.5.2(F2)	Sleeve	Binding resulting in Pull Pin remaining in position and the inability to start the Thermal Battery Timer	A)B)C)D) None; Same as 3.5.1	A)B)C) None D) Visual examination of the Pull Pin Subassembly	A)B)C)D) None required	N/A	A)B)C)D) Negligible

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3.5.3(F3)	Shear Pin (#24 AWG Buss Wire)	Shear Pin fails after Pull (Safety) Pin has pulled sufficiently to start the Timer	A)B)C) None; Same as 1.1.2 D) None; System is operating correctly and safely; however, crew member is unaware of this condition	A)B)C)D) None	A)B)C) D) None required	N/A	A)B)C) D) Negligible
3.6(G)	Pull Ring Pin (Firing Pin) No. 3 Subassembly						
3.6.1(G1)	Pull Pin	Structural failure resulting in the inability to activate the Thermal Battery	A)B)C)D) None; Same as 3.5.1	A)B)C) None D) Visual examination of the Pull Ring Subassembly	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.6.2(G2)	Sleeve	Binding resulting in Pull Pin remaining in position and the inability to activate the Thermal Battery	A)B)C)D) None; Same as 3.5.1	A)B)C) None D) Visual examination of the Pull Ring Subassembly	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.6.3(G3)	Shear Pin (#24 AWG Buss Wire)	Shear Pin fails after Pull (Safety) Pin has pulled clear of Firing Pin	A)B)C) None; Same as 1.1.2 D) None; Same as 3.5.3	A)B)C)D) None	A)B)C)D) None required	N/A	A)B)C)D) Negligible
3.7	Thermal Battery Subassembly	Premature Voltage output	A)B)C)D) None; Voltage output is stopped at the open contacts of the Thermal Battery Timer Switch; therefore, 24VDC and 5VDC cannot be supplied to the EDC and signal processor	A)B)C)D) None	A)B)C) D) None required	N/A	A)B)C)D) Negligible

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3.8	End Detonating Charge (EDC) Subassembly	Premature Detonation (Although the HNS-I is extremely insensitive and the probability of a premature detonation is very remote, (though Lead Azide is relatively more sensitive to shock and static electricity) this failure mode is being considered from an analytical viewpoint. The failure mechanisms which could cause the failure mode are unknown at this time.)	A) Possible severe injury to personnel while handling B)C) None; the Safe Arm Slide will remain in the safe position and detonation of the EDC alone is not considered sufficient to be destructive to adjacent equipment. D) Possible damage to the crew members' life support equipment (worst case during LSP deployment) resulting in crew member(s) fatality	A) None B)C) None D) None	A) None available B)C) None required D) None available	Zero N/A N/A	A) Catastrophic B)C) Negligible D) Catastrophic
3.9	High Explosive (H.E.) Charge Subassembly (HNS-II)	Premature detonation (Note: Although the nature of HNS-II is extremely insensitive and the probability of a premature detonation is very remote, this failure mode is being considered from an analytical viewpoint and the failure mechanisms which could cause the failure mode are unknown at this time.)	A) High explosive detonation would result in probable fatality to personnel and possibly damage adjacent equipment B)C) High explosive detonation would result in probable severe damage to the LM D) High explosive detonation would result in catastrophic crew member fatality	A) None B)C) Possible sensing from the I. U. or during visual L[illegible] inspection D) None	A) None available B)C) Mission abort D) None available	Zero B)C) Worst case would be prior to lunar landing and could be <1 minute D) Zero	A) Catastrophic B)C) Critical D) Catastrophic

C) Flight - The period of time beginning with escape tower separation and ending with lunar touchdown.

D1) Lunar Stay - The period of time beginning with lunar touchdown and ending with the ALSEP deployment sequence.

D2) Lunar Stay - The period of time beginning with ALSEP deployment sequence and ending with lunar lift-off.

6.3.1 Fault Tree Analysis

Introduction

This section presents a graphic display of essentially all combinations of malfunctions of the ALSEP Array E which will logically lead to a crew fatality or incapacitating injury. It conforms to the methodology established by the Boeing Company in D2-1118195-1, "Guidelines for Apollo Spacecraft Logic Diagram Analysis" for consistency within the Apollo Program.

Philosophy

The Fault Tree Analysis (Figures 6.1a - 6.1h) is a logical combination of functional fault events which can lead a path to a top undesired event or potential hazard. Each of the contributing fault events are further analyzed to determine the logical relationships of system faults which may cause them. In this manner, a diagram of logical relationship among fault events is developed and identify the basic faults which may cause the top undesired event. Capability has been maintained to adopt the fault tree to a quantative evaluation of the level of safety attained in the LSP, if desired.

Logic Definitions and Symbols

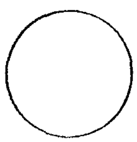
Events

a. An "Event" is a system failure resulting from one or more contributing factors. These factors are due to either failures or malfunctions of an item of hardware, or of a subsystem.

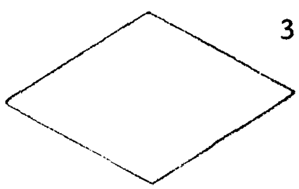
b. The symbols used to represent the various events are:

1. An event, (usually a fault or malcondition) resulting from multiple input events through a logic gate, expressed in functional terms.

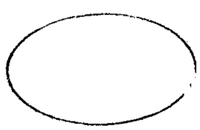
   It also represents a conditional input to an Inhibit Gate -- a condition that is assumed to exist for the life of the system. In this context, if an input event occurs, the condition is satisfied, and an output event is generated; if the condition is not satisfied, no output occurs.



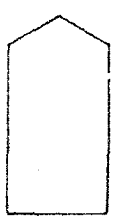
2. An "independent" event, arising from the failure of a basic hardware component; i. e., a basic fault event that requires no further development.



3. A fault event that is considered basic in a given logic diagram. The possible causes of the event are not developed either because the event is of insufficient consequence, or because the necessary information for further development is unavailable.



4. An event which describes a conditional input to any Gate. It defines the state of the system that permits or prevents occurrence of a fault. The condition may be either normal to the system, or may result from failures.



5. An event that is normally expected to occur, i. e., it does not represent a fault. An example is a phase change in a dynamic system, such as the takeoff, flight and landing phase of an aircraft flight.

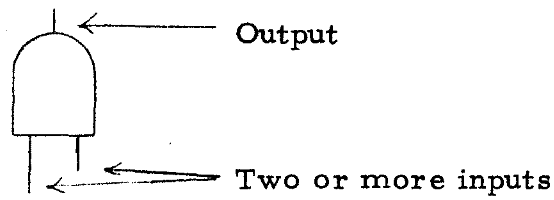
Gates

a. Gates are the decision elements of the logic diagram. Inputs to a gate always enter at the bottom; outputs always emanate from the top. In this manner, all event sequences move upward through the braches toward the top of the fault tree.

b. The symbols used to represent the various gates are:

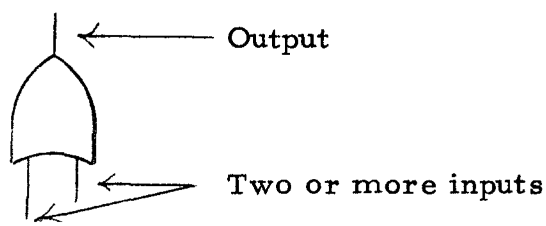
1. "AND" Gates

The "AND" gate is the logic function which requires the coexistence of all the input events in order to produce the output event.



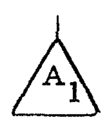
2. "OR" Gates

The "OR" gate is the logic function which requires the existence of only one of the input events to produce the output event.

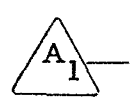


Transfer Symbols

a. A sequence of events to be transferred is denoted as follows:



b. The location to which the sequence of events are transferred is denoted as follows:



