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CONTINUATION OF SPACE SHUTTLE
PROBABILISTIC RISK ASSESSMENT, PHASE 3
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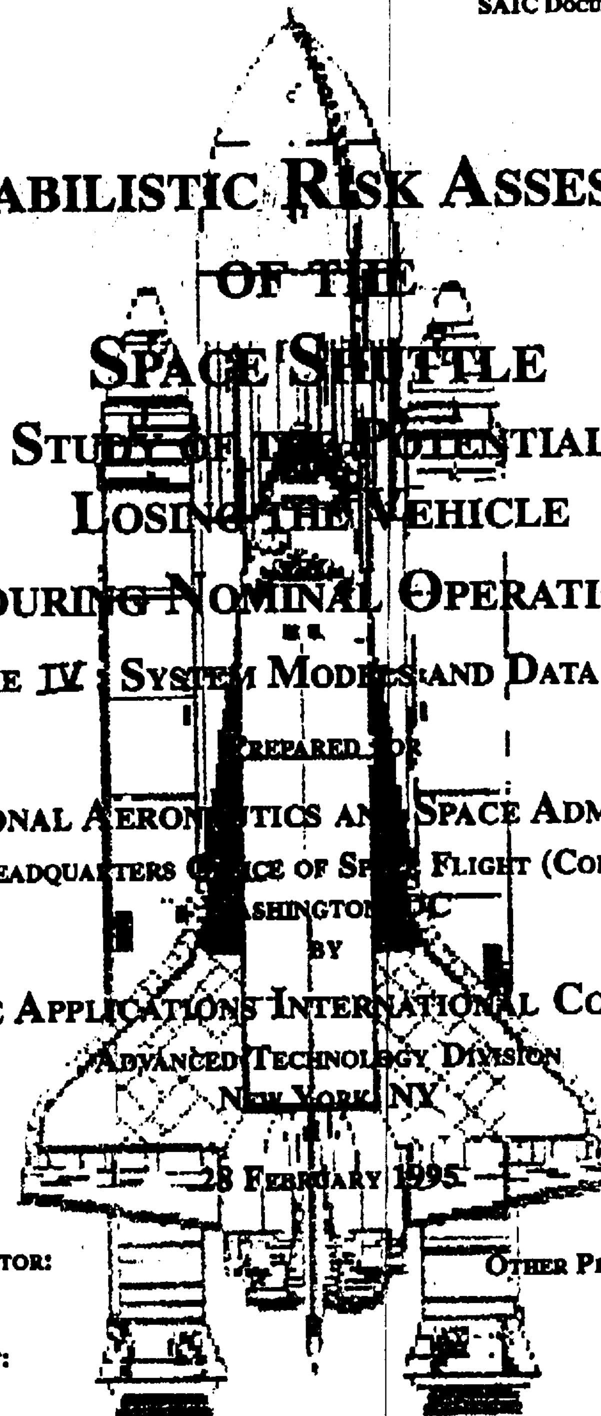

PROBABILISTIC RISK ASSESSMENT OF THE SPACE SHUTTLE

A STUDY OF THE POTENTIAL OF LOSING THE VEHICLE DURING NOMINAL OPERATION

VOLUME IV: SYSTEM MODELS AND DATA ANALYSIS

PREPARED FOR

US NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HEADQUARTERS OFFICE OF SPACE FLIGHT (CODE M)
WASHINGTON, DC

BY

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION
ADVANCED TECHNOLOGY DIVISION
NEW YORK, NY

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PRINCIPAL INVESTIGATOR:
JOSEPH R. FRAGOLA

CHIEF RISK ANALYST:
GASPARE MAGGIO

OTHER PRINCIPAL CONTRIBUTORS:
MICHAEL V. FRANK*
LUIS GEREZ+
RICHARD H. MCFADDEN
ERIN P. COLLINS
JORGE BALLESIO
PETER L. APPIGNANI
JAMES J. KARNS

* SAFETY FACTOR ASSOCIATES, INC.
ENCINITAS, CA
+EMPRESARIOS AGRUPADOS,
MADRID, SPAIN

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(NASA-CR-197811) PROBABILISTIC RISK ASSESSMENT OF THE SPACE SHUTTLE. PHASE 3: A STUDY OF THE POTENTIAL OF LOSING THE VEHICLE DURING NOMINAL OPERATION. VOLUME 4: SYSTEM MODELS AND DATA ANALYSIS (Science Applications International

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B.1. Space Shuttle Main Engine

SSME/MPS Initiator Equivalent Flight Occurences Evaluation

Record Type/ Source Study	Record/ Source ID	Date	System Element	Failure Description from Record	Analyst Comments	Engine #	Test/Flight	Redline Activation	Engine Configuration	Configuration Applicability	Event Potentiality Factor	Weighting Factor	Equivalent Flight Failures for Total Exposure Time
Initiator													
SMEPO	Loss of MCC Pressure												4.00
UCR	A020646	28-Jul-88	SYSTEM	CROSS FEED GAIN BAD AT HIGH VLV POSITIONS	THROTTLE DOWN IN THRUST LIMIT +200F	0211	901.578	HPOTP TURBINE DISCHARGE TEMPERATURE	5 FPL/PH2	1	1	1	
UCR	A015718	25-Jun-87	SYSTEM	HPOTP TURB TEMP EXCD R/L	1540 PRELIFTOFF R/L -CHANGED TO 1680	0210	750.288	HPOTP TURBINE DISCHARGE TEMPERATURE	5 FPL/PH2	1	1	1	
UCR	A016031	2-Sep-81	MINJ	SEV EROSION OF PRIM/SEC FACE PLATES	MINJ BURN OUT/REPLACED MINJ	0110	750.148	HPOTP TURBINE DISCHARGE TEMPERATURE	4 FPL	0.75	1	0.75	
UCR	A013786	15-Jul-81	MINJ	SEVERE DAMGD TO THE PRIM/SEC F PLATES	MINJ BURN OUT EXT DAM	2106	901.331	HPOTP TURBINE DISCHARGE TEMPERATURE	4 FPL	0.75	1	0.75	
UCR	A017580	23-Jul-80	MINJ	R/L C/O - HPOT TURB DISC TEMP, MAIN INJ	HOLE IN INJ LOX POST FAIL	2004	902.198	HPOTP TURBINE DISCHARGE TEMPERATURE	3 FMOF	0.5	1	0.5	
SMEPH	Loss of Gross H2 Flow												0.50
UCR	A011269	16-Apr-80	HPFTP	HI FUEL TURB DISC TEMP VOTING LOGIC C/O	TURNAROUND MAN COLLAPSED	2003	SF0901-B	HPFTP TURBINE DISCHARGE TEMPERATURE	2 MPTA	0.25	1	0.25	
UCR	A003283	10-Jul-78	HPFTP	EXTREME BULGING IN TURNAROUND MANIFOLD	BULGE IN TURBINE TURN MANIFOLD	0101	902.118	HPFTP TURBINE DISCHARGE TEMPERATURE	2 MPTA	0.25	1	0.25	
SMEMO	High Mixture Ratio in Oxidizer Preburner												0.25
UCR	A018563	28-Jan-81	SYSTEM	PREMATURE CUTOFF;OPOV POSITION	OPOV LIMIT RESET MCF	0007	750.119		2 MPTA	0.25	1	0.25	
MSFC PRACA	A08247	17-Jun-81	HYDRAULICS	ACT. CHECK-OUT MODULE FAILURE	OPOV POSITION FAILURE		Field			1	0	0	
SMEMF	High Mixture Ratio in Fuel Preburner												0.25
UCR	A018563	28-Jan-81	SYSTEM	PREMATURE CUTOFF;OPOV POSITION	OPOV LIMIT RESET MCF	0007	750.119		2 MPTA	0.25	1	0.25	
MSFC PRACA	A08247	17-Jun-81	HYDRAULICS	ACT. CHECK-OUT MODULE FAILURE	OPOV POSITION FAILURE		Field			1	0	0	
SMEPB	Loss of Fuel to Both Preburners												6.25
UCR	A021548	2-Mar-89	F/M KI	KI PREDICTION NOT PER WATER FLOW	OFF M/R-DUE TO BAD FLOWMETER CONSTANT	2107	902.465	HPOTP TURBINE DISCHARGE TEMPERATURE	5 FPL/PH2	1	1	1	
UCR	A008918	11-Dec-85	S/W KI	PREMATURE C/O; OXID TURB TEMP R/L	INCORRECT FLOWMETER CONSTANT	2028	902.386	HPOTP TURBINE DISCHARGE TEMPERATURE	5 FPL/PH2	1	1	1	
UCR	A014574	24-Jul-86	SYSTEM	PREM. C/O; HPOTP TURB. DISC.TEMP	HIGH EFF HPFTURB/2 NOZ TUBE RUPT	2106	901.485	HPOTP TURBINE DISCHARGE TEMPERATURE	5 FPL/PH2	1	1	1	
UCR	A008884	14-Apr-83	F/M KI	F/M CALIBRATION CONSTANT ESTIMATE LOW	HIGH MIXTURE RATIO DUE TO KI	2011	902.309	HPOTP TURBINE DISCHARGE TEMPERATURE	4 FPL	0.75	1	0.75	
UCR	A015578	3-Nov-80	NOZZLE	TUBES 125 THRU 148 BLOWN INWARD	NOZZLE TUBE RUPTURES	2003	SF1101-B	HPFTP TURBINE DISCHARGE TEMPERATURE	2 MPTA	0.25	1	0.25	
UCR	A018556	22-Sep-79	SYSTEM	C/O-LOX TURBINE TEMP EXCEEDED REDLINE	OVERSHOOT AT THROTTLE DOWN	0105	750.047	HPOTP TURBINE DISCHARGE TEMPERATURE	3 FMOF	0.5	1	0.5	
UCR	A018855	13-Jun-79	NOZZLE	NOZZLE TUBE RUPTURES-HPOT R/L	TUBE RUPTURE (12) DOGGY DOORS	2004	902.162	HPOTP TURBINE DISCHARGE TEMPERATURE	3 FMOF	0.5	1	0.5	
UCR	A008345	22-May-79	NOZZLE	NUMEROUS TUBE LEAKS	TUBE LEAKS (13)	2004	902.158	HPOTP TURBINE DISCHARGE TEMPERATURE	3 FMOF	0.5	1	0.5	
UCR	A008466	14-May-79	NOZZLE	HPFT OVERTEMP REDLINE CUTOFF	NOZZLE STEERHORN FAILED	0201	750.041	HPFTP TURBINE DISCHARGE TEMPERATURE	2 MPTA	0.25	1	0.25	
UCR	A008316	10-May-79	NOZZLE	NOZZLE TUBE SPLITS -COOLANT LOSS	COLD WALL TUBE LEAKS (3)	2004	902.157	HPOTP TURBINE DISCHARGE TEMPERATURE	3 FMOF	0.5	1	0.5	
SMEVP	Failure to Maintain Proper Propellant Valve Position												0.25
UCR	A018563	28-Jan-81	SYSTEM	PREMATURE CUTOFF;OPOV POSITION	OPOV LIMIT RESET MCF	0007	750.119		2 MPTA	0.25	1	0.25	
MSFC PRACA	A08247	17-Jun-81	HYDRAULICS	ACT. CHECK-OUT MODULE FAILURE	OPOV POSITION FAILURE		Field			1	0	0	
SMELO	HPFTP Coolant Liner Overpressure												0.40
MSFC PRACA	A09162	22-Apr-81	TURBOMCHNERY	COOLNT LINER PRESS HAD ABNORMAL OSCILL	HPFTP COOLANT LINER OSCILLATIONS (SMALL OVERPRESSURE) - NO EFFECT-S1D		Field	HPFTP Coolant Liner Pressure		1	0.1	0.1	
MSFC PRACA	A09680	16-Oct-81	TURBOMCHNERY	COOLANT LINER PRESSURE INCREASED	COOLANT LINER PRESSURE LIMIT (115 PSI DELTA) EXCEEDED ; 270 PSI MARGIN TO REDLINE- S1J (PHASE II FIX SUGGESTED)		Field	HPFTP Coolant Liner Pressure		1	0.1	0.1	
MSFC PRACA	A11876	28-Sep-84	TURBOMCHNERY	PRES OSCILL OF HPFTP COOLANT LINER - IFA STS-26-E-4	SEE IFA STS-26-E-4, 140 PSI MARGIN TO		Field	HPFTP Coolant Liner Pressure		1	0.1	0.1	
MSFC PRACA	A15403	25-Apr-89	TURBOMCHNERY	SPIKED BELOW 300 PSID DURING STS-55 (IFA			Field	HPFTP Coolant Liner Pressure		1	0.1	0.1	

