This Detailed System Hazard Analysis Report is presented in accordance with Paragraph 4.2.2 of ALSEP-LS-10, "System Safety Program Plan for ALSEP Flight Array E Lunar Seismic Profiling Experiment Subsystem". This is a final report; however, it will be updated as required to reflect significant design changes which may affect the safety of the experiment.

J Jones for
W. Lavin
System Safety Engineer

J Jones
J. Jones, Supervisor
Support Engineering

B. J. Rusky, Manager
ALSEP Systems Support

Jack Dye
J. Dye, Manager
LSP Experiment

1.0 INTRODUCTION & SCOPE

This Detailed System Hazard Analysis Report consists of two major sections; (1) The Detailed Fault Hazard Analysis and (2) The Fault Tree Logic Diagrams which evaluate the hazard potential of the LSP explosives during the full scope of the mission phases of installation, launch, flight, and lunar stay.

1.1 Summary and Conclusion

The Fault Hazard Analysis reveals three single point failure modes which are considered catastrophic or critical as defined in paragraph 3.3. 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 Fault Tree Logic diagrams reveal 49 independent events (basic faults) which could occur during the four operational phases on a direct path (through "or" gates) to the undesired top event of inadvertant explosion. However, 33 of these events are related to environmental instability which would require conditions well in excess of the design environmental limits to which the LSP explosives are to be subjected. An additional 11 events are sympathetic responses to an external explosion, which can be minimized by procedural means during handling and installation. These must be considered insignificant secondary hazards in the flight and lunar stay phases of the mission as the primary explosion would already have caused a catastrophic situation. Of the remaining five events, three are the result of detonation of the EDC by static electricity, which has been minimized through design features; i.e., grounded and shielded cables and the safe-arm slide ground switch. Two are the result of EMI, a problem which has been investigated and reported on in Bendix document ATM-1004 and which defines the requirements for a test to be conducted to assure the hazard is non-existent.

The hazardous limits of the basic events for high temperature, shock, and propellant degradation have not yet been defined. Preliminary evaluation shows that HNS becomes less sensitive with respect to time and autoignites at temperatures of approximately 600°F, but does detonate. These events may be deleted or have an output from an "and" gate as combinations may result in hazardous effects; however, they will remain as a worst case analysis until substantiated data dictates the changes.

1.2 Assumptions and Considerations

The following assumptions have been utilized in the preparation of this report.

- All basic fault events are independent of each other.
- The system is composed of functional elements which are either operating properly, or are in a failed state.
- The system may be represented in logic form as related combinations of possible fault event sequences, normal sequences of system operation and human factors.
- An event resulting from four or more events below an "and" gate need not be shown on the Fault Tree Analysis.

2.0 APPLICABLE DOCUMENTS

The following documents have been referred to in the preparation of this report.

2.1 References

BxA ALSEP-LS-10 6 April 1971	System Safety Plan for ALSEP Flight Array E Lunar Seismic Profiling Experiment Subsystem
Boeing D2-118195-1 25 July 1968	Guidelines for Apollo Spacecraft Logic Diagram Analysis
BxA ATM 976	Failure Mode, Effects and Criticality Analysis LSPE ALSEP Array E