ALSEP Array E LSP Experiment Fault Tree Logic Diagram

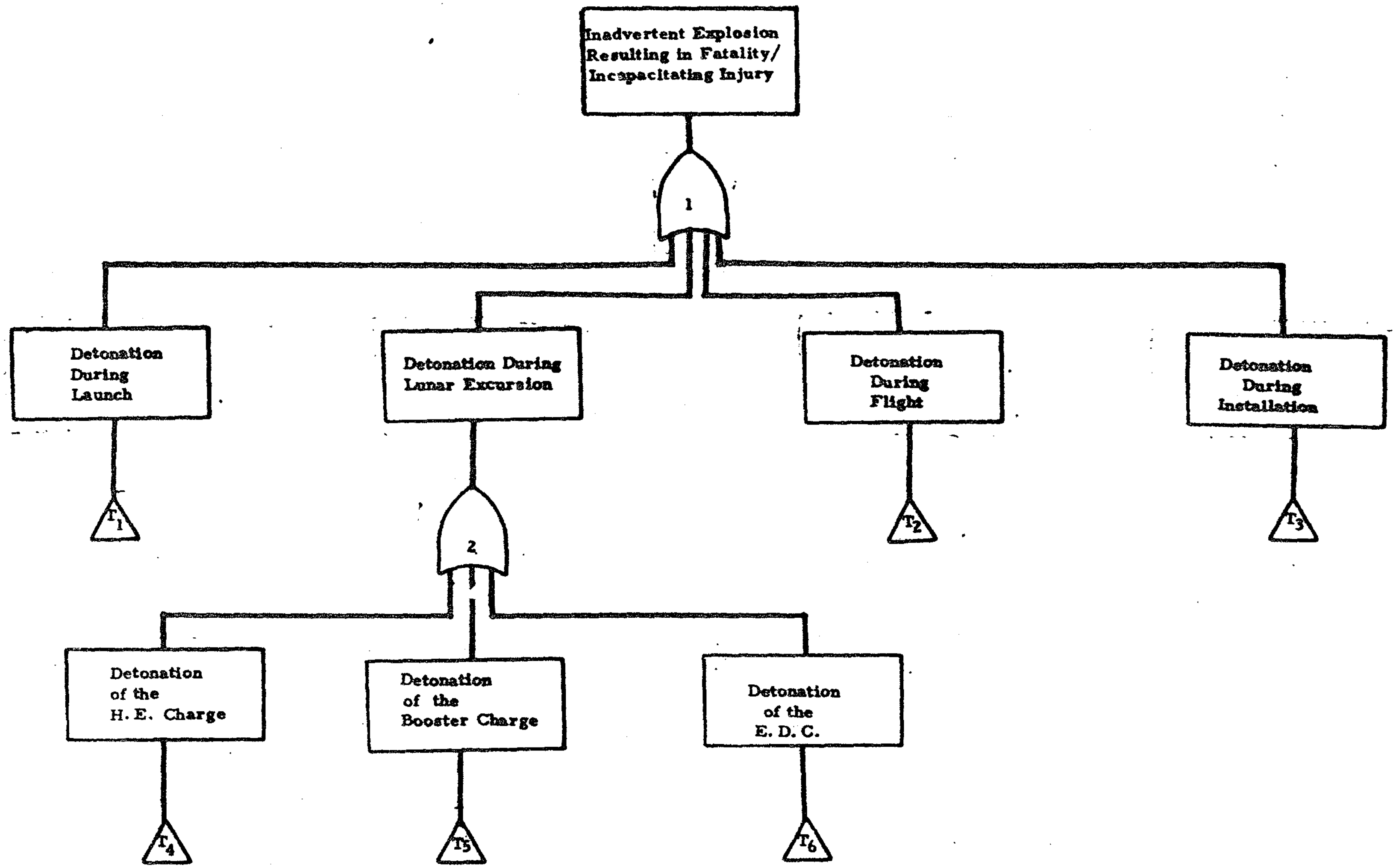
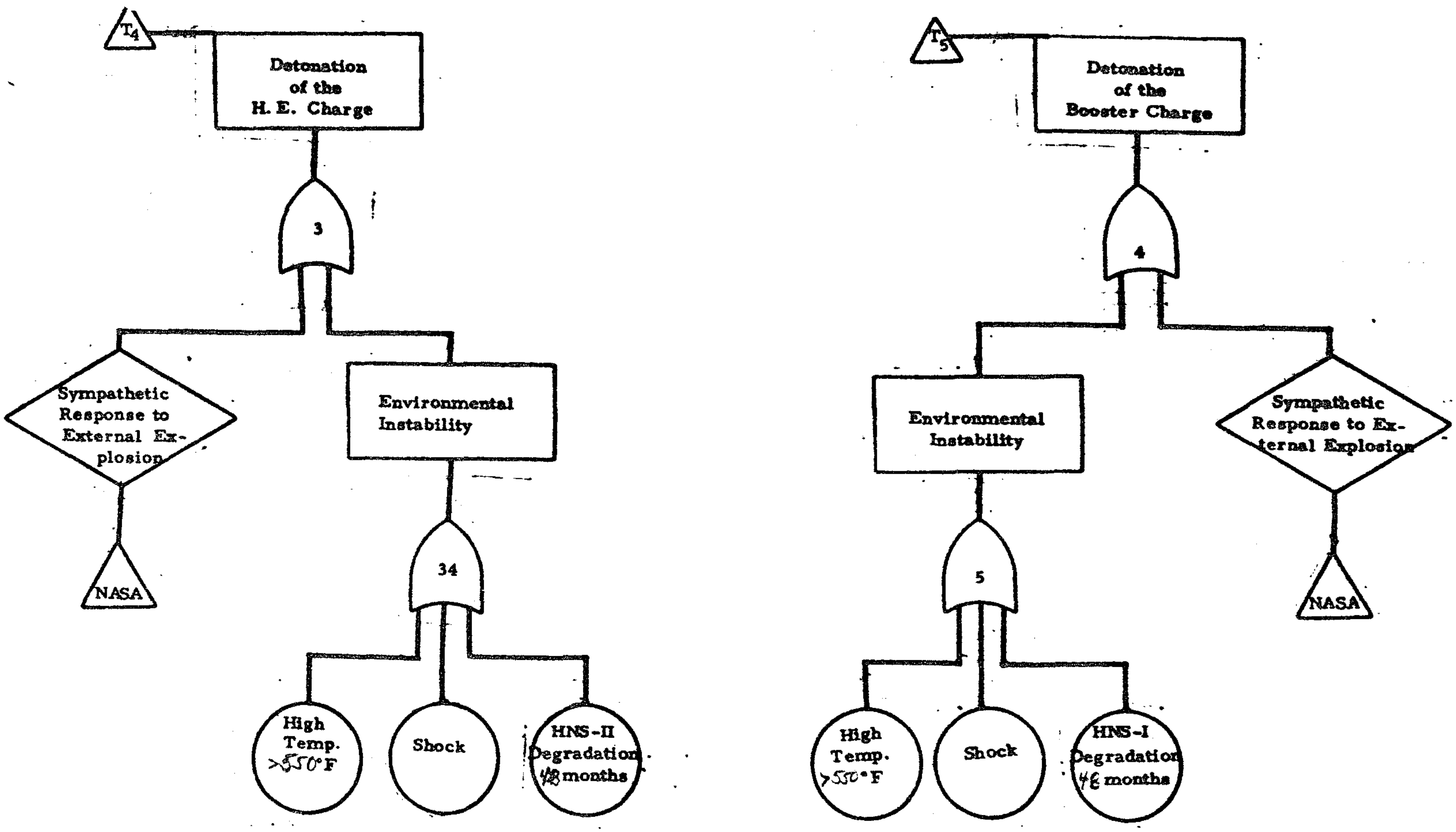


Figure 6.1a



T4
Detonation of the H. E. Charge
3
Sympathetic Response to External Explosion
Environmental Instability
NASA
34
High Temp. >550°F
Shock
HNS-II Degradation 48 months
T5
Detonation of the Booster Charge
4
Environmental Instability
Sympathetic Response to External Explosion
5
NASA
High Temp. >550°F
Shock
HNS-I Degradation 48 months