SSME/MPS Initiator Equivalent Flight Occurences Evaluation

SMEST	Critical Structural Failure of SSME Component											
Record Type	Record #	Date	System Element	NCA Nomenclature	NCA Part #	Failure Description from Record	Analyst Comments	Type	Configuration Applicability	Event Potentiality Factor	Weighting Factor	Equ. Flight Failures for Total Time
Cause ID		Initiator/Cause Description										
ANMCPSFPRPMLPOTP		STRUCTURAL FAILURE OF LPOTP										0.06
MSFC PRACA	A13505	1-Dec-86	TURBOMCHNERY	LPOTP U/N 4306	RS007801-191	LPOTP U/N 4306 HIGH BREAK AWAY IN VIOLATION OF OMRSD; ENGINE # 2012	LPOTP HIGH SHAFT TORQUE, BEARING DAMAGED	Field	1	0.02	0.02	
MSFC PRACA	A14010	1-Aug-87	TURBOMCHNERY	LPOTP U/N 2028	RS007801-191	LPOTP U/N 2028, HIGH BREAK AWAY TORQUE		Field	1	0.02	0.02	
MSFC PRACA	A14393	23-Nov-87	TURBOMCHNERY	LPOTP U/N 2030	RS007801-191	LPOTP U/N 2030 SHAFT SEIZED		Field	1	0.02	0.02	
ANMPSSFPRPMHPFSF		HPFTP IMPELLER/DIFFUSER FAILURE										0.08
MSFC PRACA	A08739	17-Oct-80	TURBOMCHNERY	RING, LOW PR ORIFICE	RS007559-009	EXCESSIVE WEAR, CRACKING, & RAISED MAT'L	COOLANT LINER PRESSURE DROPPED AT C/O & 4 SEC. HPFTP SPEED ROSE AT C/O (DAMAGE TO HPFTP, EXCESSIVE SHAFT TRAVEL, EXCESSIVE WEAR DUE TO IMBALANCE	Field	1	0.02	0.02	
MSFC PRACA	A08145	11-Apr-80	TURBOMCHNERY	IMPELLER	RS007556-013-25	IMPELLER CRACK	HPFTP IMPELLER CRACK - NO EFFECT	Field	1	0.02	0.02	
MSFC PRACA	A10076	27-May-82	TURBOMCHNERY	DIFFUSER	RS007532-091	IMPACT DAMAGE ON VANES	HPFTP IMPACT DAMAGE ON PUMP SIDE, UNKNOWN CONTAMINATION - SEEMED TO HAVE NO EFFECT BUT SOUNDED SERIOUS	Field	1	0.02	0.02	
MSFC PRACA	A10203	10-Jul-82	TURBOMCHNERY	DIFFUSER	RS007527-061	DIFFUSER NO. 8 VANE DENTED	HPFTP DIFFUSER NO 8 VANE DENTED BY IMPACT DAMAGE OF UNKNOWN CONTAMINATION - NO APPARENT EFFECT	Field	1	0.02	0.02	
ANMTBSFPRPMHPFTB		HPFTP TURBINE BLADE FAILURE										0.1
MSFC PRACA	A14130	1-Aug-87	TURBOMCHNERY	HPFT 1ST STG BLDS	R0019821-035	4007R3 HPFTP 1ST STAGE BLADE STOP FAILURE; ENGINE 2012		Field	1	0.02	0.02	
MSFC PRACA	A08076	27-Mar-80	TURBOMCHNERY	DISC 1ST STAGE ROTOR	RS007517-025	AU PLATE MISSING; CRACKS IN FIRTREE ROOTS	CRACKS IN FIRTREE ROOTS, HPFTP DISCH FIRST STAGE ROTOR	Field	1	0.02	0.02	
MSFC PRACA	A09265	26-Jun-81	TURBOMCHNERY	BLADE 1ST STAGE	R0019821-013	CRACK IN FIR TREE LOBES, 1ST STAGE BLADE, HPFTP, DISASSY INSP, CANOGA	CRACK IN FIRST STAGE BLADES - SOME INFO ON CRACKS FROM '79-'86	Field	1	0.02	0.02	
MSFC PRACA	A09461	21-Aug-81	TURBOMCHNERY	BLADE 1ST STAGE	R0019821-025	CRACK IN FIR TREE LOBES, 1ST STAGE BLADE, HPFTP, DISASSY INSP, CANOGA	CRACK IN FIRST STAGE BLADES - SOME INFO ON CRACKS FROM '79-'86	Field	1	0.02	0.02	
MSFC PRACA	A02960	4-May-77	TURBOMCHNERY	HPFTP	RS007501-261	TIP SEAL/NOZ VANES & SHROUD EROSION		Field	1	0.02	0.02	
ANMHOCDPRPMHPOCD		HPOTP FAILURE DUE TO CAVITATION DAMAGE										0.08
MSFC PRACA	A10062	1-May-82	TURBOMCHNERY	INLET VANE	RS007743-037	CAVITATION DAMAGE, INLET VANE	CAVITATION OF HPOTP - NO REDLINE, HIGHER THAN NORMAL HEAT LOSS	Field	1	0.02	0.02	
MSFC PRACA	A10069	26-May-82	TURBOMCHNERY	SEALS	RS007773-013	CAVITATION DAMAGE	CAVITATION OF HPOTP - NO REDLINE, HIGHER THAN NORMAL HEAT LOSS	Field	1	0.02	0.02	
MSFC PRACA	A10073	29-May-82	TURBOMCHNERY	IMPELLER	RS007718-043	CAVITATION DAMAGE	CAVITATION OF HPOTP - NO REDLINE, HIGHER THAN NORMAL HEAT LOSS	Field	1	0.02	0.02	
MSFC PRACA	A12023	19-Jan-85	TURBOMCHNERY	VANE, R.H.	RS007741-037	CAVITATION DAMAGE ON R.H. VANE, HPOTP		Field	1	0.02	0.02	
ANMOTSFPRPMHPOTB		HPOTP TURBINE BLADE FAILURE										0.06
MSFC PRACA	A09530	19-Sep-81	TURBOMCHNERY	HPOTP U/N 2016R3	RS007701-301	METAL PIECE LODGED IN 1ST STAGE NOZZLE	SHEET METAL SPOT WELD FAILURE WEDGED IN	Field	1	0.02	0.02	
MSFC PRACA	A01035						CRACK IN FIR TREE SHANK, 1ST STAGE BLADES HPO	Field	1	0.02	0.02	
MSFC PRACA	A12198	14-Apr-85	TURBOMCHNERY	TIP SEAL RETAINER	RS007913	TURBINE BLADE TIP SEAL GAP EXCEEDS SPEC, HPOTP U/N 4106R1	HPOTP TIP SEAL RETAINER - GAP REQ. EXCEEDED	Field	1	0.02	0.02	
ANMOTLCPRPMHPOTB		LOSS OF COOLANT TO HPOTP BEARINGS										0.04
MSFC PRACA	A06751	22-Jun-79	TURBOMCHNERY	STRUT TURB DISCHARGE	RS007779-021	JET PARTIALLY OBSTRUCTED	HPFTP CONTAMINATION (LOSS OF COOLANT), JET PARTIALLY OBSTRUCTED - NO EFFECT	Field	1	0.02	0.02	
MSFC PRACA	A12733	14-Feb-86	TURBOMCHNERY	ECCENTRIC RING	RS007879-005	ECCENTRIC RING FOUND CRUSHED POST STS-32	HPOTP ECCENTRIC RING FOUND CRUSHED, POST STS-32 (LOSS OF H2 COOLANT TO TURBINES POSSIBLE	Field	1	0.02	0.02	
ANMBBSFPRPMHPFTB		HPFTP THRUST BALL FAILURE										0.02
MSFC PRACA	A13928	3-Apr-87	TURBOMCHNERY	RING, ASSY OF	R0019213-001	IFA STS-37-E-1, HPFTP 9008 THRUST BALL CRACKED POST FLT.	HPFTP THRUST BALL CRACKED POST STS-37 - NO EFFECT	Field	1	0.02	0.02	
ANMNZSFPRPMHPONZ		HPOTP NOZZLE STRUCTURAL FAILURE										0.02
MSFC PRACA	A11642	29-Jul-84	TURBOMCHNERY	NOZZLE, 2ND STAGE	R0016027-21	2ND STAGE NOZZLE CRACKS IN TURNING VANES, HPOTP U/N 9008R2		Field	1	0.02	0.02	
ANMRRSFPRPMHPORR		HPOTP RETAINER RING FAILURE DUE TO LOSS OF BOLT PRELOAD										0.05
MSFC PRACA	A10074	29-May-82	TURBOMCHNERY	WASHER	RS007873-003	CRACKED CUPWASHERS, HPOTP, DISASSEMBLY	HPOTP CRACKED CUPWASHERS, RECURRING PROBLEM AS PER REPORT BUT CONSEQUENCES UNKNOWN	Field	1	0.01	0.01	

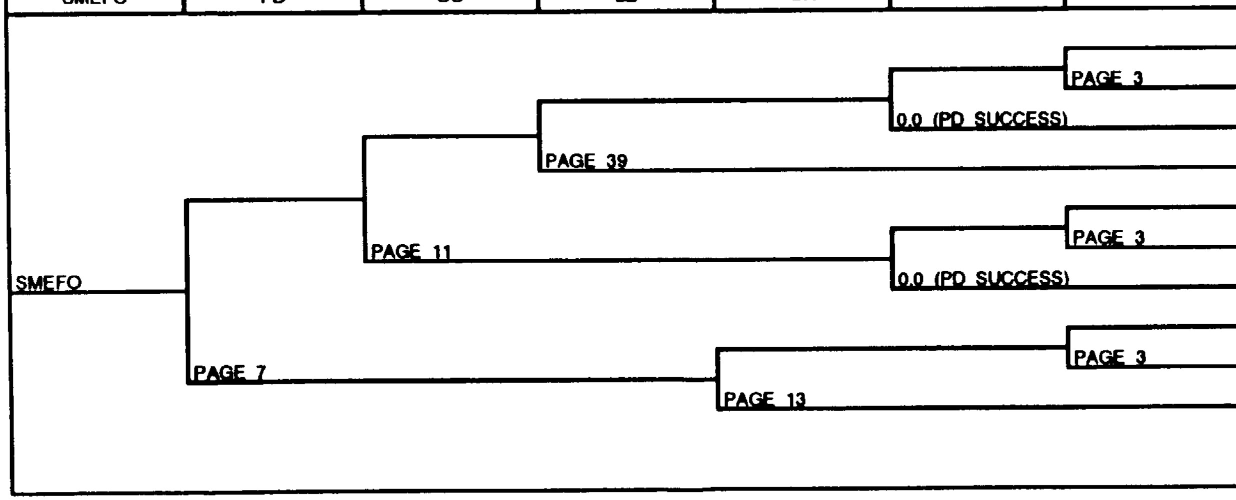
SSME/MPS Initiator Equivalent Flight Occurences Evaluation												
SMEST	Critical Structural Failure of SSME Component											
Record Type	Record #	Date	System Element	NCA Nomenclature	NCA Part #	Failure Description from Record	Analyst Comments	Type	Configuration Applicability	Event Potentiality Factor	Weighting Factor	Equ. Flight Failures for Total Time
Cause ID		Initiator/Cause Description										
MSFC PRACA	A10157	2-Jul-82	TURBOMCHNERY	CUPWASHER	RS007794-003	BROKEN CUPWASHER, HPOTP, DISASSEMBLY	HPOTP CRACKED CUPWASHERS, DEBRIS PEANS THE SURFACE OF THE MAIN IMPELLER OUTER SHROUD, RETAINERS RING AND SILVER SEAL AT THE PRESSURE SENSING ORIFICE AREA	Field	1	0.01	0.01	
MSFC PRACA	A10157	2-Jul-82	TURBOMCHNERY	CUPWASHER	RS007794-003	BROKEN CUPWASHER, HPOTP, DISASSEMBLY	HPOTP DIFFUSER MATERIAL MISSING AT RADIUS FILLET AREA - NO APPARENT EFFECT	Field	1	0.01	0.01	
MSFC PRACA	A12196	19-Apr-85	TURBOMCHNERY	CUPWASHERS	R032220-3	CUPWASHERS (3) ROTATED DURING HOT FIRE, HPOTP U/N 2222R1; ENGINE 2022	3 ROTATED CUPWASHERS IN HPOTP	Field	1	0.01	0.01	
MSFC PRACA	A12197	19-Apr-85	TURBOMCHNERY	CUPWASHERS	R032220-3	CUPWASHERS (2) ROTATED DURING HOT-FIRE, HPOTP 4105R1; ENGINE 2026	2 ROTATED CUPWASHERS	Field	1	0.01	0.01	
ANMOBSFPRPMHPOBR		HPOTP BEARING FAILURE DUE TO SPALLING, PITTING, WEAR OR CORR										0.18
MSFC PRACA	A11925	17-Dec-84	TURBOMCHNERY	TURBINE END #3 BRNG	RS007955-301	NO. 3 BEARING INNER RACE CRACK, HPOTP U/N 9109R1		Field	1	0.02	0.02	
MSFC PRACA	A05502	28-Aug-78	TURBOMCHNERY	HPOTP U/N 0007R2	RS007701-271	SPALLED BALLS AND SURFACE DISTRESS/RACES		Field	1	0.02	0.02	
MSFC PRACA	A05502	28-Aug-78	TURBOMCHNERY	HPOTP U/N 0007R2	RS007701-271	SPALLED BALLS AND SURFACE DISTRESS/RACES	SPALLED BALLS & SURFACE DISTRESS OF RACES (CAUSED SUB SYN VIB - MAYBE STRUCTURAL	Field	1	0.02	0.02	
MSFC PRACA	A05503	26-Aug-78	TURBOMCHNERY	HPOTP U/N 0007R2	RS007701-271	SURFACE DISTRESS ON RACES		Field	1	0.02	0.02	
MSFC PRACA	A06344	3-Apr-79	TURBOMCHNERY	HPOTP U/N 2404	33DRS007701-171	SPALLED BALLS AND GAGE DELAMINATION		Field	1	0.02	0.02	
MSFC PRACA	A11925	17-Dec-84	TURBOMCHNERY	TURBINE END #3 BRNG	RS007955-301	NO. 3 BEARING INNER RACE CRACK, HPOTP U/N 9109R1	HPOTP #3,4 BEARING (TURBINE END) INNER FACE FAILURE - PUMP OPERATED W/ HIGH SYNCHRONOUS VIBRATION DURING STS-27 ECP 1046 REDESIGN	Field	1	0.02	0.02	
MSFC PRACA	A11969	20-Jan-85	TURBOMCHNERY	BEARING #4	RS007955-301	CRACKS IN #4 TURBINE END BEARING RACE, HPOTP U/N 9109R1	HPOTP #3,4 BEARING (TURBINE END) INNER FACE FAILURE - PUMP OPERATED W/ HIGH SYNCHRONOUS VIBRATION DURING STS-27 ECP 1046 REDESIGN	Field	1	0.02	0.02	
MSFC PRACA	A14156	1-Aug-87	TURBOMCHNERY	HPOTP U/N 4009R3	RS007701-531	HPOTP U/N 4009R3 STRAIN GAGE DATA DISCREPANCY; BEARING WEAR		Field	1	0.02	0.02	
MSFC PRACA	A14792	23-Mar-88	TURBOMCHNERY	HPOTP U/N 4305R2	RS007701-531	HPOTP U/N 4305R2 BEARING CAGE FREQUENCIES		Field	1	0.02	0.02	
ANMHOEVPRPMHPOEV		HPOTP EXCESSIVE VIBRATION										0.02
MSFC PRACA	A15189	12-Jan-89	TURBOMCHNERY	HPOTP	RS007701-591	HIGH SYNCHRONOUS VIBRATIONS ON HPOTP U/N 9409; STS-64		Field	1	0.02	0.02	
ANMLPSFPRPMMI	MI LOX POST STRUCTURAL FAILURE											0.06
MSFC PRACA	A05916	16-Dec-78	COMBUSTION	MAIN INJECTOR	RS009122-391	SLIGHT LOX POST EROSION		Field	1	0.02	0.02	
MSFC PRACA	A08769	22-Oct-80	COMBUSTION	RETAINER	RS009133-011	RETAINER BURN THRU & GALLING		Field	1	0.02	0.02	
MSFC PRACA	A09173	3-May-81	COMBUSTION	MAIN INJECTOR	RS009122-801	H/S RETAINER DAMAGE		Field	1	0.02	0.02	
ANMBESFPRPMMIBE		BAFFLE ELEMENT INNER COPPER JACKET BURNTHROUGH										0.02
MSFC PRACA	08707/A0870	7-Oct-80	COMBUSTION	BAFFLE ELEMENT	R0019527-091	INNER COPPER JACKET BURN THROUGH		Field	1	0.02	0.02	
ANMFAERPRPMFPASI		EXTERNAL RUPTURE OF FPB ASI LOX LINE										0.02
MSFC PRACA	A07144	29-Aug-79	ENGINE	ENGINE SYSTEM	RS007001-061	FPB-ASI LOX LINE RUPTURED		Field	1	0.02	0.02	
ANMFPSFPRPMFPBFP		FPB FACEPLATE FAILURE DUE TO EROSION										0.06
MSFC PRACA	A04677	18-Apr-78	COMBUSTION	FPB INJECTOR	RS009020-601	INJECTOR FACE EROSION		Field	1	0.02	0.02	
MSFC PRACA	A09846	25-Nov-81	COMBUSTION	FPB INJECTOR	RS009020-821	EROSION ON INJECTOR FACEPLATE		Field	1	0.02	0.02	
MSFC PRACA	A09917	28-Jan-82	COMBUSTION	FPB INJECTOR	RS009020-771	EROSION AND SLAG ON INJECTOR FACEPLATE		Field	1	0.02	0.02	