3.0 DETAILED FAULT HAZARD ANALYSIS

3.1 Introduction

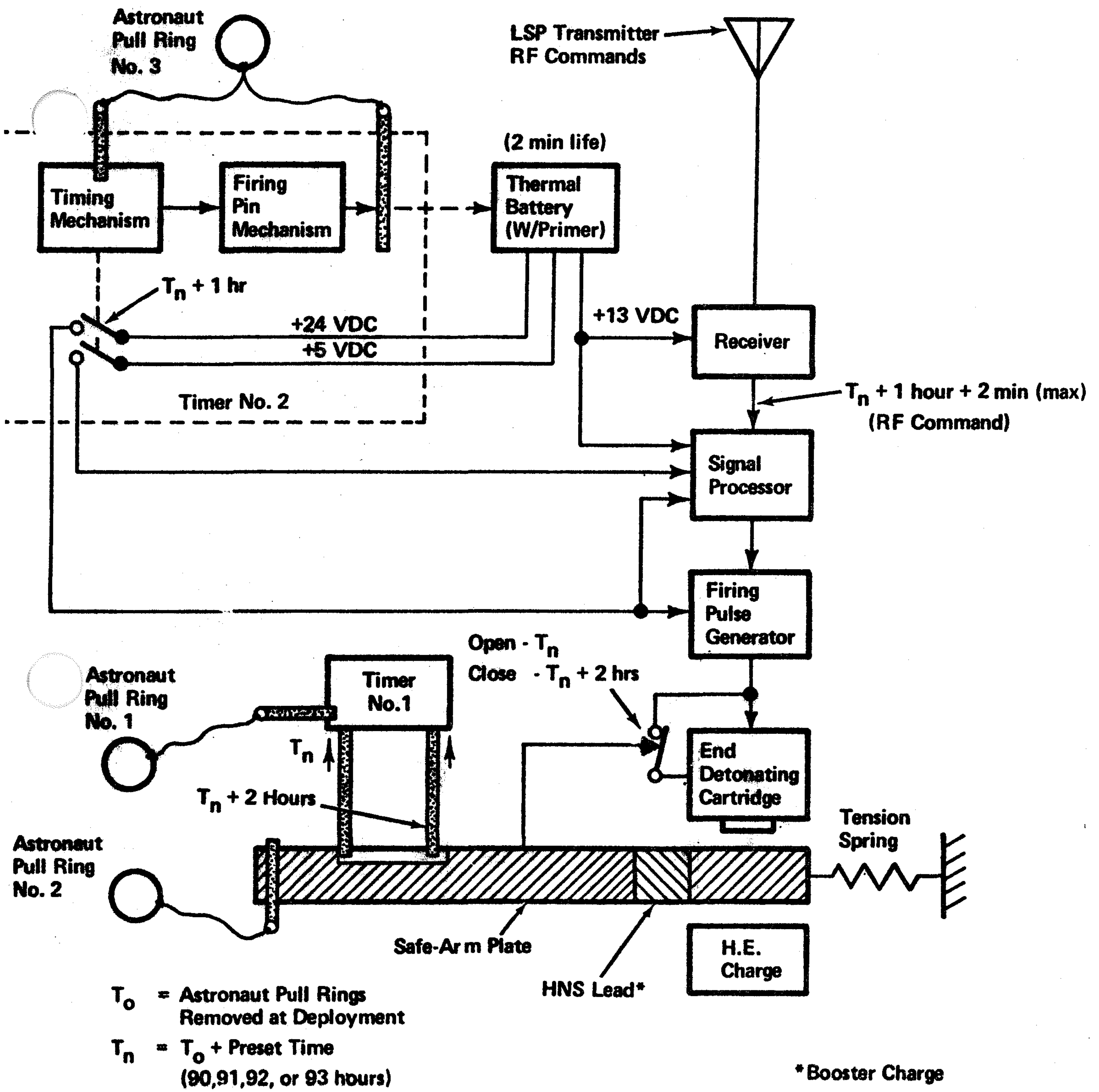
This section presents an analysis of failure modes of the equipment within the ALSEP Array E, and their hazardous effects upon personnel and adjacent equipments during the mission phasessof installation, launch, flight and lunar stay. The analysis is based primarily on the Failure Mode, Effect and Criticality Analysis (BxA ATM-976) and the Block Diagram of the Explosive Package as shown in Figure 1. The analysis has not considered failures modes of piece parts within the electronic packages because of the multiple redundant safety features within the system which will not allow any single electronic failure mode to result in a hazard. However, when pertinent, this kind of failure mode has been incorporated in the fault tree under "and" gate Number 9.

3.2 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 4.0.

3.3 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.



BLOCK DIAGRAM OF EXPLOSIVE PACKAGE

FIGURE 1.

- 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 of 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.

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

D) Lunar Stay - The period of time beginning with lunar touchdown and ending with lunar lift-off.

4.0 FAULT TREE ANALYSIS

4.1 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.

4.2 Philosophy

The Fault Tree Analysis (Figures 2a through 2h) 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.

4.3 Logic Definitions and Symbols

4.3.1 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 represente 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.

4.3.2 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 branches 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.

Output

Two or more inputs

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.

Output

Two or more inputs

4.3.3 Transfer Symbols

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

A_1

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

A_1

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

ALSEP ARRAY E

FAULT HAZARD ANALYSIS SHEET

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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

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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 CLASSIFI CATION
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

MISSION PHASE	ALSEP ARRAY E	
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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
1.3(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

MISSION PHASE	ALSEP ARRAY E	
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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
1.4(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) None; Safe/Arm Plate is held in the safe position with Pull Ring Pin No. 2. D) None; Lock-up of the Pull Ring Pin #2 by the Safe Arm Plate will not allow Pull Ring Pin #2 to be removed	A)B)C) None D) Pull Ring Pin #2 cannot be removed	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) Pull Ring Pin #2 cannot be removed	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) Pull Ring Pin #2 cannot be removed	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 (τ)	HAZARD CLASSIFICATION
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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ITEM NO. (FMECA #)	PART/COMPONENT	FAILURE MODE AND EFFECT	HAZARD EFFECT	METHOD OF DETECTION	CORRECTIVE ACTION	CREW REACTION TIME (τ)	HAZARD CLASSIFICATION
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)						

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

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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
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 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
3.1.4(B3)	First Wheel	Gear teeth strippage resulting in loss of energy 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
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

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

ALSEP ARRAY E

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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
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 (τ)	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

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

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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
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

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

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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 CLASSIFI CATION
3.4.7(E7)	Firing Pin Lock	Structural failure resulting in lock-up of the Pull Ring Pin No. 3	A)B)C) 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 D) None; Firing Pin will lock-up Pull Ring Pin resulting in the inability to release the complete Pull Ring No. 3 Subassembly	A)B)C) None D) Visual	A)B)C)D) None required	N/A	A)B)C)D) 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 Subassembly	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

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

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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
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

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

ALSEP ARRAY E

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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
3.8	End Detonating Charge (EDC) Subassembly	Premature Detonation (Although the HNS-1 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 LM 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