Figure 6.1b

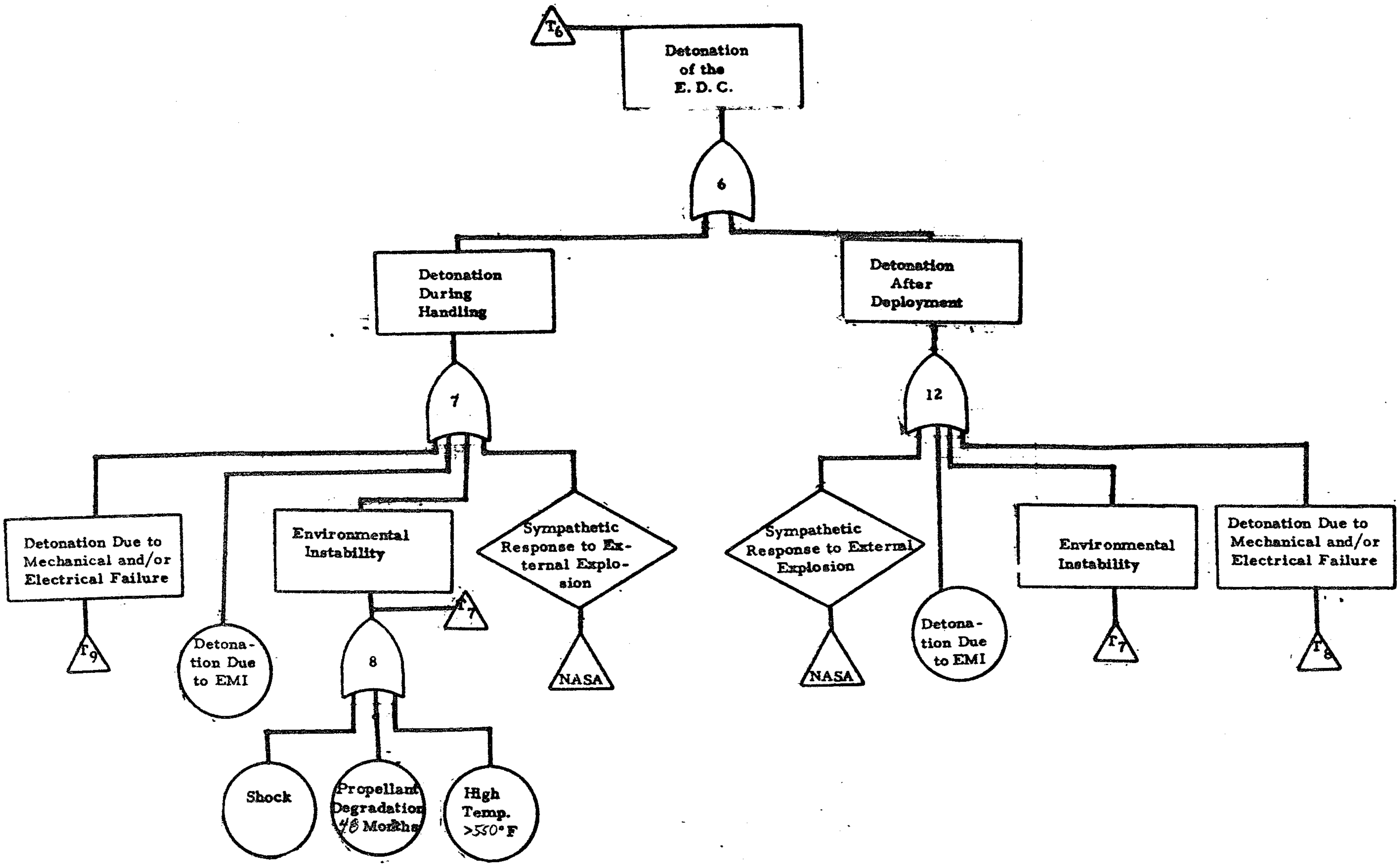

T6
Detonation of the E. D. C.
6
Detonation During Handling
Detonation After Deployment
7
12
Detonation Due to Mechanical and/or Electrical Failure
T9
Detona- tion Due to EMI
Environmental Instability
T7
8
Shock
Propellant Degradation 48 Months
High Temp. >550°F
Sympathetic Response to External Explosion
NASA
Sympathetic Response to External Explosion
NASA
Detona- tion Due to EMI
Environmental Instability
T7
Detonation Due to Mechanical and/or Electrical Failure
T8

Figure 6.1c

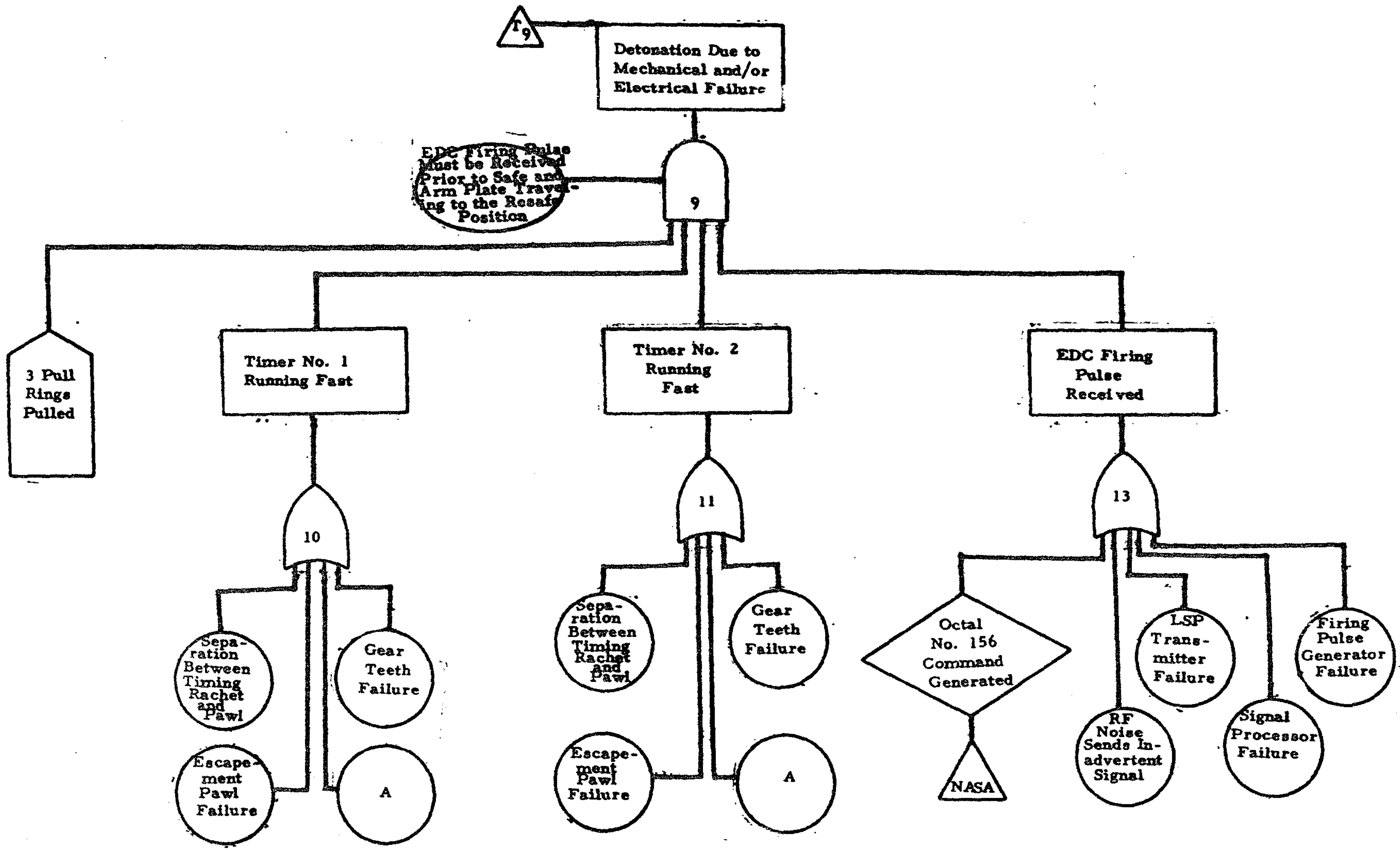
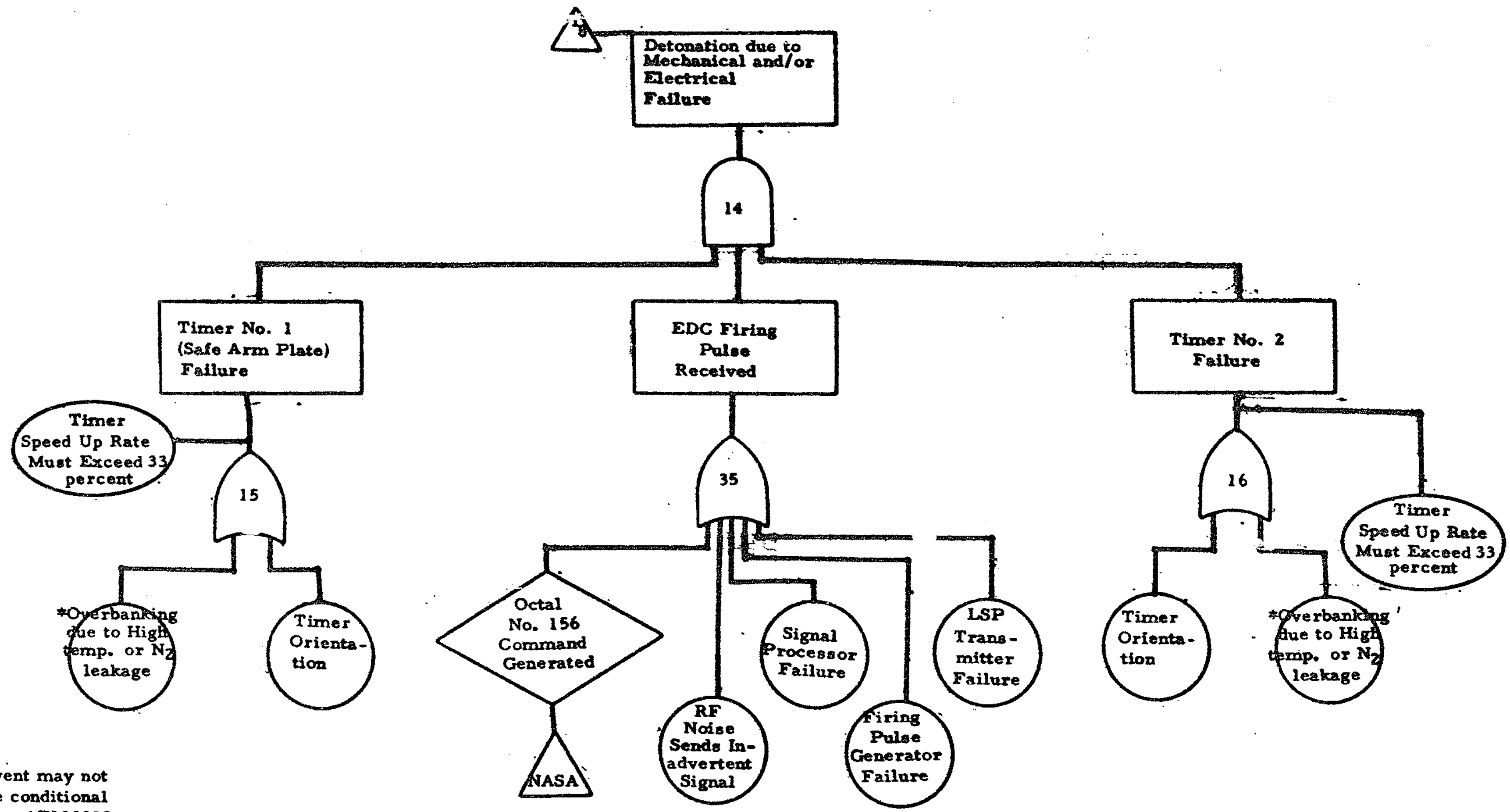