SSME/MPS Initiator Equivalent Flight Occurences Evaluation				Nominal Ope
Initiator ID	Cause ID	Description	Source	Equivalent Flight Failures for Total Exposure Time
SMEST		Structural Failure of SSME Components Leading to LOV		0.00
	ANMMWSFPRPMMCCMW	MCC MANIFOLD WELD FAILURE	MCC PRA	0.10
	ANMEDDBPRPMEDNCO	FAILURE IN EDNI LINER CLOSEOUT STRUCTURE	MCC PRA	0.07
	ANMHWCRPRPMMCCHW	MCC HOT GAS WALL FAILURE DUE TO UNSTABLE CRACK GROWTH	MCC PRA	0.02
	ANMFRBTPRPMFRI	FAILURE OF FLOW RECIRCULATION INHIBITOR	MCC PRA	0.02
	ANMCCCRPRPMMCCCC	FAILURE OF MCC COOLANT CHANNEL DUE TO UNSTABLE CRACK GROWTH	MCC PRA	0.00
	ANMMBSFPRPMMCCBP	MCC MULTIPLE BOLT FAILURE DUE TO INADEQUATE PRELOAD	MCC PRA	0.04
	ANMHMWFPRPMHGMWF	HGM TRANSFER TUBE WELD FAILURE	WELD STUDY	0.01
SMEHL		Hydraulic Lock-up Required	PRA APU Analysis	1.59
SMELP		Propellant Management System And/Or SSME Combustible Leakage	Lockheed PRA	0.32
SMELH		Helium System Leakage	Lockheed PRA	0.26
SMEPG		Failure To Provide Helium Pogo Charge	NPRD-3	0.24
SMEPV		Failure To Maintain Propellant Supply System Valve Positions	MPS F.R.D., NPRD91	
SMEDS		Simultaneous Dual SSME Shutdown	See Fault Tree in Next Section	
SMECD		Nominal MECO & Dump; No Mainstage Initiators	PRA Preliminary Results	

SSME/MPS Initiator Frequency Summary

			Total Exposure Time	621491	sec		
			Nominal Operation Time	520	sec		
Initiator ID	Initiator Description	Equivalent Flight Occurrences for Total Exposure Time	One Engine Initiator Freq (per mission)	Cluster Initiator Freq (per mission)	Mean # of Missions Between Occurrences	Percent of Non-nominal Initiators	Development
SMEFO	Loss of MCC Pressure	4.00	3.35E-03	1.00E-02	100	25.87%	Event Tree 1
SMEFH	Loss of Gross H2 Flow	0.50	4.18E-04	1.25E-03	797	3.24%	Event Tree 2
SMEMO	High Mixture Ratio in Oxidizer Preburner	0.25	2.09E-04	6.27E-04	1594	1.62%	Event Tree 3
SMEMF	High Mixture Ratio in Fuel Preburner	0.25	2.09E-04	6.27E-04	1594	1.62%	Event Tree 4
SMEPB	Loss of Fuel to Both Preburners	6.25	5.23E-03	1.56E-02	64	40.34%	Event Tree 5
SMEVP	Failure to Maintain Proper SSME Propellant Valve Position	0.25	2.09E-04	6.27E-04	1594	1.62%	Event Tree 6
SMELO	HPFTP Coolant Liner Overpressure	0.40	3.35E-04	1.00E-03	996	2.59%	Event Tree 7
SMEST	Critical Structural Failure of SSME Components	1.13	9.53E-04	2.85E-03	350	7.38%	Fault Trees-Page 55
SMEHL	Hydraulic Lock-up Required	1.59	1.33E-03	4.00E-03	250	10.34%	Event Tree 8
SMELP	Propellant Management System And/Or SSME Combustible Leakage	0.32	2.65E-04	7.96E-04	1256	2.06%	Fault Trees-Page 54
SMELH	Helium System Leakage	0.26	2.15E-04	6.46E-04	1548	1.67%	Event Tree 9
SMEPG	Failure To Provide Helium Pogo Charge	0.24	2.02E-04	6.05E-04	1653	1.56%	Event Tree 10
SMEPV	Failure To Maintain Propellant Supply System Valve Positions	0.01		1.89E-05	52910	0.05%	Fault Trees-Page 65
SMEDS	Simultaneous Dual SSME Shutdown	0.00		1.00E-05	100000	0.03%	Fault Trees-Page 53 Event Tree 11
SMECD	Nominal MECO & Dump; No Mainstage Initiators	376		9.43E-01	1.060		Event Tree 12

INITIATOR	PROTECTIVE EVENTS					MITIGATING EVENT
LOSS OF MCC PRESSURE	Pc PRESSURE DROP DETECTED.	CONTROLLER INCREASES O2 TO OPB	OPOV COMMAND LIMIT ENGAGED	HPOTP TD TEMP REDLINE DETECTED	MCC Pc REDLINE DETECTED	EMERGENCY HYDRAULIC SHUTDOWN
SMEFO	PD	OO	LE	OR	PR	EH



SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#	TRANSFER TO
9.97E-03	OK abort		1	
1.16E-08	LOV	FO/EH	2	
0.00E+00	LOV	FO/PR	3	
2.30E-05	TRANSFER	FO/LE	4	SMEMO EVENT TREE
1.00E-06	OK abort		5	
1.16E-12	LOV	FO/OO/EH	6	
0.00E+00	LOV	FO/OO/PR	7	
1.50E-06	OK abort		8	
1.74E-12	LOV	FO/PD/EH	9	
2.25E-10	LOV	FO/PD/OR	10	

LOSS OF GROSS O2 FLOW EVENT TREE 1 REV. 1

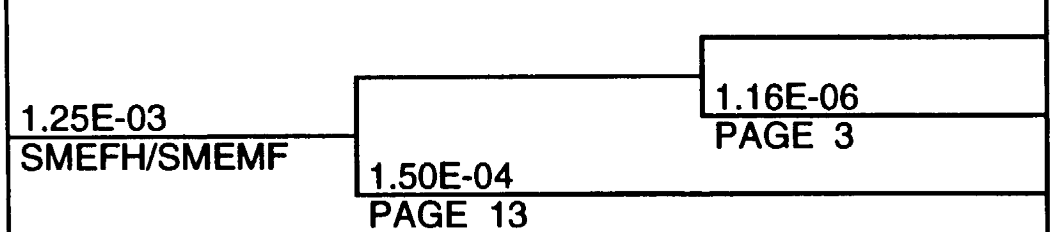
TRANSFER	PROTECTIVE EVENT	MITIGATING EVENT	SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
HIGH MIXTURE RATIO IN OPB	HPOTP DT REDLINE DETECTED	EMERGENCY HYDRAULIC SHUTDOWN				
SMEFO/SMEMO	OR	EH				
2.30E-05 SMEFO/SMEMO			2.30E-05	OK abort		1
		1.16E-06 PAGE 3	2.67E-11	LOV	MO/EH	2
	1.50E-04 PAGE 13		3.45E-09	LOV	MO/OR	3

HIGH MIXTURE RATIO IN OXIDIZER PREBURNER EVENT TREE 1A REV. 1

INITIATOR	PROTECTIVE EVENT	SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#	TRANSFER TO
LOSS OF GROSS H2 FLOW	CONTROLLER INCREASES O2 FLOW TO FPB					
SMEFH	OF					
SMEFH		1.25E-03	TRANSFER		1	SMEMF EVENT TREE
	PAGE 9	1.25E-07	TRANSFER	FH/OF	2	SMEPB EVENT TREE

LOSS OF GROSS H2 FLOW EVENT TREE 2 REV. 1

TRANSFER	PROTECTIVE EVENT	MITIGATING EVENT	SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
HIGH MIXTURE RATIO IN FPB	HPFTP DT REDLINE DETECTED	EMERGENCY HYDRAULIC SHUTDOWN				
SMEFH/SMEMF	FR	EH				



SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
1.25E-03	OK abort		1
1.45E-09	LOV	MF/EH	2
1.88E-07	LOV	MF/FR	3

HIGH MIXTURE RATIO IN FUEL PREBURNER EVENT TREE 2A REV. 1

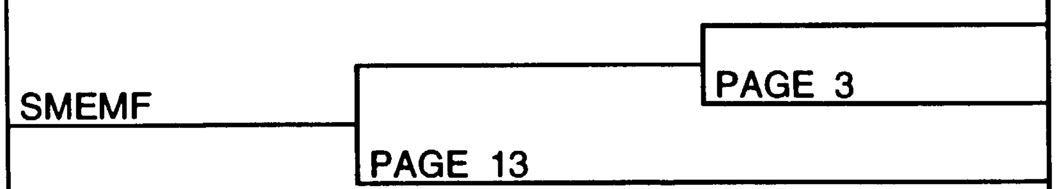
TRANSFER	PROTECTIVE EVENT	MITIGATING EVENT	SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
LOSS OF FUEL TO BOTH PREBURNERS	HPFTP OR HPOTP DT REDLINE DETECTED	EMERGENCY HYDRAULIC SHUTDOWN				
SMEFH/SMEPB	TR	EH				
1.25E-07 SMEFH/SMEPB			1.25E-07	OK abort		1
		1.16E-06 PAGE 3	1.45E-13	LOV	PB/EH	2
	2.25E-08 PAGE 13		2.81E-15	LOV	PB/TR	3