ALSEP Array E LSP Experiment Fault Tree Logic Diagram

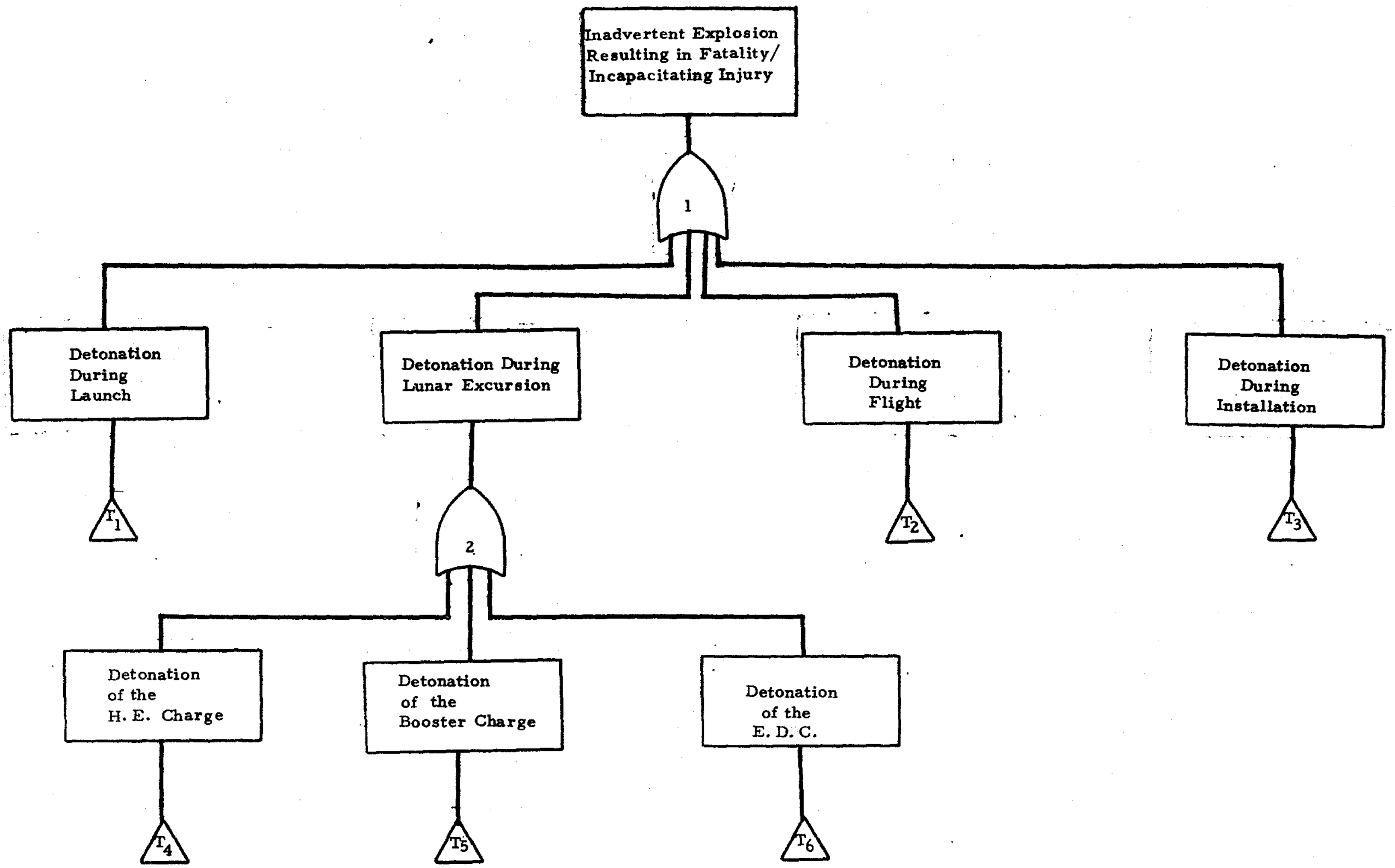
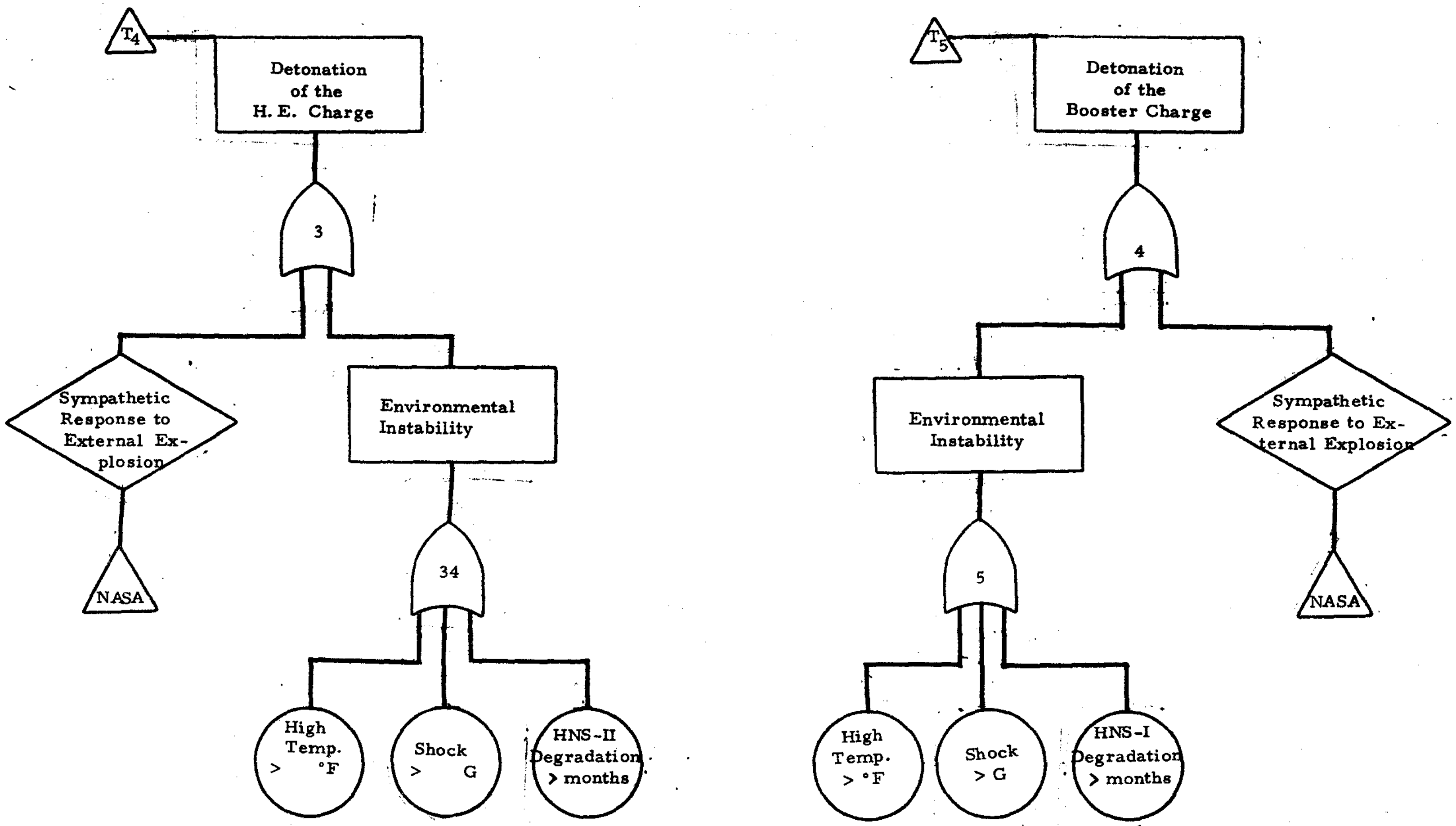