T9
Detonation Due to Mechanical and/or Electrical Failure
EDC Firing Pulse Must be Received Prior to Safe and Arm Plate Traveling to the Resafe Position
9
3 Pull Rings Pulled
Timer No. 1 Running Fast
Timer No. 2 Running Fast
EDC Firing Pulse Received
10
11
13
Separation Between Timing Rachet and Pawl
Gear Teeth Failure
Escapement Pawl Failure
A
Separation Between Timing Rachet and Pawl
Gear Teeth Failure
Escapement Pawl Failure
A
Octal No. 156 Command Generated
NASA
RF Noise Sends Inadvertent Signal
LSP Transmitter Failure
Signal Processor Failure
Firing Pulse Generator Failure

Figure 6.1d



*This event may not meet the conditional input. See ATM 1038.

Figure 6.1e

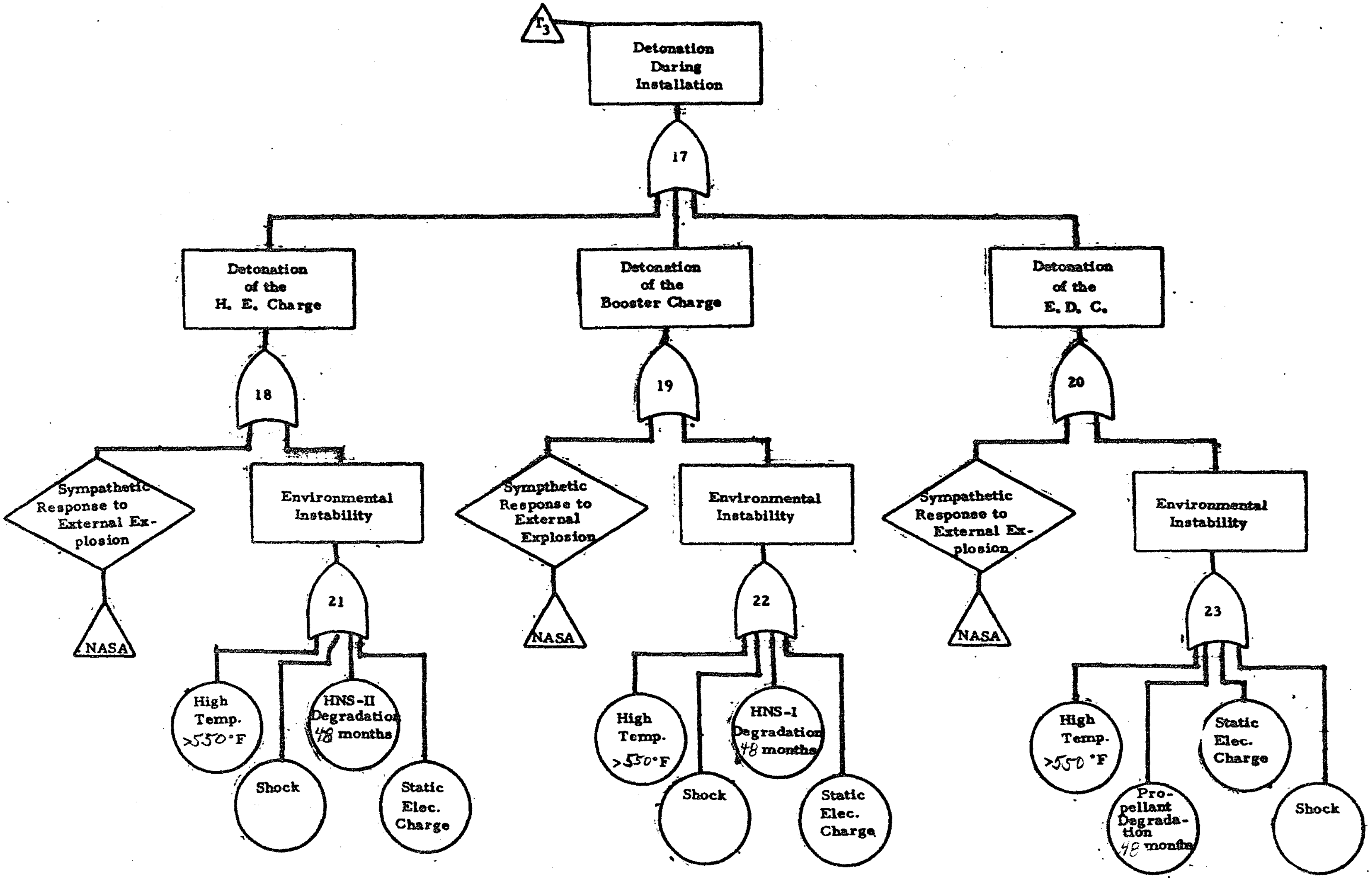
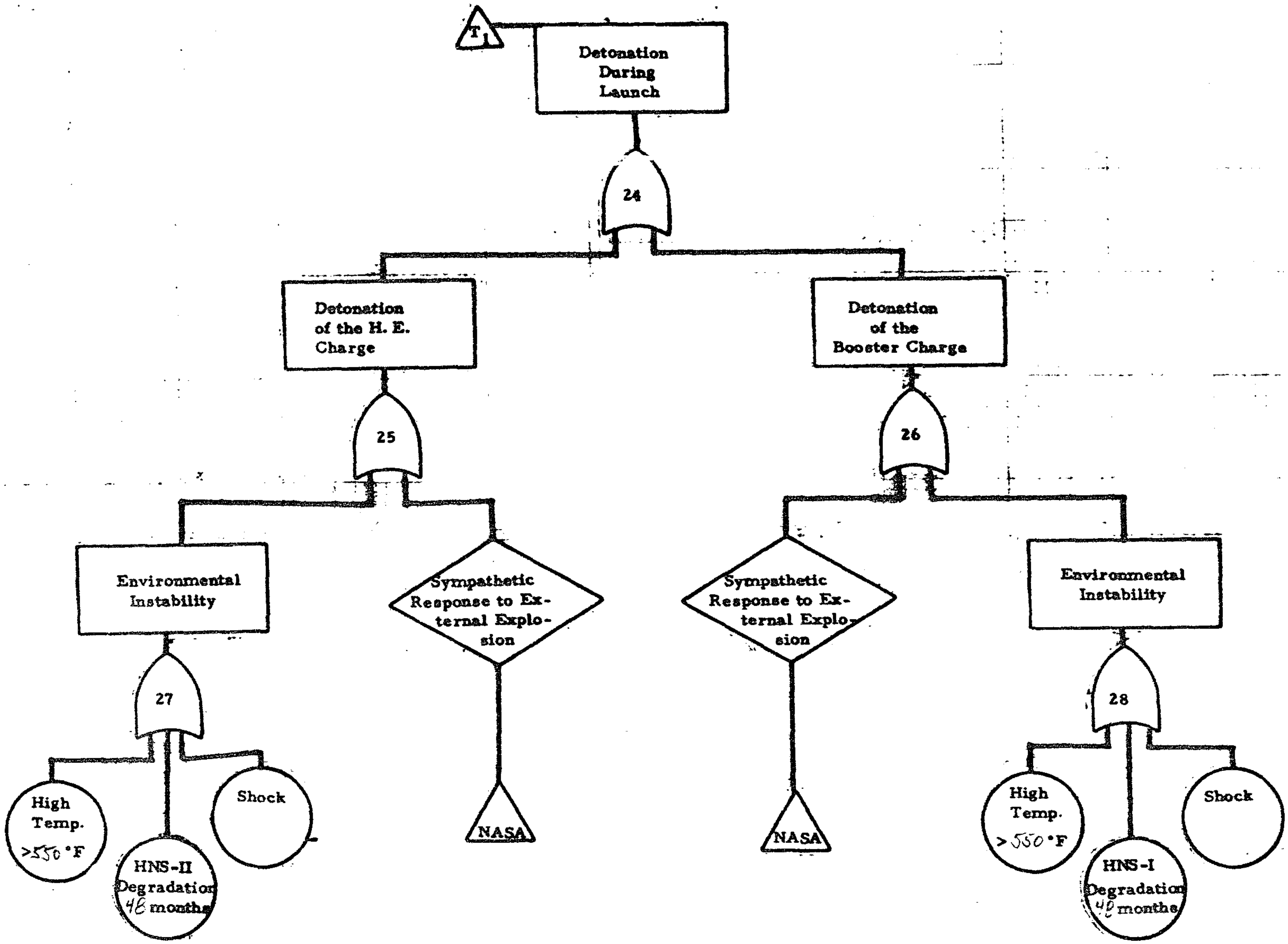
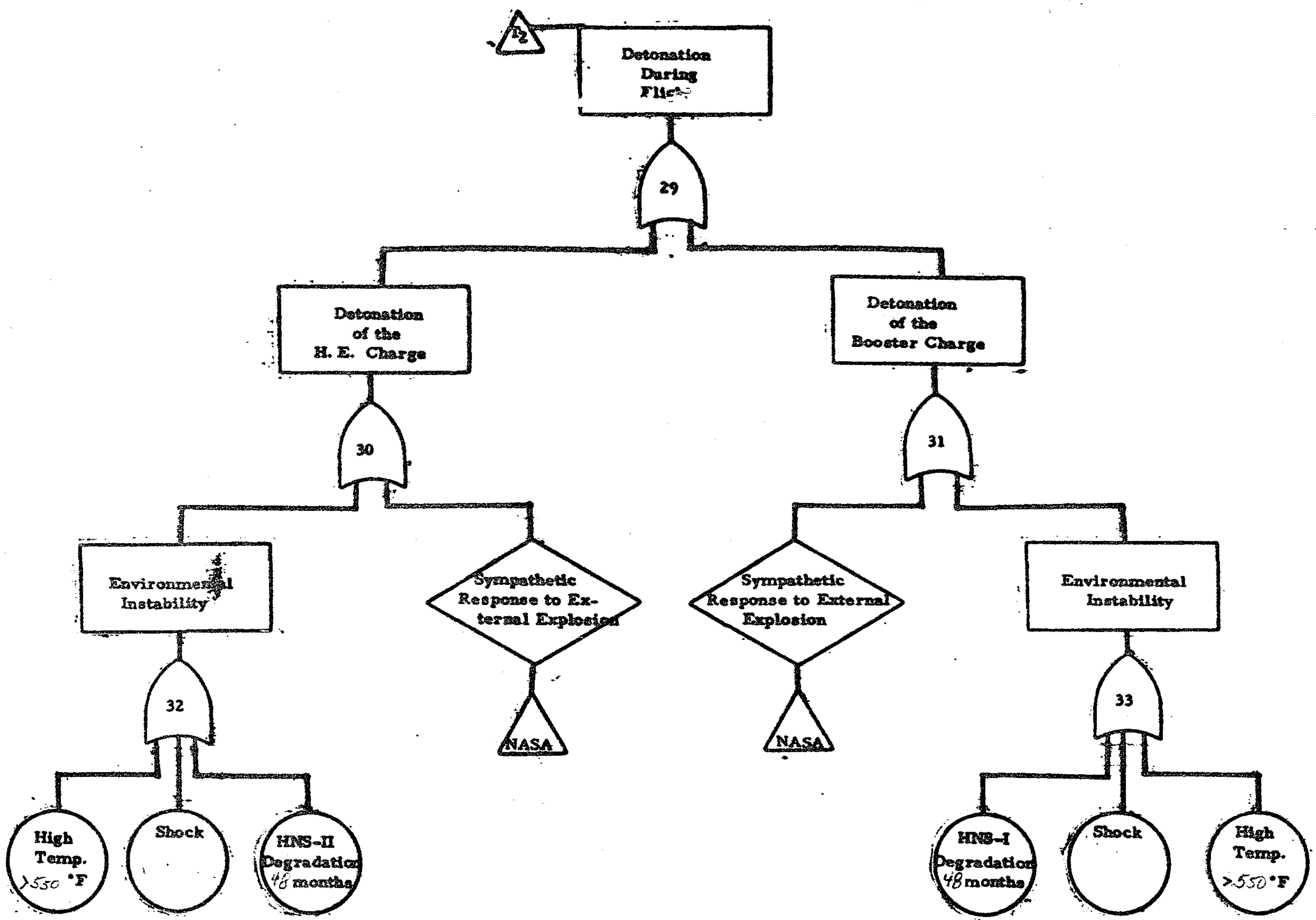