LOSS OF FUEL TO BOTH PREBURNERS EVENT TREE 2B REV. 1

INITIATOR	PROTECTIVE EVENT	MITIGATING EVENT	SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
HIGH MIXT. RATIO IN OPB	HPOTP DT REDLINE DETECTED	EMERGENCY HYDRAULIC SHUTDOWN				
SMEMO	OR	EH				
			6.27E-04	OK abort		1
6.27E-04 SMEMO		1.16E-06 PAGE 3	7.27E-10	LOV	MO/EH	2
	1.50E-04 PAGE 13		9.41E-08	LOV	MO/OR	3

HIGH MIXTURE RATIO IN OXIDIZER PREBURNER EVENT TREE 3 REV. 1

INITIATOR	PROTECTIVE EVENT	MITIGATING EVENT	SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
HIGH MIXTURE RATIO IN FPB	HPFTP DT REDLINE DETECTED	EMERGENCY HYDRAULIC SHUTDOWN				
SMEMF	FR	EH				



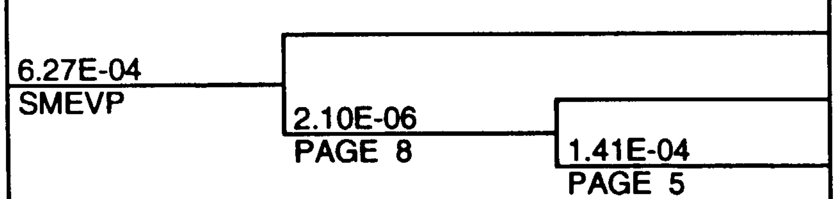
SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
6.27E-04	OK abort		1
7.27E-10	LOV	MF/EH	2
9.41E-08	LOV	MF/FR	3

HIGH MIXTURE RATIO IN FUEL PREBURNER EVENT TREE 4 REV. 1

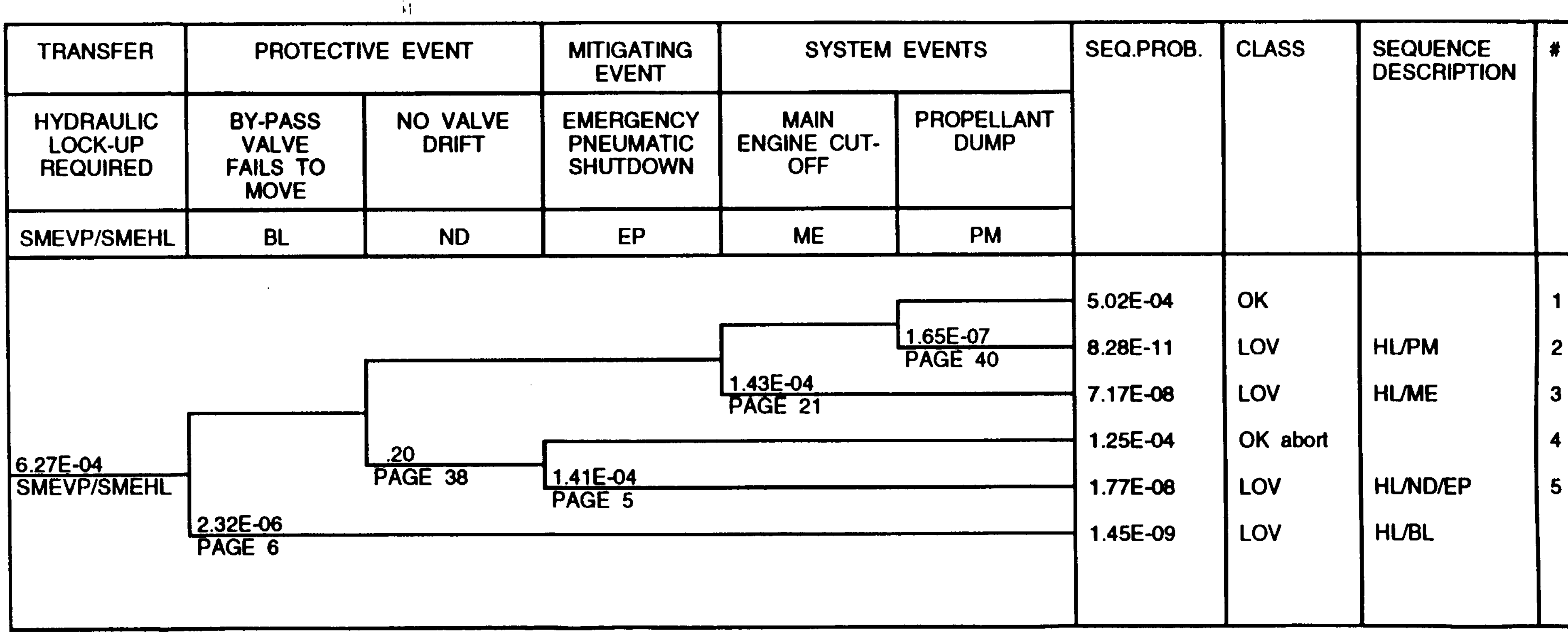
INITIATOR	PROTECTIVE EVENT	MITIGATING EVENT	SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
LOSS OF FUEL TO BOTH PREBURNERS	HPFTP OR HPOTP DT REDLINE DETECTED	EMERGENCY HYDRAULIC SHUTDOWN				
SMEPB	TR	EH				
SMEPB			1.56E-02	OK abort		1
		PAGE 3	1.81E-08	LOV	PB/EH	2
	PAGE 13		3.51E-10	LOV	PB/TR	3

LOSS OF FUEL TO BOTH PREBURNERS EVENT TREE 5 REV. 1

INITIATOR	MITIGATING EVENTS		SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#	TRANSFER TO
FAILURE TO MAINTAIN SSME VALVE POSITIONS	FAIL-SAFE SERVOSWITCH WORKS	EMERGENCY PNEUMATIC SHUTDOWN					
SMEVP	HL	EP					
			6.27E-04	TRANSFER		1	SMEHL EVENT TREE
			1.32E-09	OK abort		2	
			1.86E-13	LOV	VP/HL/EP	3	

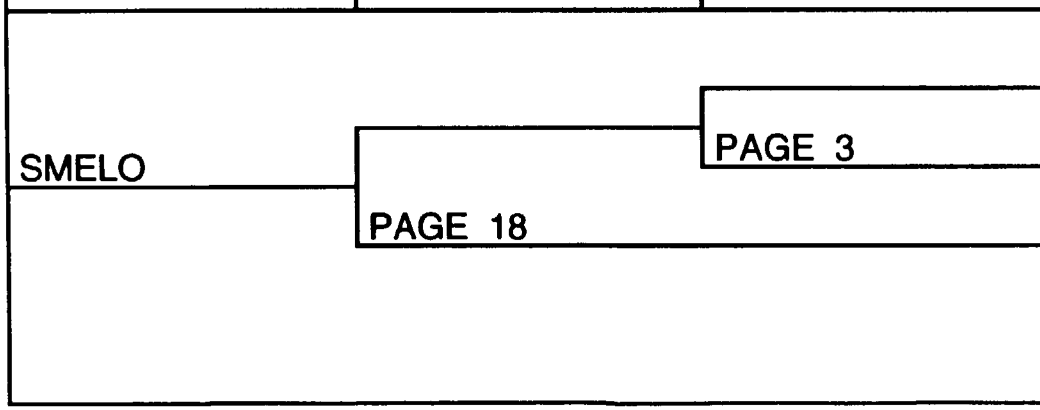


FAILURE TO MAINTAIN SSME VALVES POSITION EVENT TREE 6 REV. 1



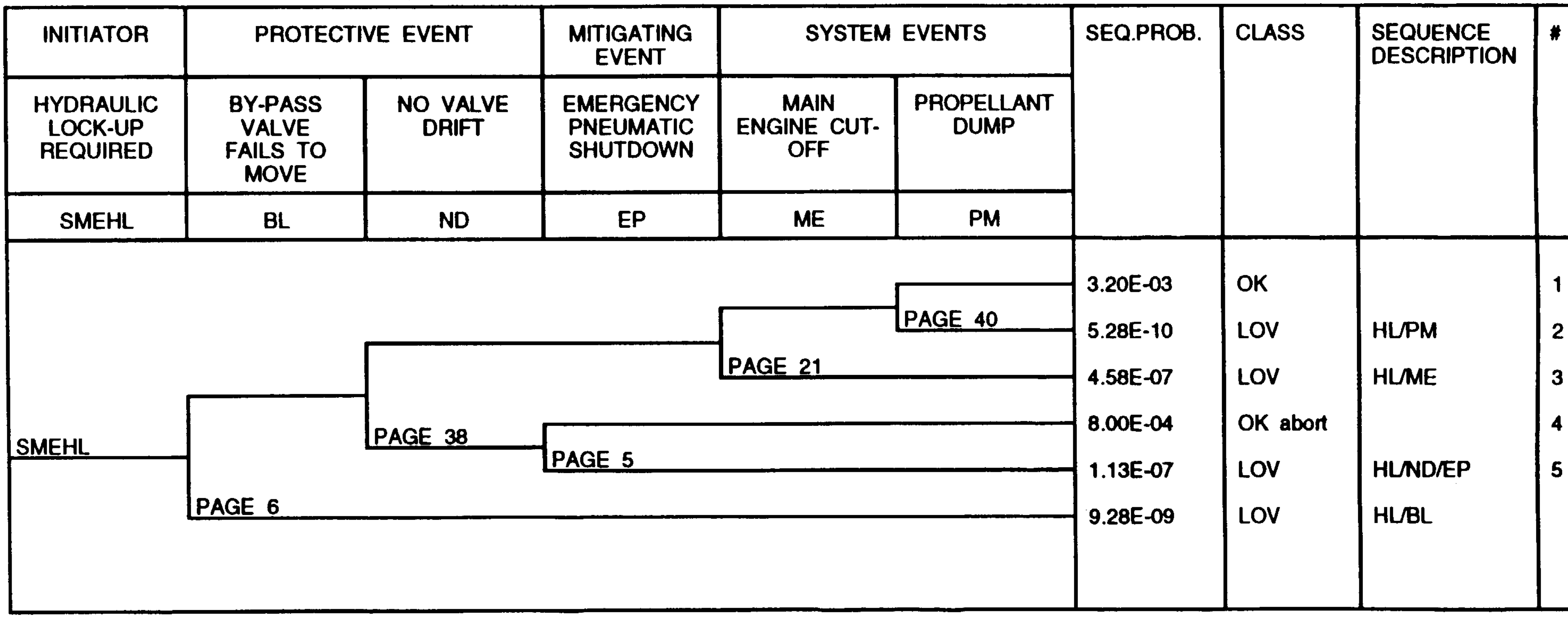
FAILURE TO PERFORM HYDRAULIC LOCK-UP EVENT TREE 6A REV. 1

INITIATOR	PROTECTIVE EVENT	MITIGATING EVENT	SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
COOLANT LINER OVERPRESSURE.	REDLINE DETECTED	EMERGENCY HYDRAULIC SHUTDOWN				
SMELO	OP	EH				



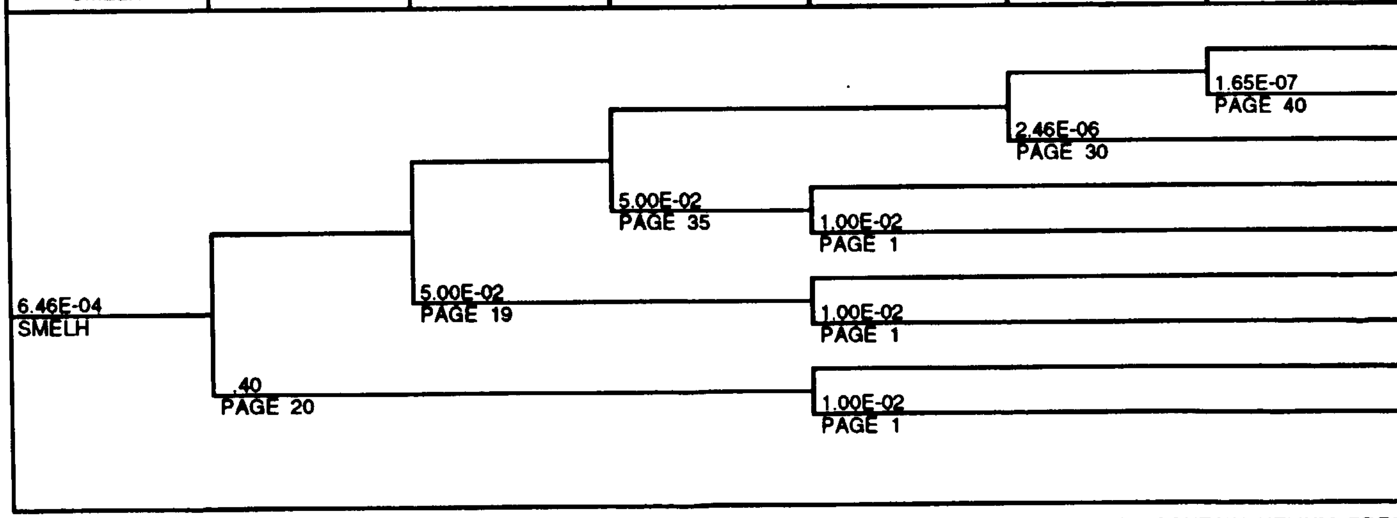
SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
1.00E-03	OK abort		1
1.16E-09	LOV	LO/EH	2
1.50E-07	LOV	LO/OP	3