Figure 2a



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

Figure 2b

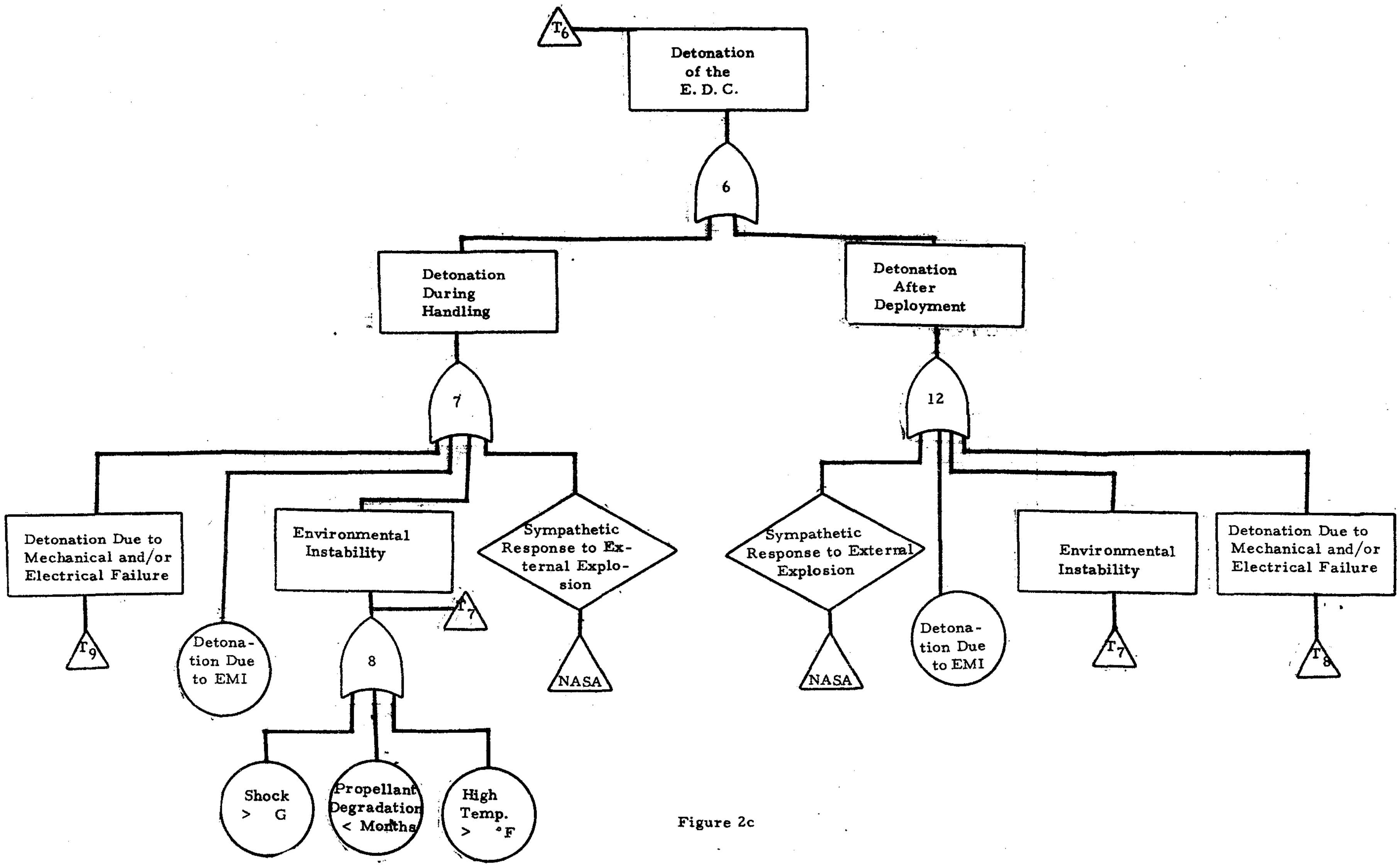

T6
Detonation of the E. D. C.
6
Detonation During Handling
Detonation After Deployment
7
12
Detonation Due to Mechanical and/or Electrical Failure
Detonation Due to EMI
Environmental Instability
Sympathetic Response to External Explosion
Sympathetic Response to External Explosion
Detonation Due to EMI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