T3
Detonation During Installation
17
Detonation of the H. E. Charge
Detonation of the Booster Charge
Detonation of the E. D. C.
18
19
20
Sympathetic Response to External Explosion
Environmental Instability
Sympthetic Response to External Explosion
Environmental Instability
Sympathetic Response to External Explosion
Environmental Instability
NASA
21
NASA
22
NASA
23
High Temp. >550°F
Shock
HNS-II Degradation 48 months
Static Elec. Charge
High Temp. >550°F
Shock
HNS-I Degradation 48 months
Static Elec. Charge
High Temp. >550°F
Propellant Degradation 48 months
Static Elec. Charge
Shock

Figure 6.1f



T1
Detonation During Launch
24
Detonation of the H. E. Charge
Detonation of the Booster Charge
25
26
Environmental Instability
Sympathetic Response to External Explosion
Sympathetic Response to External Explosion
Environmental Instability
27
28
High Temp. >550°F
HNS-II Degradation 48 months
Shock
NASA
NASA
High Temp. >550°F
HNS-I Degradation 48 months
Shock

Figure 6.1g



T2
Detonation During Flight
29
Detonation of the H. E. Charge
Detonation of the Booster Charge
30
31
Environmental Instability
Sympathetic Response to External Explosion
Sympathetic Response to External Explosion
Environmental Instability
32
NASA
NASA
33
High Temp. >550 °F
Shock
HNS-II Degradation 48 months
HNS-I Degradation 48 months
Shock
High Temp. >550 °F

Figure 6.1h

6.4 Secondary Fault Hazard Analysis Interpretation

Analysis Description

This analysis is based upon the BxA Test Set (Figure 6-2) which is similar to the deliverable test set with the following exceptions:

(1) The deliverable test set has 3 separate power supplies as shown in Figure 6-3 which is designated PS 1, PS 2, and PS 3, and

(2) The deliverable test set has an RF Generator circuit which provides a processed signal to the explosive package

Form Description

- Part I.D. No. - Reference designator of an item
- Part/Circuit Nomenclature - Name of the part on circuit under analysis
- Failure Mode - Possible ways in which an item may fail
- E&S/A Test Set Hazard Effect - A brief description of the safety hazards within the Test Set associated with the failure mode.
- LSP Hazard Effect - A brief description of the safety hazards involved in the LSP associated with the failure mode.
- Corrective Action - Measure which can be taken in order to counteract or control the hazard.
- Detection Method Indicator - Available indications which will display the existence of the failure.
- Hazard Classification - Same as Paragraph 6.3.

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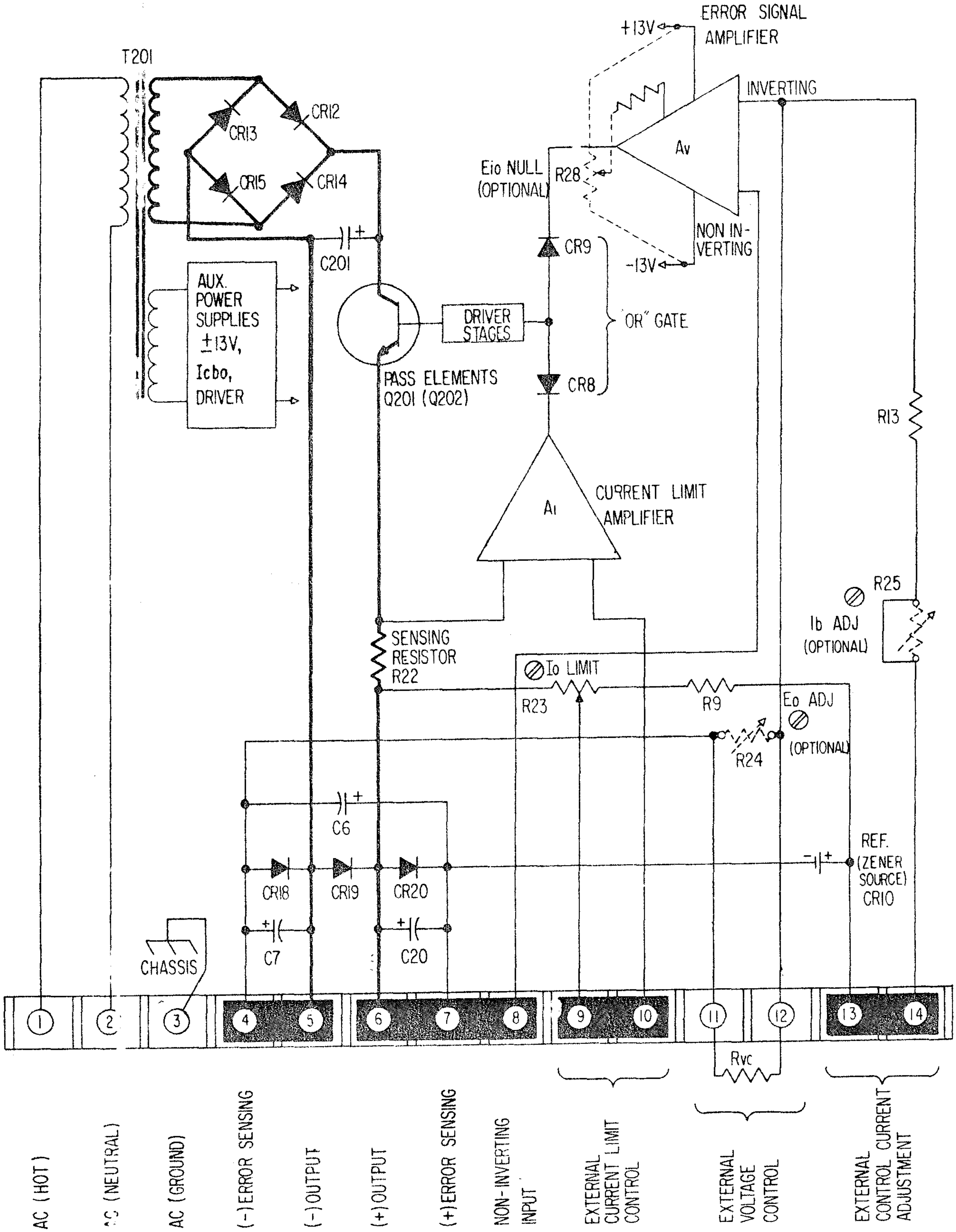