COOLANT LINER OVERPRESSURE EVENT TREE 7 REV. 1



FAILURE TO PERFORM HYDRAULIC LOCK-UP EVENT TREE 8 REV. 1

INITIATOR	PROTECTIVE EVENT	MITIGATING EVENTS			SYSTEM EVENTS		SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
FAILURE TO CONTAIN HELIUM PRESSU RE BOUNDARY	HELIUM LEAKAGE IS ISOLATABLE	HELIUM LEAKAGE ISOLATED	ALTERNATIVE HELIUM SUPPLY AVAILABLE	MANUAL HYDRALIC SHUTDOWN	MAIN ENGINE CUT-OFF	PROPELLANT DUMP				
SMELH	IL	IH	AH	EM	ME	PM				



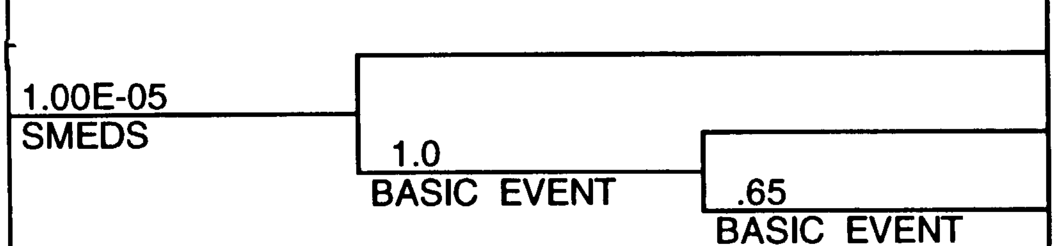
SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
3.52E-04	OK		1
5.81E-11	LOV	LH/PM	2
8.66E-10	LOV	LH/ME	3
1.83E-05	OK abort		4
1.85E-07	LOV	LH/AH/EM	5
1.93E-05	OK abort		6
1.95E-07	LOV	LH/IH/EM	7
2.53E-04	OK abort		8
2.56E-06	LOV	LH/IL/EM	9

FAILURE TO CONTAIN HELIUM PRESSURE BOUNDARY EVENT TREE 9 REV. 1

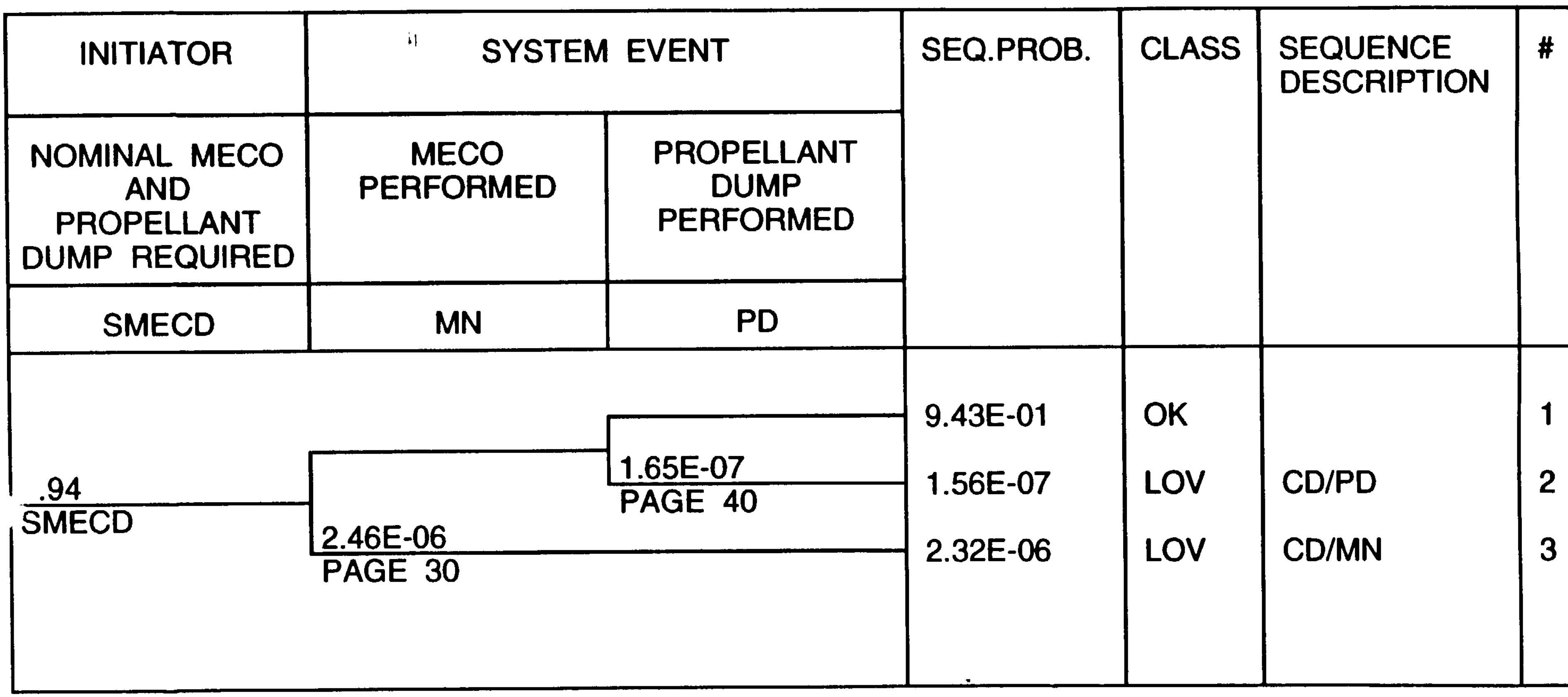
INITIATOR	PROTECTIVE EVENT	MITIGATING EVENT	SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
FAILARE TO PRECHARGE POGO ACC.	LOW POGO PRESSURE DETECTED	EMERGENCY HYDRAULIC SHUTDOWN				
SMEPG	PP	EH				
			6.05E-04	OK abort		1
SMEPG		PAGE 3	7.02E-10	LOV	PG/EH	2
	BASIC EVENT		9.08E-08	LOV	PG/PP	3

FAILURES DURING POGO ACCUMULATOR PRECHARGE EVENT TREE 10 REV. 1

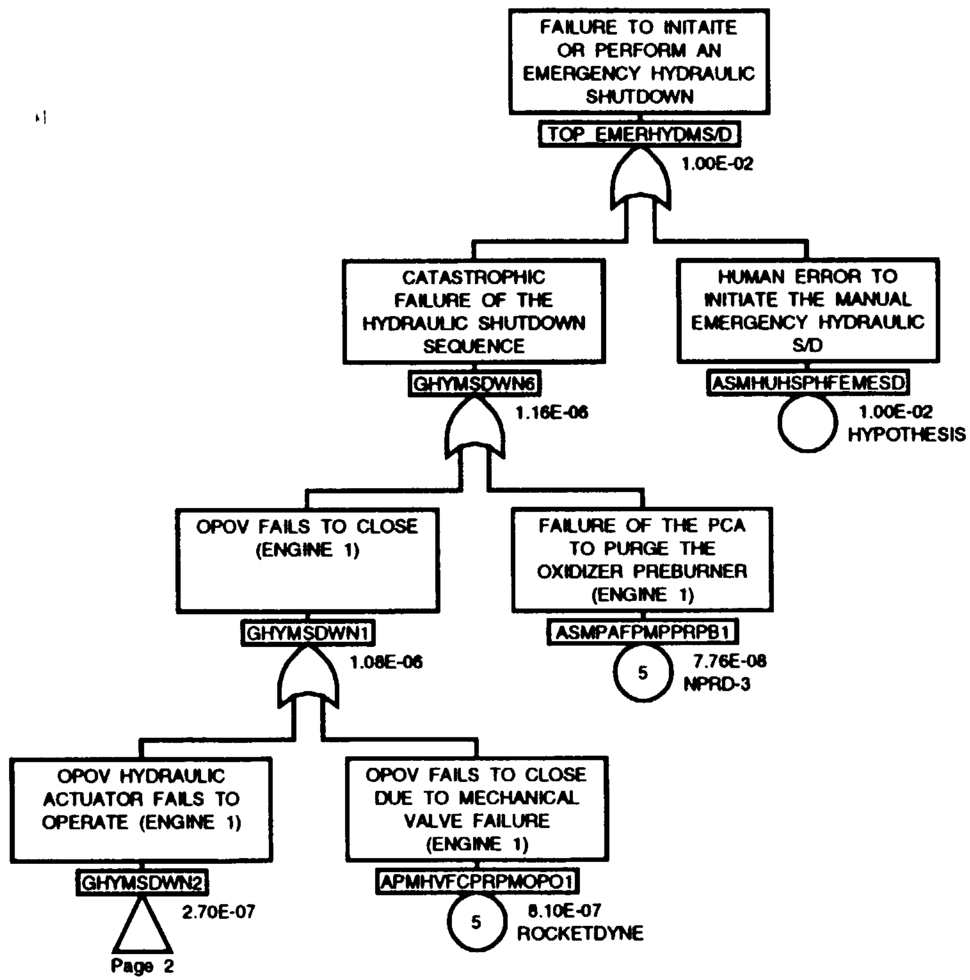
INITIATOR	MITIGATIVE EVENT		SEQ.PROB.	CLASS	SEQUENCE DESCRIPTION	#
DUAL SSME PREMATURE SHUTDOWN	DUAL SSME PREMATURE S/D BEFORE LIFT-OFF	DUAL SSME PREMATURE S/D AFTER DROOP(109)				
SMEDS	BL	AC				
			0.00E+00	OK abort		1
			3.54E-06	OK abort		2
			6.46E-06	LOV	DS/BL/AC	3