Figure 2c

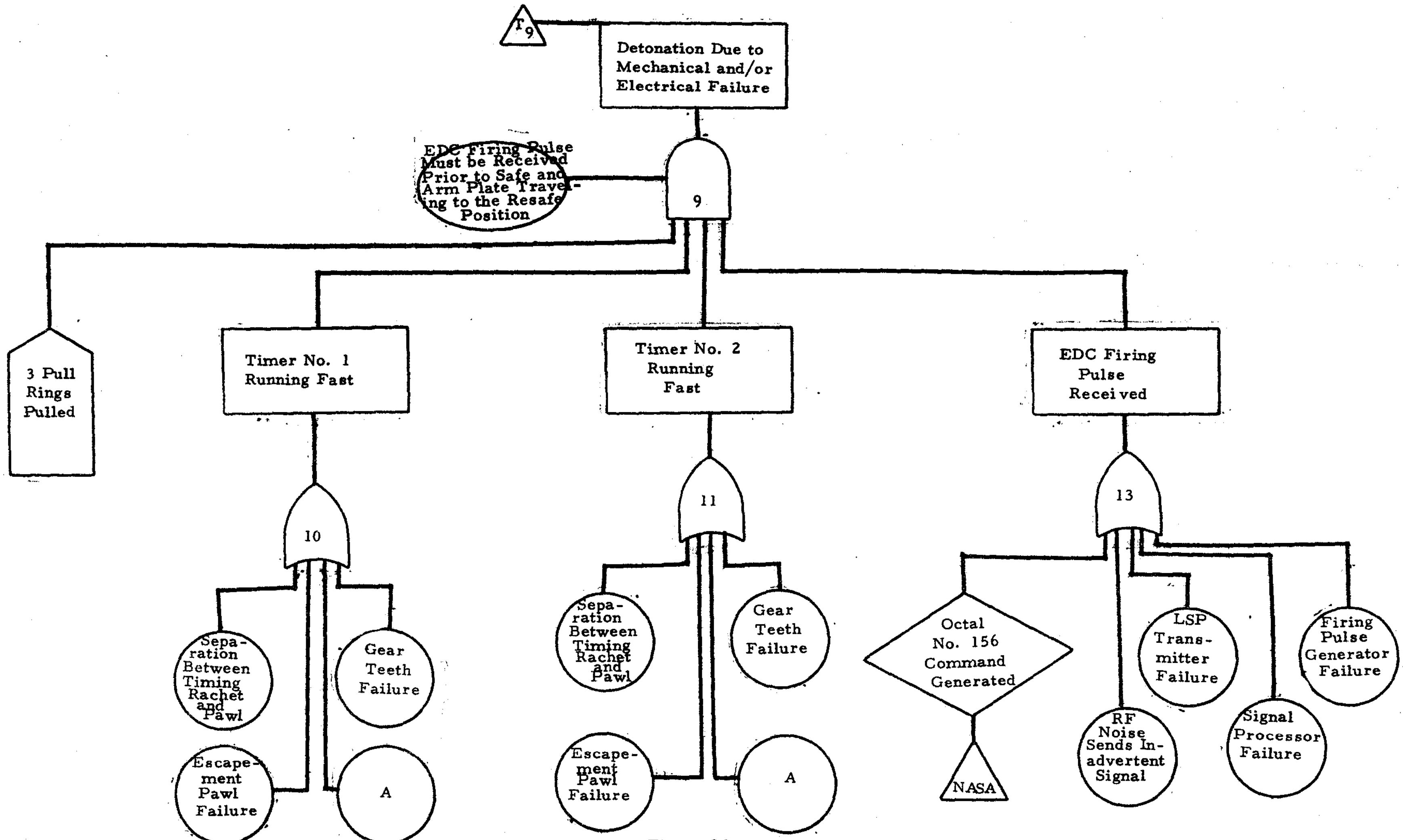
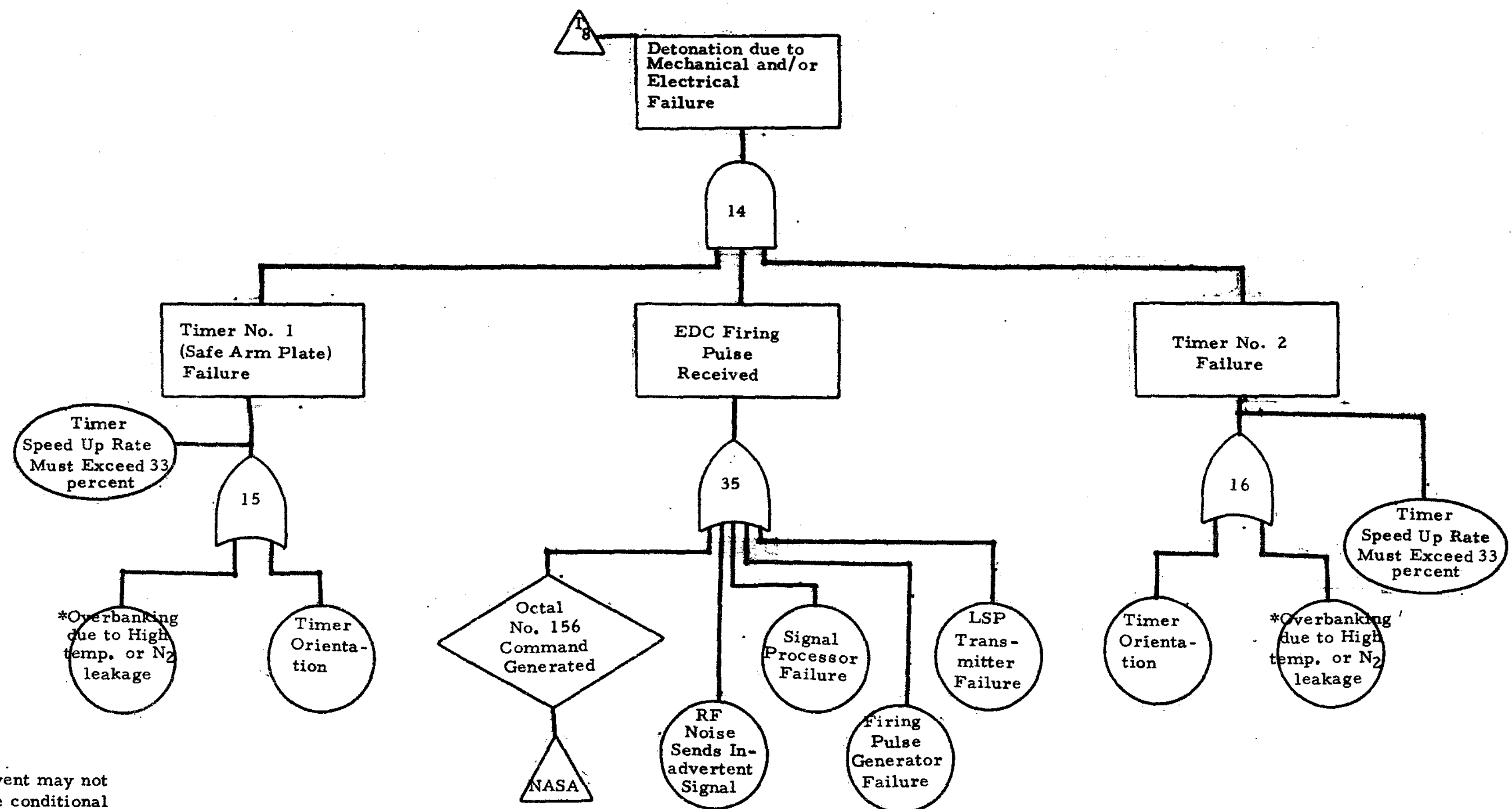