POWER SUPPJY, SIMPLIFIED DIAGRAM

Figure 6.3

CONNECTION DIAGRAM, EXPLOSIVE PACKAGE ELECTRONICS

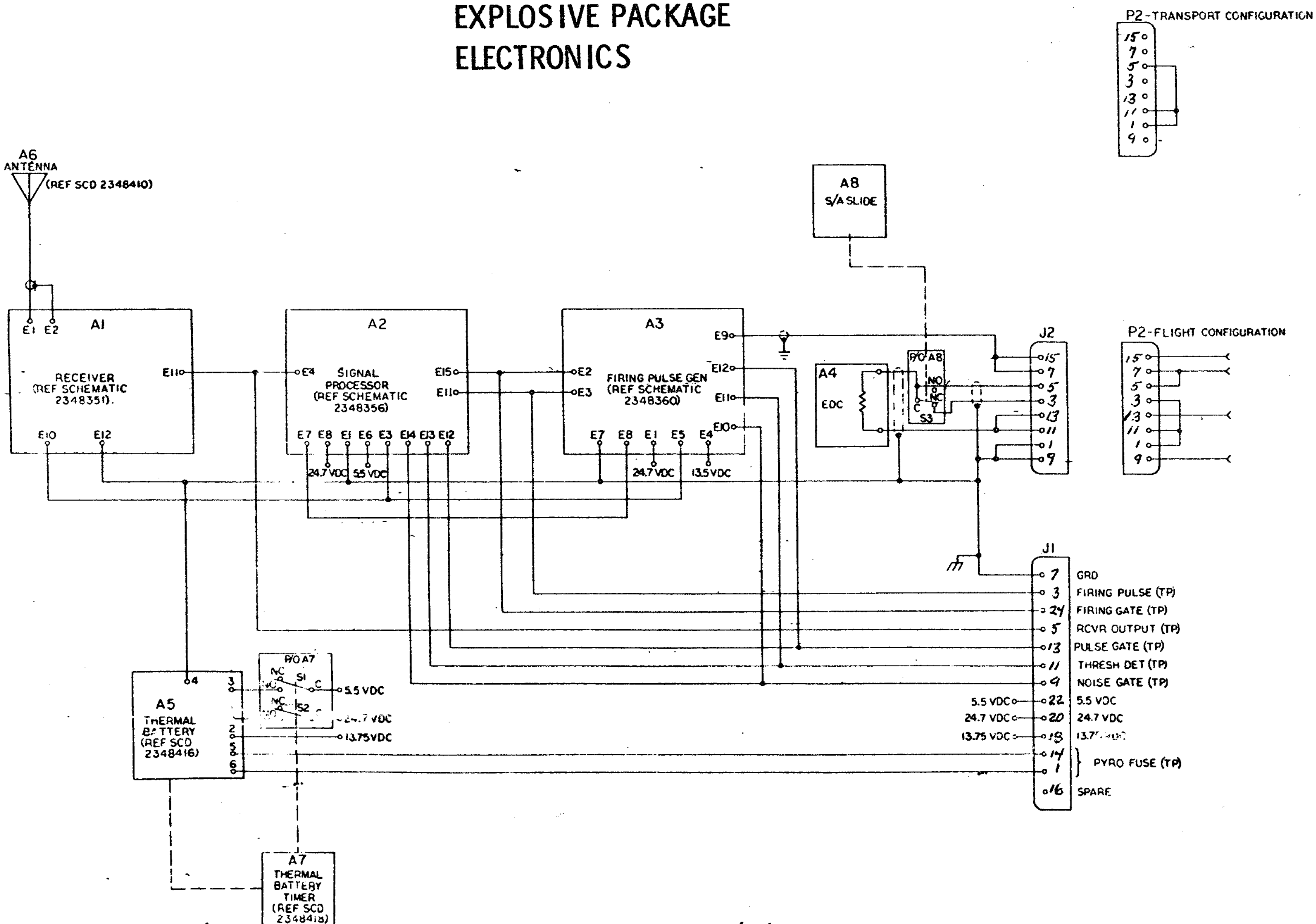

Figure 6.4

6.5 Operational Hazard Analysis

Philosophy

This analysis has been performed by evaluating the effects of environmental extremes, human errors, interaction with other equipments, and possible inherent failures throughout the life cycle phases of the equipment in order to determine operational hazards to which personnel, equipment, facilities, and flight hardware may be exposed. The results of this analysis may be utilized as a design tool to; (1) eliminate the hazards through design changes, (2) minimize hazards through procedural means, or (3) provide awareness of the existence of the hazards by identifying them in applicable procedures. This analysis supplements the Detailed Hazard Analysis (ATM 1049).

Definitions

AIRME:	Apollo Initiator Resistance Measurement Equipment
BxA:	Bendix Aerospace Systems Division
Detonator Assembly:	An EDC with a 2 conductor shielded cable attached and encapsulated at the attachment point
EDC:	End Detonating Cartridge (Contains 100 milligrams Lead Azaid and 100 milligrams HNS-1)
E&SA:	Electronic and Safe/Arm Assembly - The assembly consisting of the timers, the Thermal Battery, the EP Electronics, the Safe/Arm Slide Assembly, and the EDC. In addition to the operating E&SA there is a "structural" E&SA, which is merely a representative mass, to which live H&C's are attached for shipment as an EPTM.

EP:	Explosive Package - The assembly that results from the mating of an Electronic and Safe/Arm Assembly and a Housing and Charge Assembly.
EPTM:	Explosive Package Transport Module - One complete flight array of EP's consisting of eight EP's, mounted four each on two transport frames.
Explosive Safety Distance:	The distance from an explosive charge at which the safety of unprotected personnel is assured without special protective measures.
H&C:	Housing and Charge Assembly - A fiberglass housing containing a block of high explosives which is mated to the E&SA to make an EP. In addition to the live H&C's, there are inert H&C's to which the operational E&SA's are attached for shipment as an EPTM. (Contains HNS-II in following amounts; 1/8, 1/4, 1/2, 1, 3, and 6 pounds).
HNS:	Hexanitrostilibene
HNS-I:	Superfine HNS
HNS-II:	Relatively large grain HNS
KSC:	Kennedy Space Center
LEAD:	Booster Charge - contains HNS-II (approximately 150 milligrams)
LSP:	Lunar Seismic Profiling Experiment
NOL:	Naval Ordnance Laboratory
WSTF:	White Sands Test Facility

6.5.1 MANUFACTURING AND ASSEMBLY

6.5.1.1 Assembly at BxA

During the Manufacturing and Assembly phase at BxA the EDCs and Lead Assemblies are placed in a segregated and isolated area within the Bonded Stores prior to removal to the assembly area.

Assembly of the LSP explosive subassemblies are performed in a specified access controlled area which have explosive warning placards posted in all entrances, and prominant signs which prohibit smoking within the area.

An EDC Holding fixture is provided to ensure protection of personnel and adjacent equipment in the event of an inadvertent detonation, while the EDC is being built up into a detonator assembly. During this assembly the personnel are grounded to avoid detonation by a static electric charge.