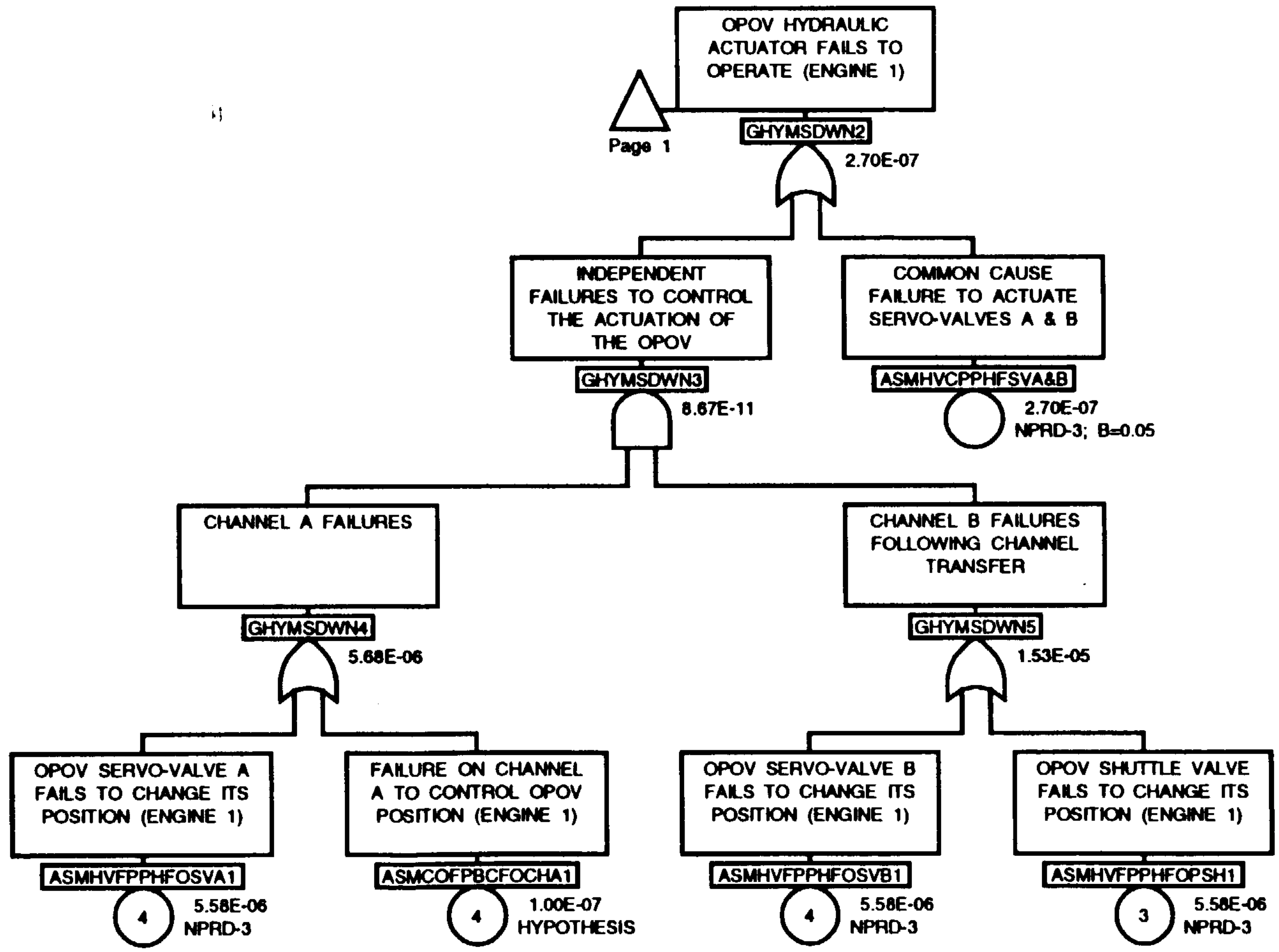


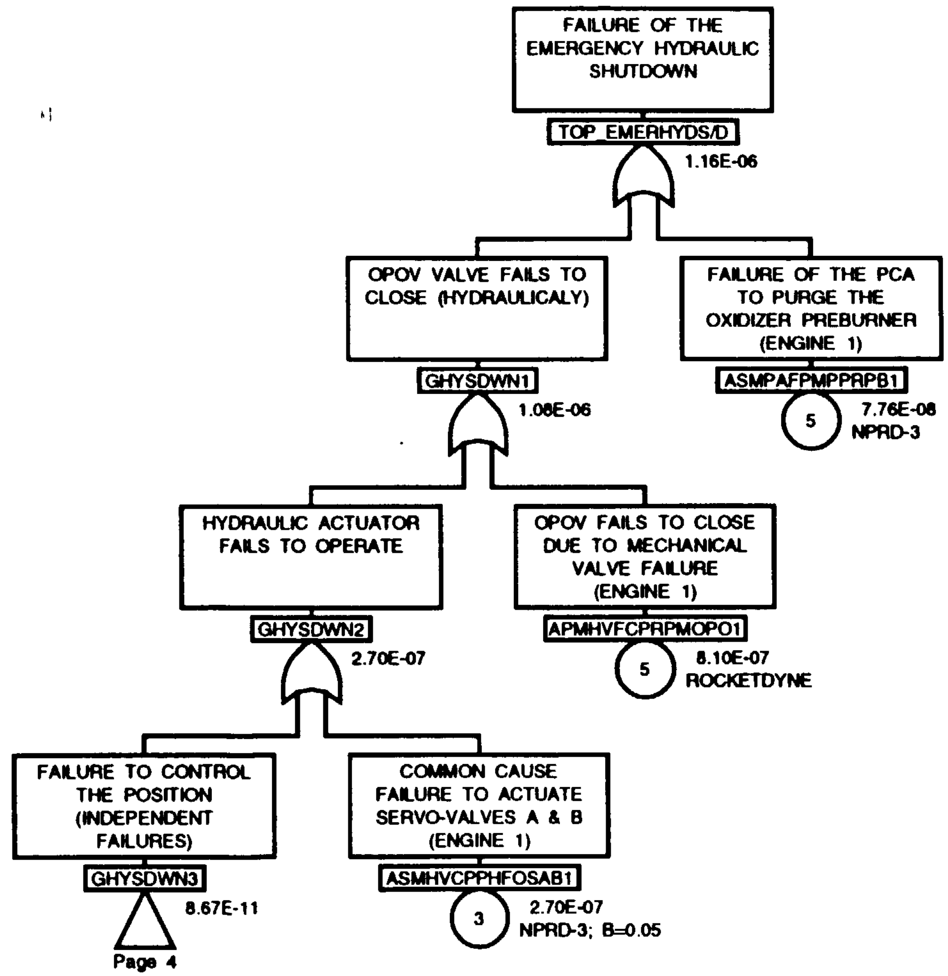
DUAL SSME PREMATURE SHUTDOWNEVENT TREE 11 REV. 1

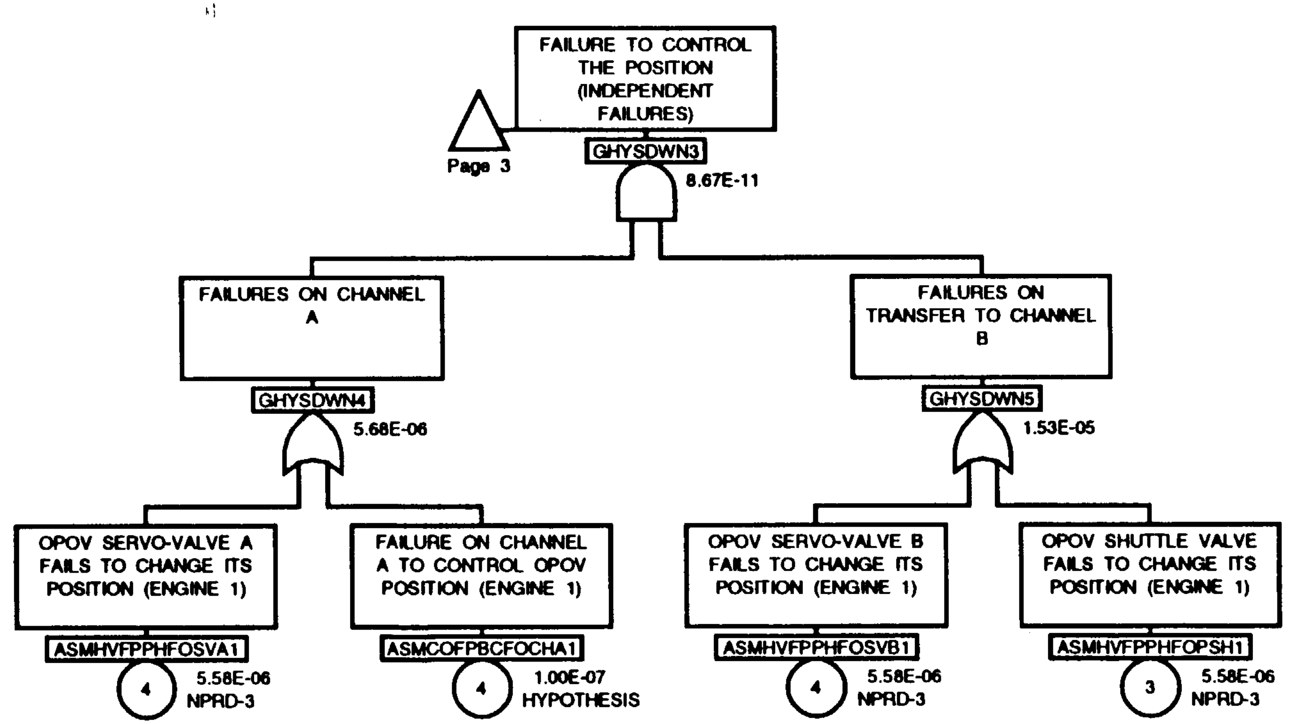


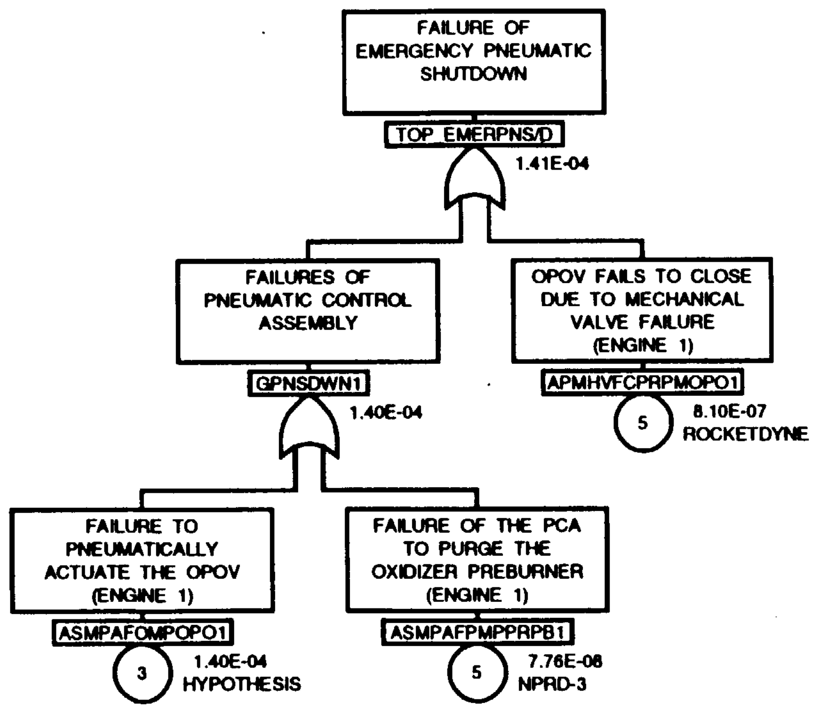
FAILURE TO PERFORM NOMINAL MECO & PROPELLANT DUMP EVENT TREE 12 REV. 1

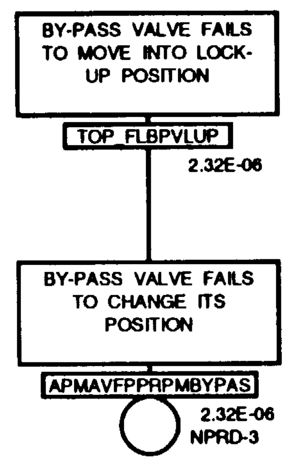

FAILURE TO INITAITE OR PERFORM AN EMERGENCY HYDRAULIC SHUTDOWN
TOP EMERHYDMS/D
1.00E-02
CATASTROPHIC FAILURE OF THE HYDRAULIC SHUTDOWN SEQUENCE
GHYMSDWN6
1.16E-06
HUMAN ERROR TO INITIATE THE MANUAL EMERGENCY HYDRAULIC S/D
ASMHUHSPHFEMESD
1.00E-02
HYPOTHESIS
OPOV FAILS TO CLOSE (ENGINE 1)
GHYMSDWN1
1.08E-06
FAILURE OF THE PCA TO PURGE THE OXIDIZER PREBURNER (ENGINE 1)
ASMPAFPMPPRPB1
5
7.76E-08
NPRD-3
OPOV HYDRAULIC ACTUATOR FAILS TO OPERATE (ENGINE 1)
GHYMSDWN2
2.70E-07
Page 2
OPOV FAILS TO CLOSE DUE TO MECHANICAL VALVE FAILURE (ENGINE 1)
APMHVFCPRPMOPO1
5
8.10E-07
ROCKETDYNE

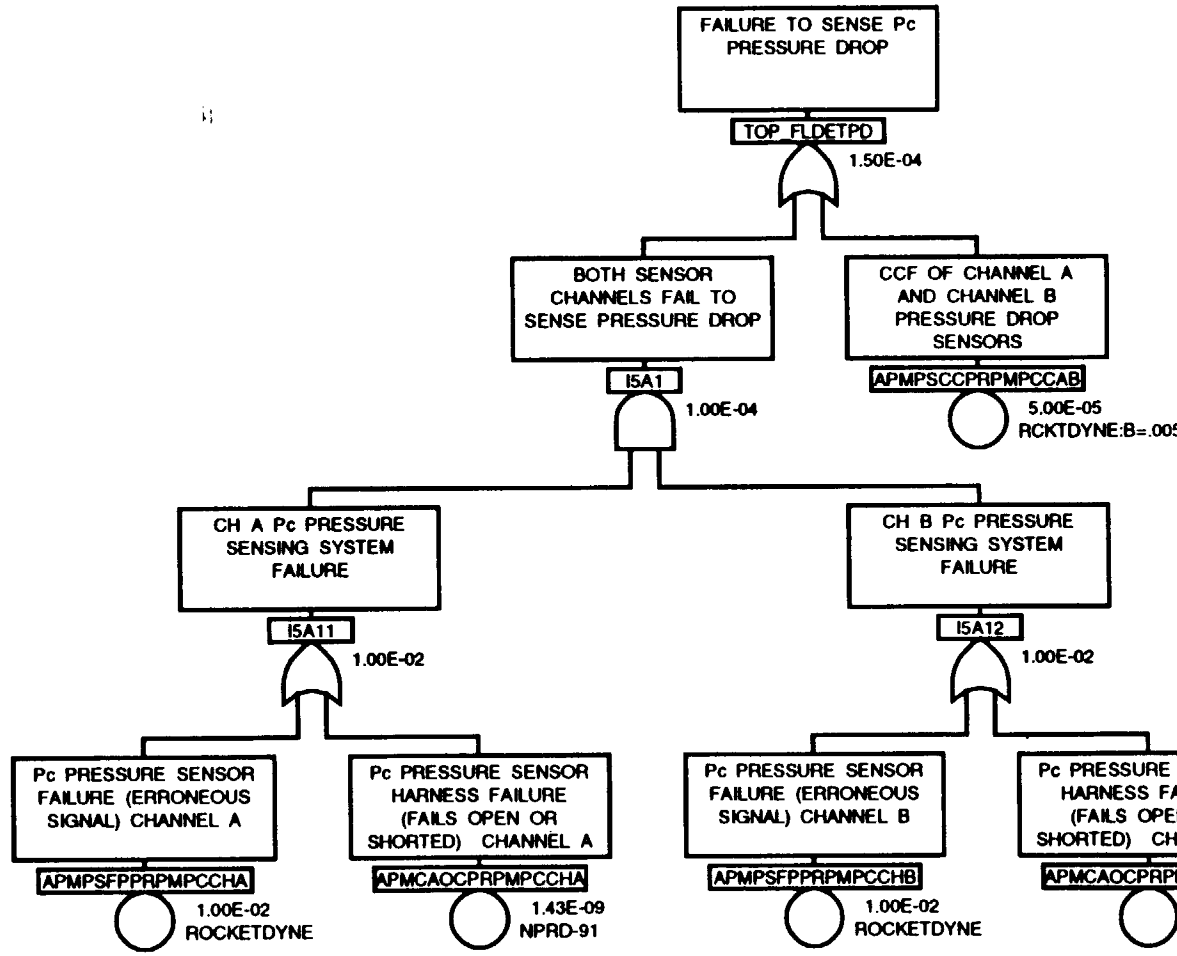

OPOV HYDRAULIC ACTUATOR FAILS TO OPERATE (ENGINE 1)
Page 1
GHYMSDWN2
2.70E-07
INDEPENDENT FAILURES TO CONTROL THE ACTUATION OF THE OPOV
GHYMSDWN3
8.67E-11
COMMON CAUSE FAILURE TO ACTUATE SERVO-VALVES A & B
ASMHVCPPHFSVA&B
2.70E-07
NPRD-3; B=0.05
CHANNEL A FAILURES
GHYMSDWN4
5.68E-06
CHANNEL B FAILURES FOLLOWING CHANNEL TRANSFER
GHYMSDWN5
1.53E-05
OPOV SERVO-VALVE A FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFOSVA1
4
5.58E-06
NPRD-3
FAILURE ON CHANNEL A TO CONTROL OPOV POSITION (ENGINE 1)
ASMCOFPBCFOCHA1
4
1.00E-07
HYPOTHESIS
OPOV SERVO-VALVE B FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFOSVB1
4
5.58E-06
NPRD-3
OPOV SHUTTLE VALVE FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFOPSH1
3
5.58E-06
NPRD-3