T9
Detonation Due to Mechanical and/or Electrical Failure
EDC Firing Pulse Must be Received Prior to Safe and Arm Plate Traveling to the Resafe Position
9
3 Pull Rings Pulled
Timer No. 1 Running Fast
Timer No. 2 Running Fast
EDC Firing Pulse Received
10
11
13
Separation Between Timing Rachet and Pawl
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 2d



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

Figure 2e

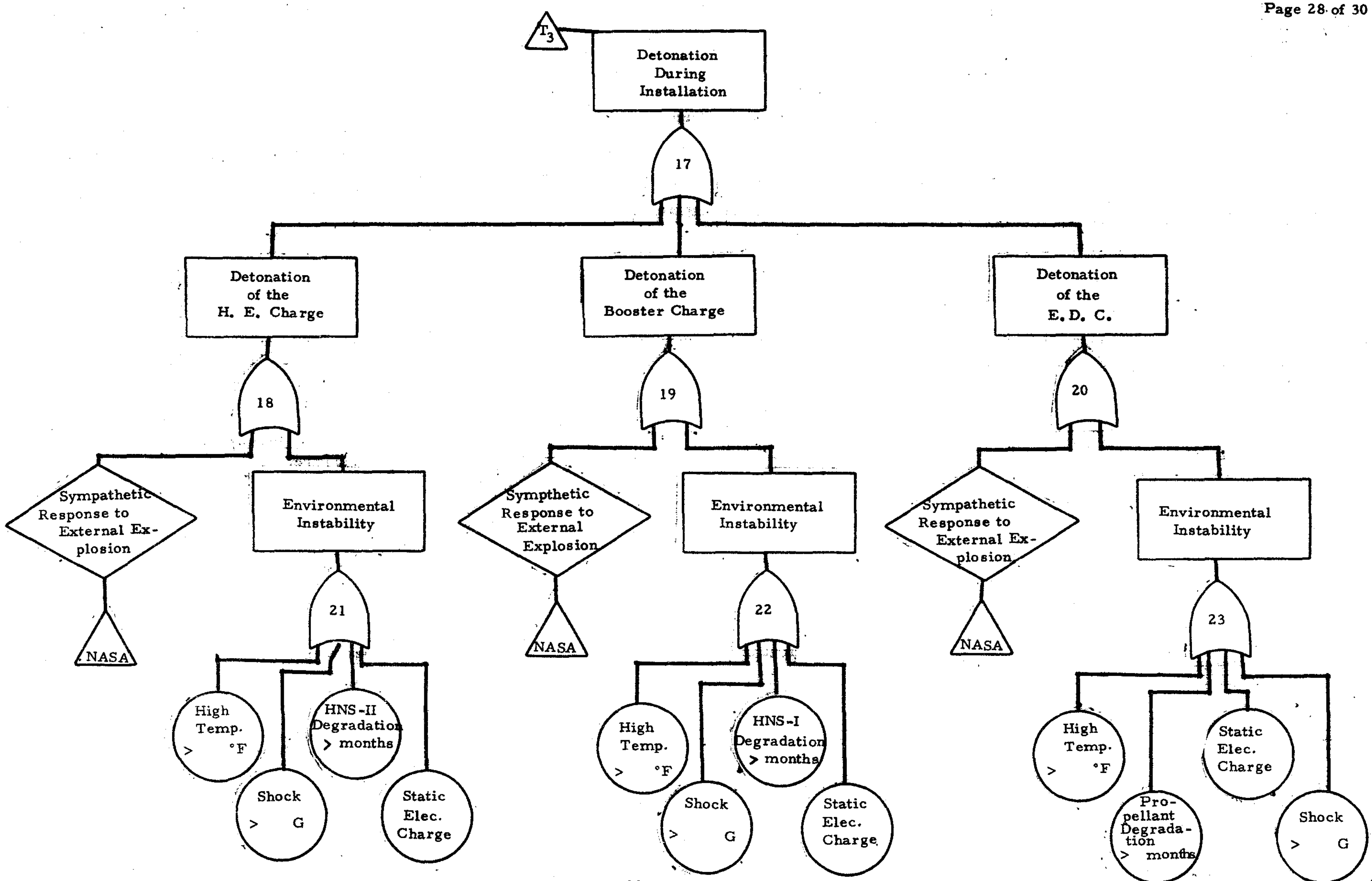

T3
Detonation During Installation
17
Detonation of the H. E. Charge
Detonation of the Booster Charge
Detonation of the E. D. C.
18
19
20
Sympathetic Response to External Explosion
Environmental Instability
Sympthetic Response to External Explosion
Environmental Instability
Sympathetic Response to External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