6.5.1.2 Assembly at WSTF

The H&C's and E&SA's are brought from the storage areas to an assembly area, where the E&SA is placed on top of the H&C and a vertically downward pressure is applied on the E&SA with an EP Assembly press. Eight screws are installed in the mounting holes and tightened to 5 ± 1/2 inch pounds.

6.5.1.3 Assembly at KSC

Eight E&SA's and H&C's are assembled into eight EP's in a controlled assembly area by BxA-KSC personnel and installed on two Transport frames to complete the EPTM. The EPTM is then installed on the LM pallet.

6.5.1.4 Hazard Consideration #1

Incorrect assembly of Timer No. 1 to the Safe-Arm Plate during assembly at BxA (para. 6.5.1.1) could result in the arming pin not engaging the Safe-Arm Plate, (Fig. 3), allowing immediate movement of the safe-arm plate to the armed position upon removal of Pull Ring Pin No. 2.

6.5.1.4.1 Recommendation

Verify that the arming pin retains the safe/arm slide in the safe position prior to final installation of the Safe/Arm Slide safety pin.

6.5.1.5 Hazard Consideration #2

A cold solder joint at the EDC grounding switch could result in an open circuit, causing the EDC to be in an unsafe condition during handling and testing.

6.5.1.5.1 Recommendations

Perform continuity check after assembly of the EDC grounding switch connections.

6.5.1.6 Hazard Consideration #3

Incorrect installation of Timer Starter Pins (Pull Ring Numbers 1 or 3) could result in inadvertent timer operation.

6.5.1.6.1 Recommendations

Visual inspection to verify that the timer pawl remains engaged with the start tooth. Temporarily lock wire pins in place and maintain security on timers to avoid tampering.

6.5.2 HANDLING & TRANSPORTATION (H&T)

6.5.2.1 H&T to WSTF & KSC

The LSP is transported as an EPTM consisting of two transport frames with four E&SA's assembled to four inert H&C's mounted on each of the two transport frames.

The EPTM is transported in one ALSEP shipping container by escorted air freight. The E&SA's are categorized as Class "C" Explosives (defined in KSC Explosive Safety Handbook) as each contains one EDC and one Lead.

The live H&C's are Class "A" explosive and are transported separately by the NOL, in NOL provided shipping containers. BxA is responsible for the coordination of the delivery of the H&C's with NOL to assure schedule compatibility, and for notification of cognizant site safety personnel upon arrival of the shipments.

6.5.2.2 H&T to LM

Prior to launch the E&SA's and H&C's are removed from their storage areas, assembled into EP's and transported as an EPTM on the LM pallet for installation in the LM.

6.5.2.3 Hazard Consideration

There are no known unique hazards during this operational phase. Although allowable maximum packaged storage temperature, (80°F: 26.7°C) for the experiment may be exceeded during transportation or storage, HNS sensitivity is nearly constant to temperatures up to 400°F and does not constitute a hazard unique to this operation.

6.5.3 STORAGE

6.5.3.1 <u>WSTF Storage</u>

The E&SA's and the H&C's prior to assembly, and the EP's after assembly are placed in a non-environmentally controlled containers and stored in a non-environmentally controlled structure until ready for use at the test site.

6.5.3.2 <u>KSC Storage</u>

The above storage procedure differs at KSC where the E&SA's are stored within the environmentally controlled shipping container in a bonded environmentally controlled area, while the H&C's are stored in an explosive storage bunker. The two assemblies are not combined into EP's until shortly before installation into the LM.

6.5.3.3 <u>Hazard Consideration</u>

Same as paragraph 6.5.2.3 for WSTF storage.

6.5.3.3.1 <u>Recommendations</u>

Same as paragraph 6.5.2.3.1.

6.5.4 MAINTENANCE

6.5.4.1 <u>WSTF Maintenance</u>

After the EP's are assembled they are placed in individual containers and transported to the deployment sites. If a mishap should occur which requires a maintenance action, the EP's would be disassembled and the E&SA returned to a maintenance area and repaired prior to redeployment.

6.5.4.2 KSC Maintenance

During the Crew Fit and Function (CF^2) exercise the EPTM with live EDC's and Leads, and an inert H&C block are deployed, simulating Lunar deployment. The results of the exercise will determine necessary modifications and decal implacements. The items used for CF^2 will be refurbished as necessary for use as flight hardware. The EP pull pins will not be exercised at this time.

6.5.4.3 Conclusion

There are no known unique hazards during these operational phases.

6.5.5 TEST

6.5.5.1 Functional Test

Functional testing is conducted on the E&SA's (without an H&C) at BxA, WSTF, and KSC during various points of the hardware flow. The functional tests are conducted to determine the electronics equipment integrity after environmental testing. Three types of testing equipment are used for the functional tests; (1) The LSP-ETS Electronics and S/A Assembly which provides for suppling 5.5, 13.75, 24.75 VDC to the E&SA and provides a load for the E&SA assembly checkout. A ground is provided across the EDC connections to maintain the E&SA assembly in a safe condition when it is functioned and allowing the grounding switch to be opened, (2) The AIRME which allows the testing of the EDC Bridgewire. This test is done by allowing a maximum of 20.0 milliamperes to flow across the EDC bridgewire for a maximum of 15 seconds (automatic timer to keep exposure time of all initiators approximately equal). During this test the EDC grounding switch connection cannot be grounded in order to provide the measurement, (3) A modified ALINCO test set to perform the same function as the AIRME. The major difference between the two is that the ALINCO does not have the 110 Volt hazard, does not have the timer capability, and allows a maximum current of 5 milliamperes across the bridgewire. The modification of the ALINCO test set consists of an added resistance range to the instrument from a maximum of 30 ohms to a maximum of 3000 ohms.

6.5.5.2 Destructive Test

Destructive testing is conducted at WSTF only. The E&SA and H&C assemblies are combined into an Explosive Package and transported to the test site for "time-out" period subsequent Explosive Packages are being assembled and awaiting deployment. The sequence of Explosive Packages are as follows; (a) one package deployed and three being assembled during "time-out", (b) three packages deployed while four being assembled during "time-out", (c) four packages being deployed while four being assembled and, (e) four being deployed while none are being assembled.

6.5.5.3 Hazard Consideration

An open circuit at the test set EDC grounding connection during a functional (Paragraph 6.5.5.1) would allow the EDC to remain in an unsafe condition when the Safe-Arm Slide moves to the armed position.

6.5.5.3.1 Recommendation

The hazardous condition can be minimized by providing for a continuity check of the ground connection prior to testing, however this would not allow for awareness of the circuit opening after the continuity check. The hazardous condition can be eliminated with the use of an indicator which will allow the test conductor to be aware of an open circuit throughout the testing phase.

6.5.5.4 Hazard Consideration

The LSPE Field Test Plan (WSTF) operational sequence (paragraph 6.8) allows subsequent sets of explosive packages to be assembled during the "time-out" period of a previously deployed package. This could allow assembled packages to be stored approximately 3 days without test result knowledge, and could lead to possible additional handling in the event of test failure or premature detonation which would require field modifications.

6.5.5.4.1 Recommendation

Subsequent packages should not be assembled until after the test results have been examined, (in the case of a premature detonation of an unknown cause, the HE packages can be detonated without loss of the E&SA's), or a minimum consideration would be to not assemble subsequent packages at least 8 hours prior to detonation.

6.5.5.5 Hazard Condition

During functional testing of the EDC bridgewire with AIRME, the initiator is shorted in a safe condition with switch SID and SIE until the test is conducted (15 sec). The Modified ALINCO Tester used at WSTF does not incorporate this safety feature, resulting in an unsafe condition of EDC through the testing operation.

6.5.5.5.1 Recommendation

Incorporate the shorting feature of the AIRME into the ALINCO Tester.

6.5.6 LUNAR

6.5.6.1 Lunar Deployment

The LSP is transported to the Moon in the descent stage of the LM and deployed on the lunar surface during the second and third periods of extra-vehicular activity. During flight the explosive materials in the LSP are completely contained within 8 Explosive Packages stored in Quadrant III of the LM descent stage. During lunar deployment the Explosive Packages are removed from the LM and placed in Lunar Roving Vehicle for deployment at a distance from a few meters to a maximum of 3.5 km from the ALSEP Central Station, at which time the safety pull pins (3) are removed to start the timers, and the antenna is deployed. The timers are set to allow the Explosive Packages to be Armed at a minimum time of 90 hours after the pins are removed, at which time, the Crew Members have left the lunar surface, and the Explosive Packages may be detonated. If the Explosive Packages are not detonated within 2 hours after the armed position is attained the Safe-Arm Plate moves to a resafe position and cannot be detonated by a command signal.

6.5.6.2 Conclusion

There are no known unique hazards during this operational phase.