FAILURE OF THE EMERGENCY HYDRAULIC SHUTDOWN
TOP_EMERHYDS/D
1.16E-06
OPOV VALVE FAILS TO CLOSE (HYDRAULICALY)
GHYSDWN1
1.08E-06
FAILURE OF THE PCA TO PURGE THE OXIDIZER PREBURNER (ENGINE 1)
ASMPAFPMPPRPB1
5
7.76E-08
NPRD-3
HYDRAULIC ACTUATOR FAILS TO OPERATE
GHYSDWN2
2.70E-07
OPOV FAILS TO CLOSE DUE TO MECHANICAL VALVE FAILURE (ENGINE 1)
APMHVFCPRPMOPO1
5
8.10E-07
ROCKETDYNE
FAILURE TO CONTROL THE POSITION (INDEPENDENT FAILURES)
GHYSDWN3
8.67E-11
Page 4
COMMON CAUSE FAILURE TO ACTUATE SERVO-VALVES A & B (ENGINE 1)
ASMHVCPPHFOSAB1
3
2.70E-07
NPRD-3; B=0.05

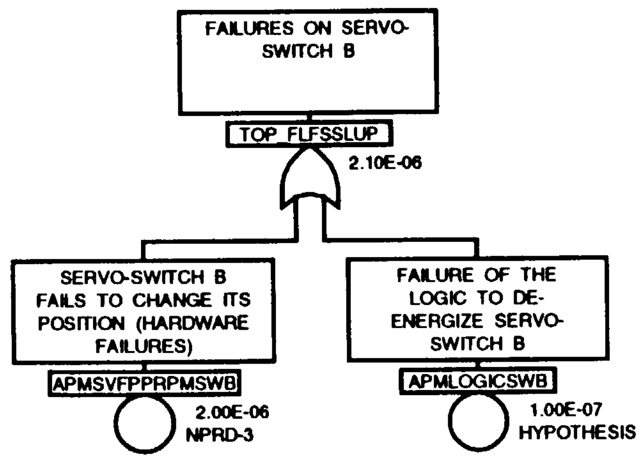

FAILURE TO CONTROL THE POSITION (INDEPENDENT FAILURES)
Page 3
GHYSDWN3
8.67E-11
FAILURES ON CHANNEL A
GHYSDWN4
5.68E-06
FAILURES ON TRANSFER TO CHANNEL B
GHYSDWN5
1.53E-05
OPOV SERVO-VALVE A FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFOSVA1
4
5.58E-06
NPRD-3
FAILURE ON CHANNEL A TO CONTROL OPOV POSITION (ENGINE 1)
ASMCOFPBCFOCHA1
4
1.00E-07
HYPOTHESIS
OPOV SERVO-VALVE B FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFOSVB1
4
5.58E-06
NPRD-3
OPOV SHUTTLE VALVE FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFOPSH1
3
5.58E-06
NPRD-3

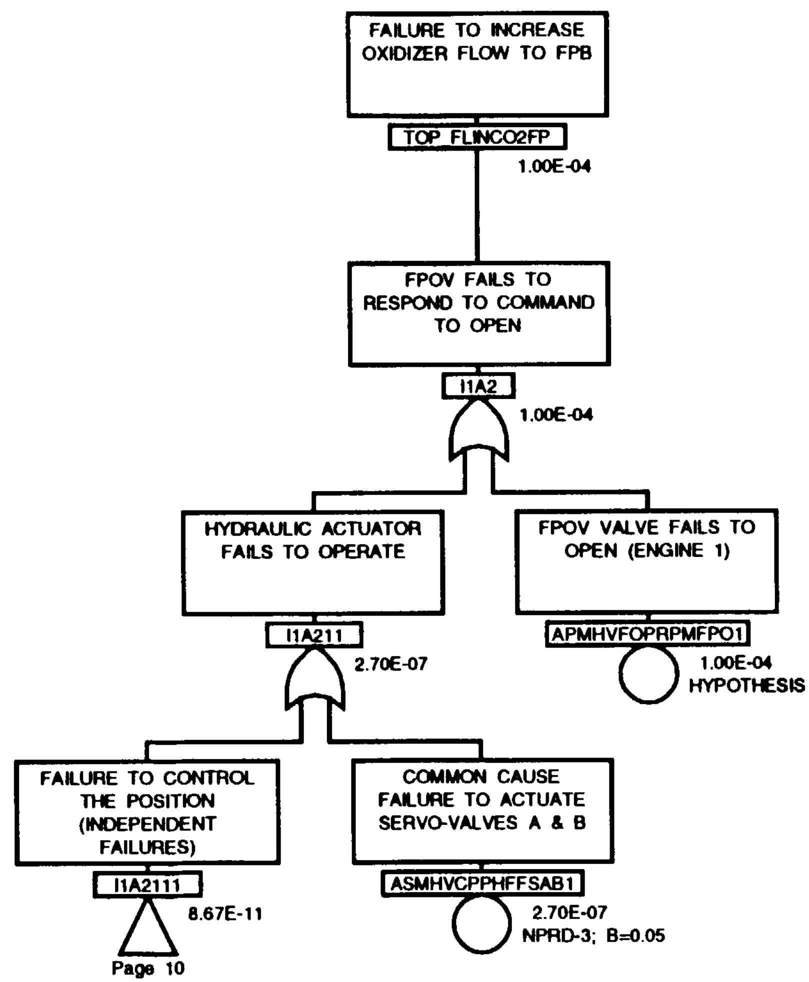

FAILURE OF EMERGENCY PNEUMATIC SHUTDOWN
TOP EMERPNS/D
1.41E-04
FAILURES OF PNEUMATIC CONTROL ASSEMBLY
GPNSDWN1
1.40E-04
OPOV FAILS TO CLOSE DUE TO MECHANICAL VALVE FAILURE (ENGINE 1)
APMHVFCPRPMOPO1
5
8.10E-07
ROCKETDYNE
FAILURE TO PNEUMATICALLY ACTUATE THE OPOV (ENGINE 1)
ASMPAFOMPOPO1
3
1.40E-04
HYPOTHESIS
FAILURE OF THE PCA TO PURGE THE OXIDIZER PREBURNER (ENGINE 1)
ASMPAFPMPPRPB1
5
7.76E-08
NPRD-3

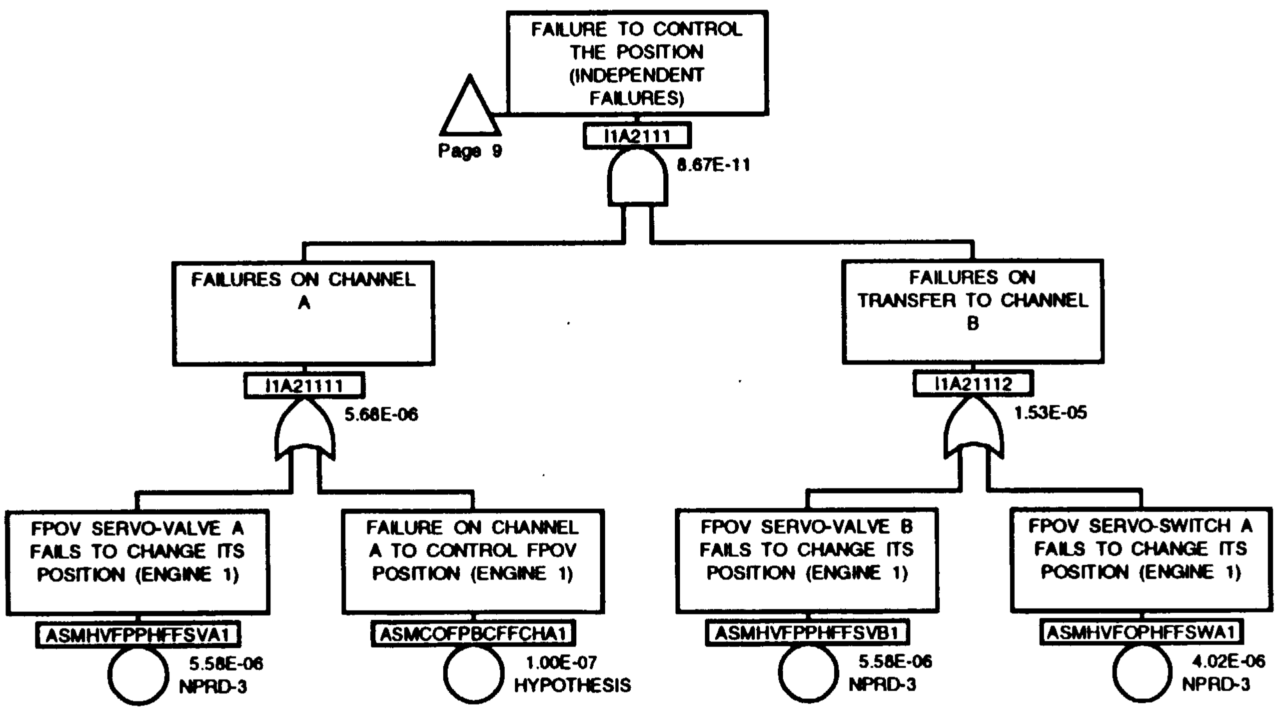

BY-PASS VALVE FAILS TO MOVE INTO LOCK-UP POSITION
TOP FLBPVLUP
2.32E-06
BY-PASS VALVE FAILS TO CHANGE ITS POSITION
APMAVFPPRPMBYPAS
2.32E-06
NPRD-3