Figure 2f

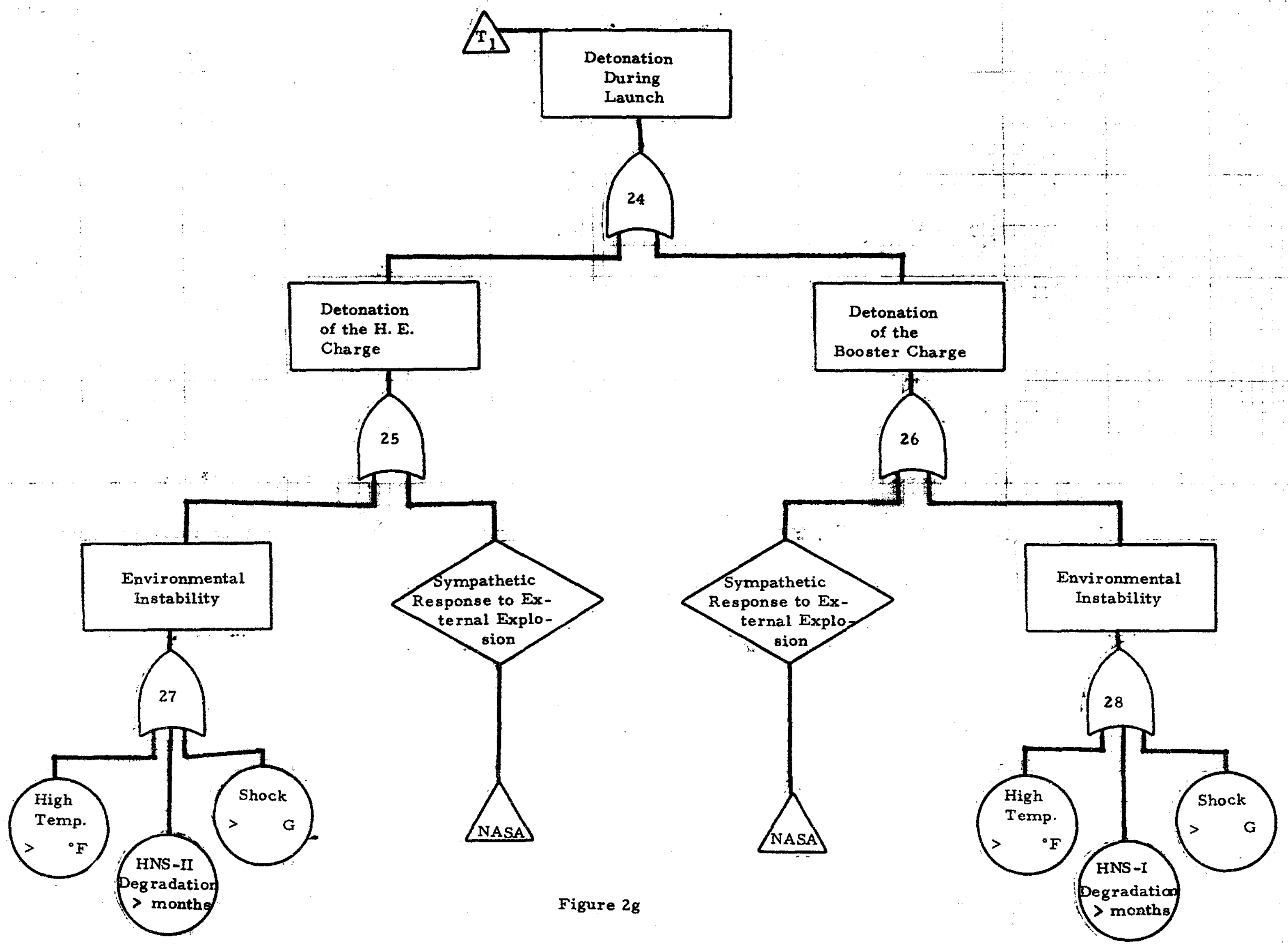

T1
Detonation During Launch
24
Detonation of the H. E. Charge
Detonation of the Booster Charge
25
26
Environmental Instability
Sympathetic Response to External Explosion
Sympathetic Response to External Explosion
Environmental Instability
27
NASA
NASA
28
High Temp. > °F
HNS-II Degradation > months
Shock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