7.0 SUMMARY OF SAFETY FEATURES

7.1 Explosive Package Design Features

When the Explosive Packages are in storage during transit to the lunar surface or are on the LRV and until the Explosive Package is deployed on the lunar surface the following safety features of the Explosive Package exist:

1) The EDC Bridgwire is shorted.
2) The Thermal Battery is disconnected from the electrical firing and receiving circuits.
3) The Thermal Battery is de-activated resulting in no electrical power in the Explosive Package.
4) The Safe/ Arm Slide provides a mechanical barrier between the output of the EDC and the HNS Explosive Charge (see Section 7.2).
5) The HNS is a highly stable explosive which cannot be detonated except thru a high speed plasma shock.
6) The Safe/Arm Slide Timer Firing Pin is locked by a pull pin so that if prematurely released the pull pin cannot be removed and the slide cannot move to the respective arm position.
7) The Thermal Battery Timer Firing Pin is locked by a pull pin so that if prematurely released the pull pin cannot be removed and the Firing Pin cannot activate the Thermal Battery.
8) The Safe/Arm Timer is locked in a "0" position by a pull pin. If the Timer prematurely advances, the pull pin monitors the time at the "0" position and locks so that the pull pin cannot be removed.
9) The Thermal Battery Timer is locked in a "0" position by a pull pin. If the Timer prematurely advances, the pull pin monitors the time at the "0" position and locks so that the pull pin cannot be removed.

The following conditions must be satisfied for detonation of the Explosive Package when deployed on the lunar surface.

1) The removal, by vertical pull of the safe/arm timer pull pin, 1/4 turn and vertical pull of the safe/arm slide pull pin and the vertical pull of the gang bar assembly including the thermal battery timer pull pin and thermal battery timer safing pin.

1) Continued -

Premature occurrence of any of the following events results in a pull pin locking up, preventing detonation of the Explosive Package:

- Battery Timer timing movement
- Battery Timer firing pin movement
- Safe/Arm slide movement
- Safe/Arm slide timer movement

2) At "t" hours* the Safe/Arm timer functions to release the safe/arm slide to the arm position shown by an orange indicator moving to the arm position and opening the activation switch to remove the EDC short. NOTE: The EDC short is in place at all times except when the slide is in the arm position.
3) At "t + 1" hours the thermal battery timer functions to release the firing pin to strike and actuate the thermal battery connecting the output of the thermal battery to the firing circuit.
4) The thermal battery when activated will power the receiving and firing circuits one (1) minute minimum. If the firing signal is not received within three (3) minutes of thermal battery activation, firing capacitors will be discharged through leak resistors, thus diminishing the voltage below the firing level.
5) A special 3 pulsed encoded firing signal is required to fire the end detonating cartridge.

If the Explosive Package is not detonated within the two hour safe/arm slide firing window, the slide will move to the resafe position thus activating the switch to reapply the short across the end detonating cartridge.

7.2 Verification of Safe/Arm Slide Safety Feature

The Naval Ordnance Laboratory, White Oak, Md, has conducted tests to verify that detonation of the EDC while it is in the Safe or Resafe position will not cause the Explosive Package to detonate.

The test setup is shown in Figure 7.1. The tests performed are as follows.

* t = 90, 91, 92, and 93 hours after removal of pull pins.

1) Varicomp Safety Tests

The Lead contained PETN, Interface No. 1, was 0.0 inch gap. Six shots were made in the Safe position; two shots were made in the Resafe position. In all test shots the detonation did not propagate through explosive train.

2) Design Safety Tests

The Lead contained HNS-IIA, Interface No. 1, was 0.0 inch gap. Six shots were made in the safe position; four shots were made in the resafe position. In all test shots the detonation did not propagate through the explosive train.

3) Lead Misalignment Safety Tests

Two shots were made with the attenuator in the slide 0.100 inch off center and two shots were made with the attenuator in the slide 0.200 inch off center. In all test shots the detonation did not propagate through the explosive train.

4) Further Design Safety Tests

On September 16, 1971 at the Naval Ordnance Laboratory, a demonstration of the Safe/Arm Slide Safety Test was conducted using 1/8 lb. and 6 lb. Housing and Charge Assemblies. Both of these tests failed in that the EDC charge coined the Safe/Arm Slide although detonation of the HNS high explosive did not occur. Failure was attributed to the lack of heat treatment to the slides. It was determined that heat treated slides would be used for Prototype but that heat treatment was not enough of a safety factor for Qual/Flight so the design of the slide was modified to incorporate a radius rather than a sharp corner in the RTV filled safety bore.

During the week ending September 26, three unradiused slides were sent to NOL, two were heat treated, the third was not. The unheat-treated slide failed during test in that the slide coined. The heat treated slides did not fail. This test confirmed that the lack of heat treatment was a contributing factor to the Safe/Arm Slide failure.

4) Continued

On October 11, 1971 six additional slides, which were heat treated but unradiused were sent to NOL for test. The first four were tested by firing at room temperature. This detonation did not coin the slide. The two remaining slides were tested at 200°F. The detonation coined through the first of these two slides resulting in the suspension of testing pending further analysis. As a result of this failure all prototype, qualification and flight slides were to be both radiused and heat treated. The prototype unradiused slides were destroyed with Qual/Flight slides used as replacements and the rebuilding of new color coded Qual/Flight slides initiated.

Two of the radiused, heat treated original Qual/Flight slides were shipped on November 5,to NOL. Conclusive testing was conducted verifying that the radiused and heat treated Safe/Arm slides will contain the inadvertent detonation of an EDC while in the safe and resafe position.

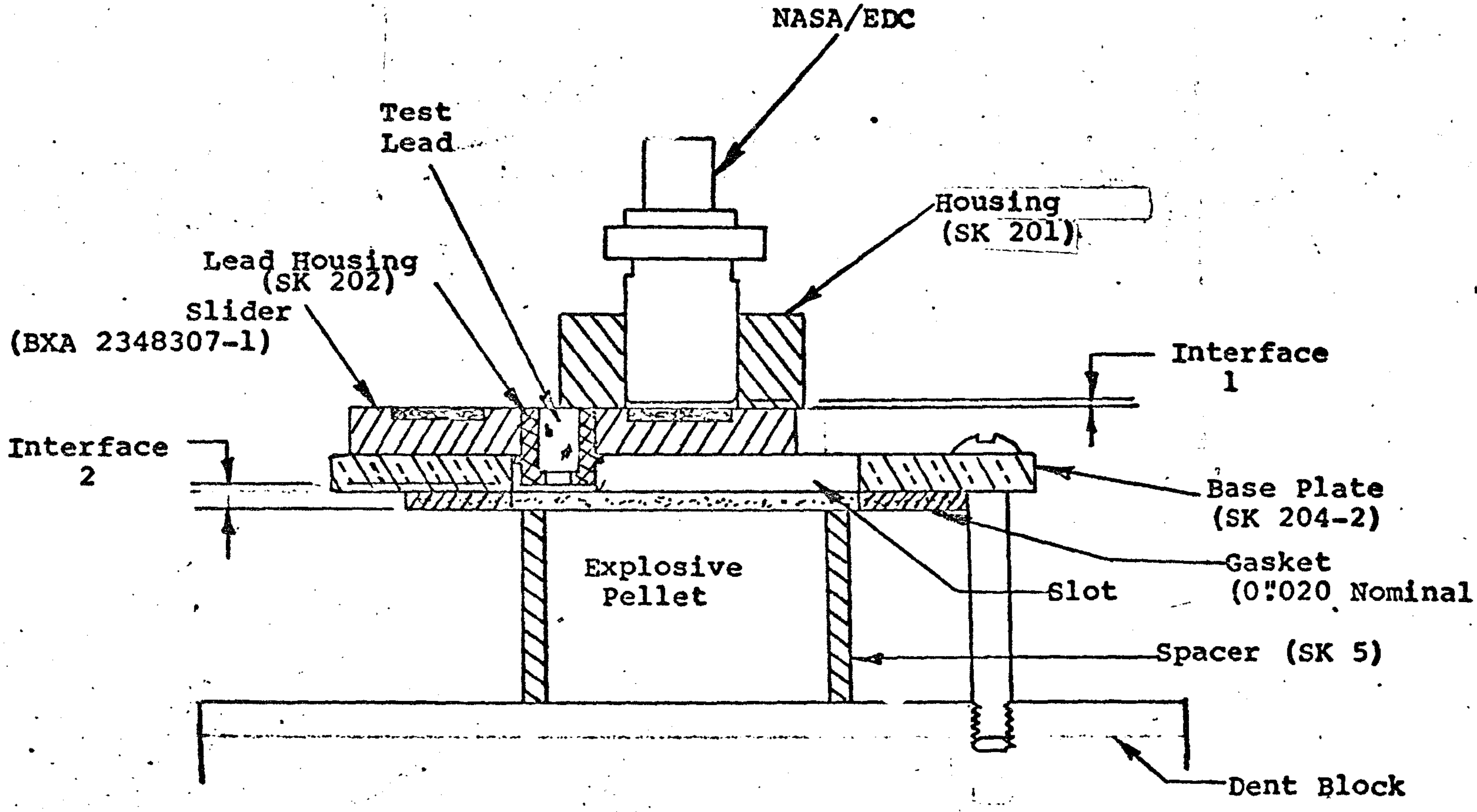

Figure 7.1 ARRANGEMENT USED FOR SAFETY TEST