Figure 2g

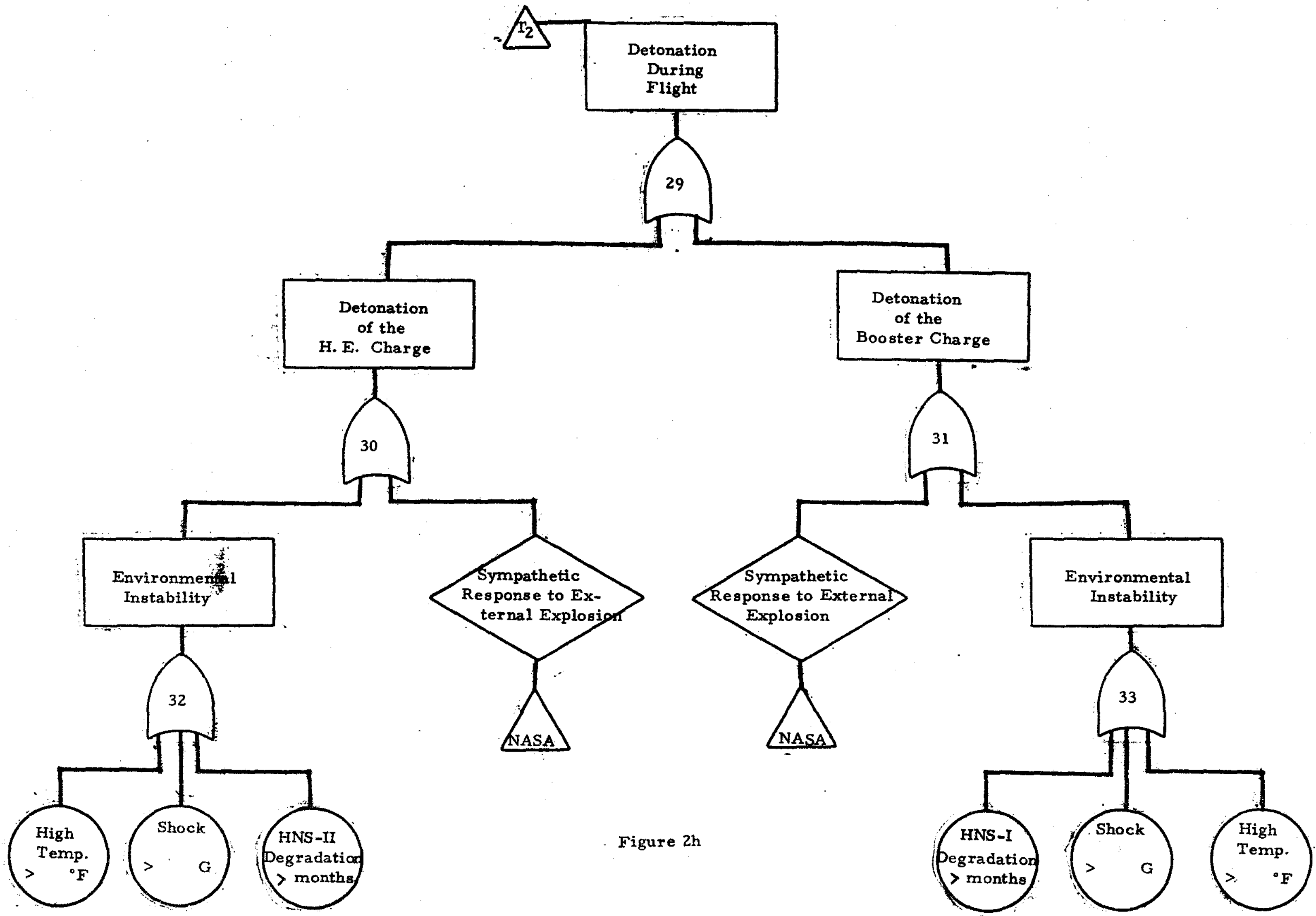

T2
Detonation During Flight
29
Detonation of the H. E. Charge
Detonation of the Booster Charge
30
31
Environmental Instability
Sympathetic Response to External Explosion
Sympathetic Response to External Explosion
Environmental Instability
32
NASA
NASA
33
High Temp. > °F
Shock > G
HNS-II Degradation >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

Figure 2h