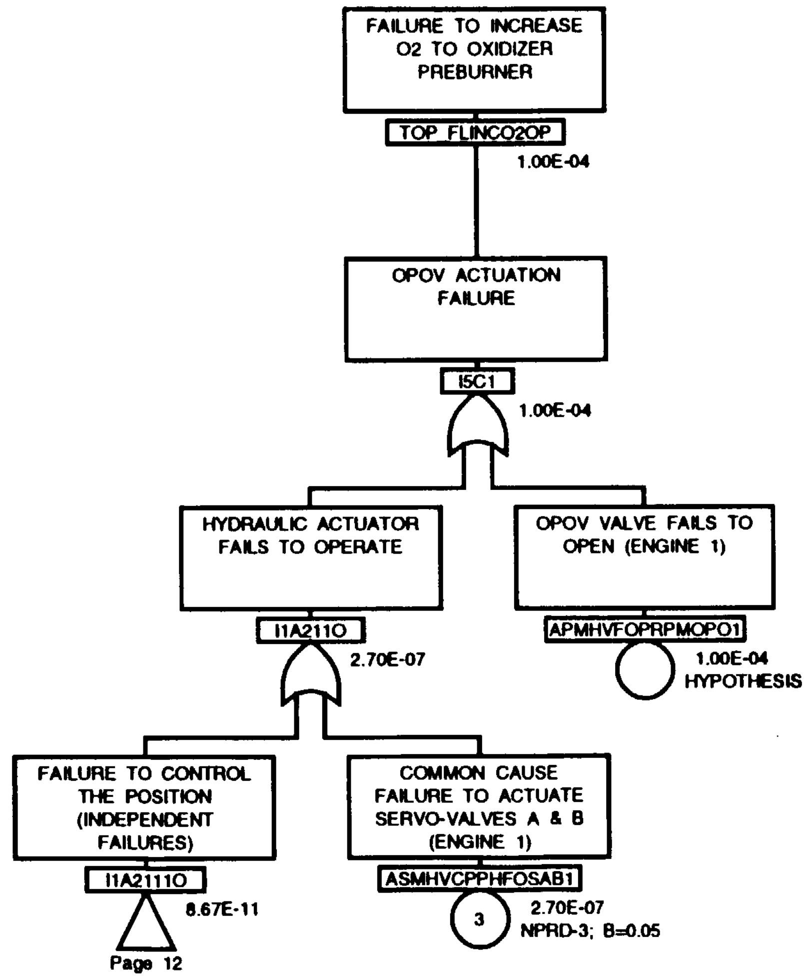


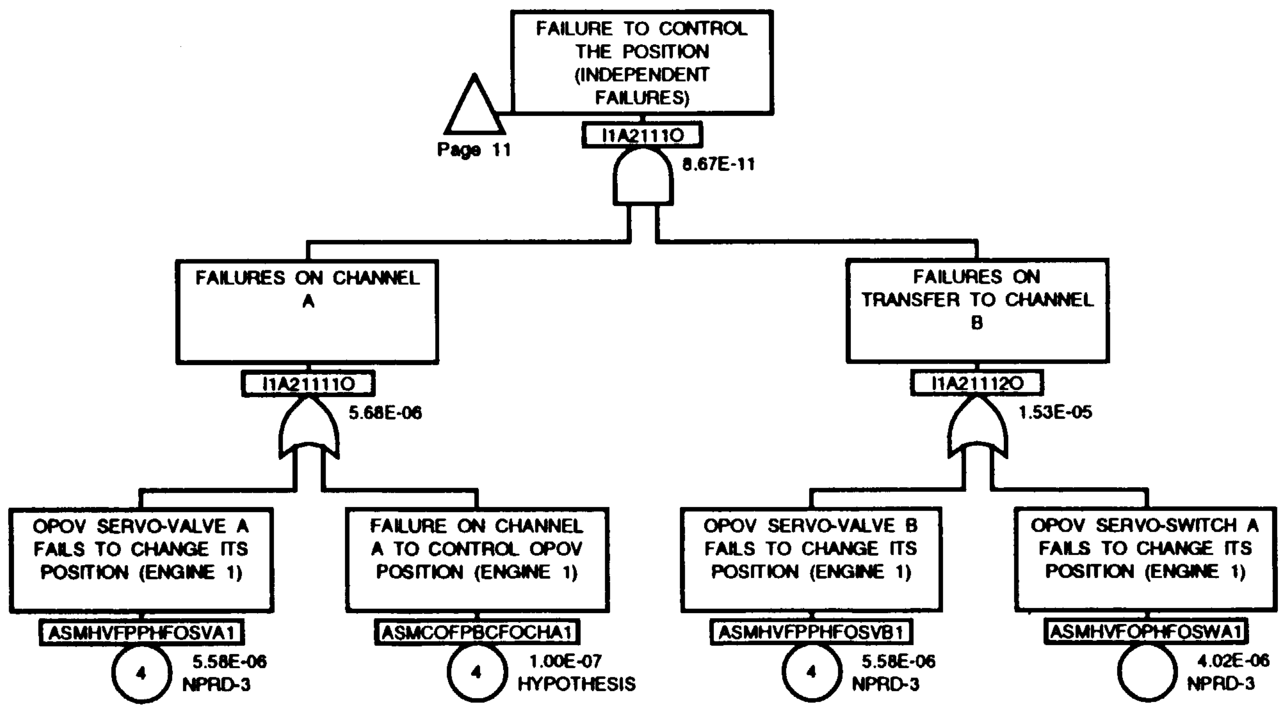
FAILURE TO SENSE Pc PRESSURE DROP
TOP FLDETPD
1.50E-04
BOTH SENSOR CHANNELS FAIL TO SENSE PRESSURE DROP
I5A1
1.00E-04
CCF OF CHANNEL A AND CHANNEL B PRESSURE DROP SENSORS
APMPSCCPRPMPCCAB
5.00E-05
RCKTDYNE:B=.005
CH A Pc PRESSURE SENSING SYSTEM FAILURE
I5A11
1.00E-02
CH B Pc PRESSURE SENSING SYSTEM FAILURE
I5A12
1.00E-02
Pc PRESSURE SENSOR FAILURE (ERRONEOUS SIGNAL) CHANNEL A
APMPSFPPRPMPCCHA
1.00E-02
ROCKETDYNE
Pc PRESSURE SENSOR HARNESS FAILURE (FAILS OPEN OR SHORTED) CHANNEL A
APMCAOCPRPMPCCHA
1.43E-09
NPRD-91
Pc PRESSURE SENSOR FAILURE (ERRONEOUS SIGNAL) CHANNEL B
APMPSFPPRPMPCCHB
1.00E-02
ROCKETDYNE
Pc PRESSURE SENSOR HARNESS FAILURE (FAILS OPEN OR SHORTED) CHANNEL B
APMCAOCPRPMPCCHB
1.43E-09
NPRD-91

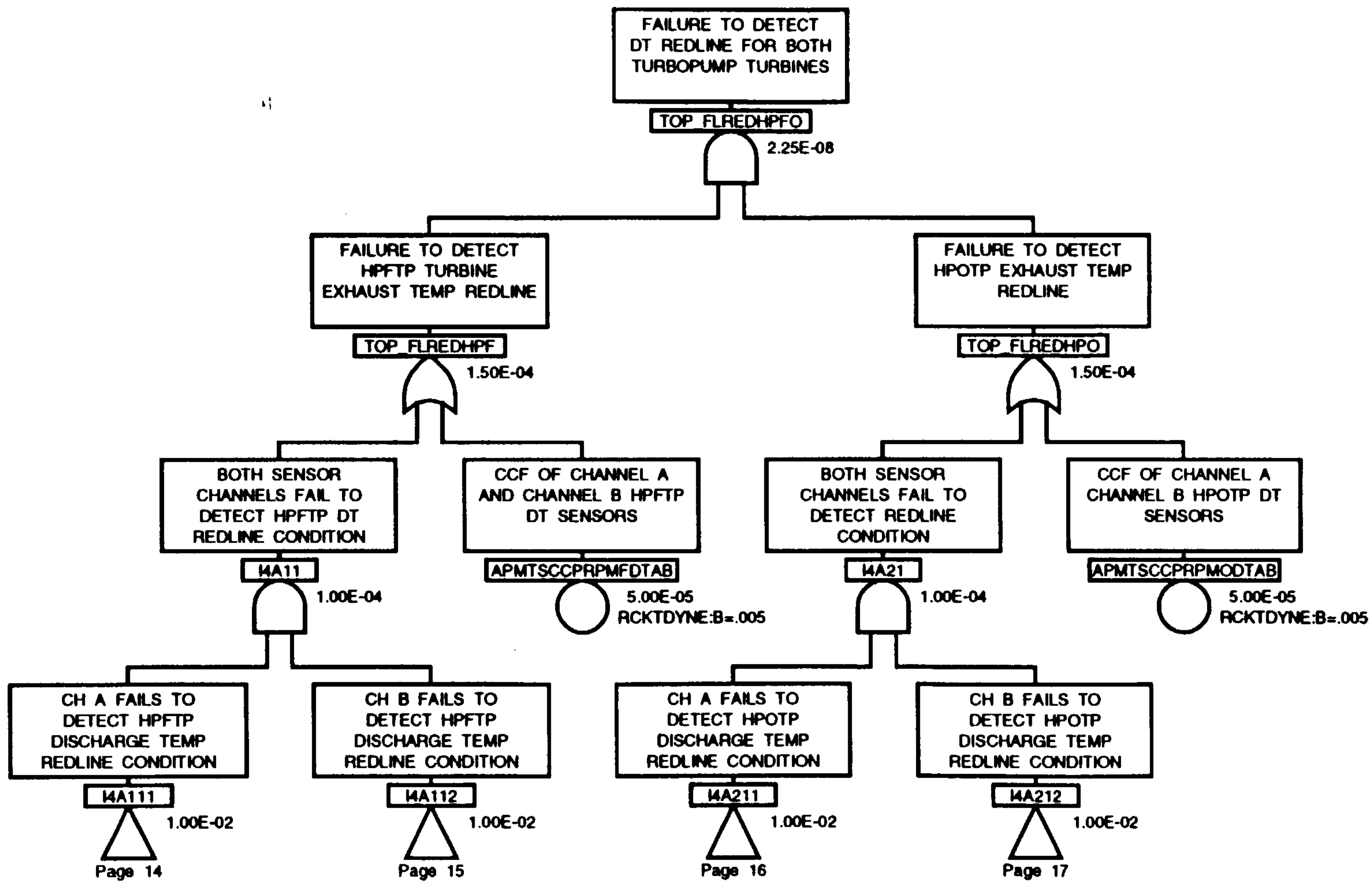

FAILURES ON SERVO-SWITCH B
TOP FLFSSLUP
2.10E-06
SERVO-SWITCH B FAILS TO CHANGE ITS POSITION (HARDWARE FAILURES)
APMSVFPPRPMSWB
2.00E-06
NPRD-3
FAILURE OF THE LOGIC TO DE-ENERGIZE SERVO-SWITCH B
APMLOGICSWB
1.00E-07
HYPOTHESIS

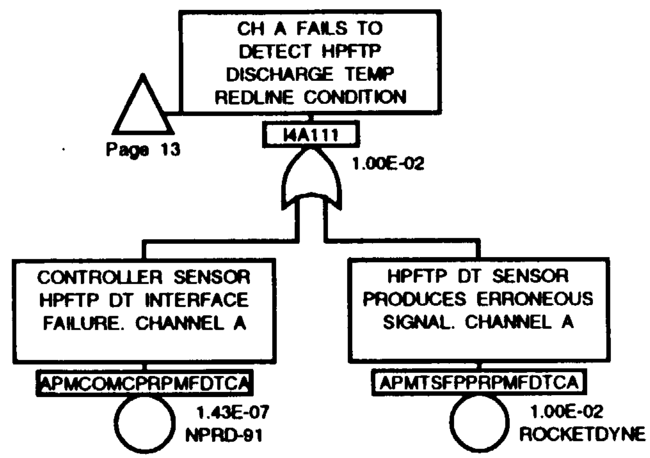

FAILURE TO INCREASE OXIDIZER FLOW TO FPB
TOP FLINCO2FP
1.00E-04
FPOV FAILS TO RESPOND TO COMMAND TO OPEN
I1A2
1.00E-04
HYDRAULIC ACTUATOR FAILS TO OPERATE
I1A211
2.70E-07
FPOV VALVE FAILS TO OPEN (ENGINE 1)
APMHVFOPRPMFPO1
1.00E-04
HYPOTHESIS
FAILURE TO CONTROL THE POSITION (INDEPENDENT FAILURES)
I1A2111
8.67E-11
Page 10
COMMON CAUSE FAILURE TO ACTUATE SERVO-VALVES A & B
ASMHVCPPHFFSAB1
2.70E-07
NPRD-3; B=0.05

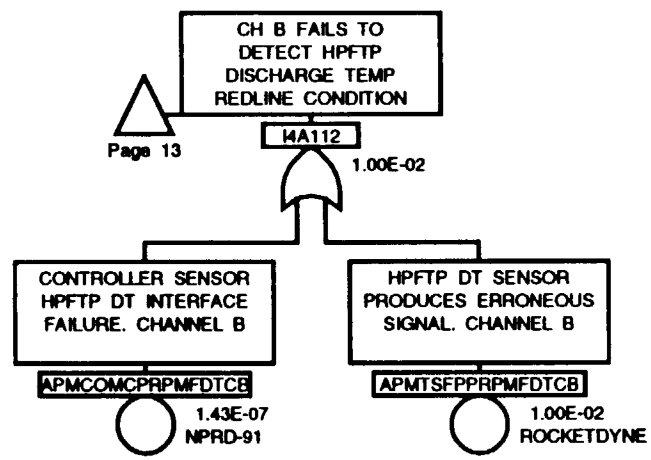

FAILURE TO CONTROL THE POSITION (INDEPENDENT FAILURES)
I1A2111
8.67E-11
Page 9
FAILURES ON CHANNEL A
I1A21111
5.68E-06
FAILURES ON TRANSFER TO CHANNEL B
I1A21112
1.53E-05
FPOV SERVO-VALVE A FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFFSVA1
5.58E-06
NPRD-3
FAILURE ON CHANNEL A TO CONTROL FPOV POSITION (ENGINE 1)
ASMCOFPBCFFCHA1
1.00E-07
HYPOTHESIS
FPOV SERVO-VALVE B FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFFSVB1
5.58E-06
NPRD-3
FPOV SERVO-SWITCH A FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFOPHFFSWA1
4.02E-06
NPRD-3

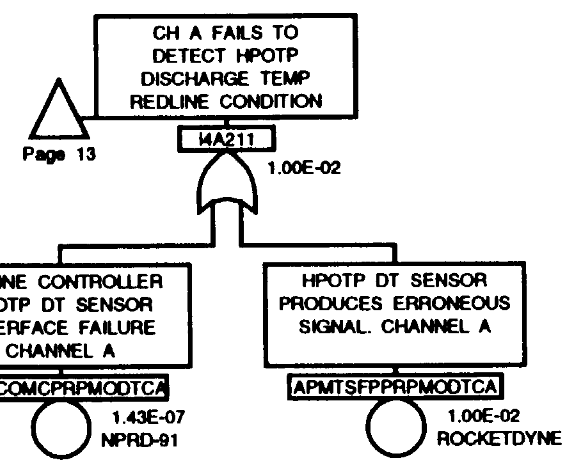

FAILURE TO INCREASE O2 TO OXIDIZER PREBURNER
TOP FLINCO2OP
1.00E-04
OPOV ACTUATION FAILURE
I5C1
1.00E-04
HYDRAULIC ACTUATOR FAILS TO OPERATE
I1A211O
2.70E-07
OPOV VALVE FAILS TO OPEN (ENGINE 1)
APMHVFOPRPMOPO1
1.00E-04
HYPOTHESIS
FAILURE TO CONTROL THE POSITION (INDEPENDENT FAILURES)
I1A2111O
8.67E-11
Page 12
COMMON CAUSE FAILURE TO ACTUATE SERVO-VALVES A & B (ENGINE 1)
ASMHVCPPHFOSAB1
3
2.70E-07
NPRD-3; B=0.05

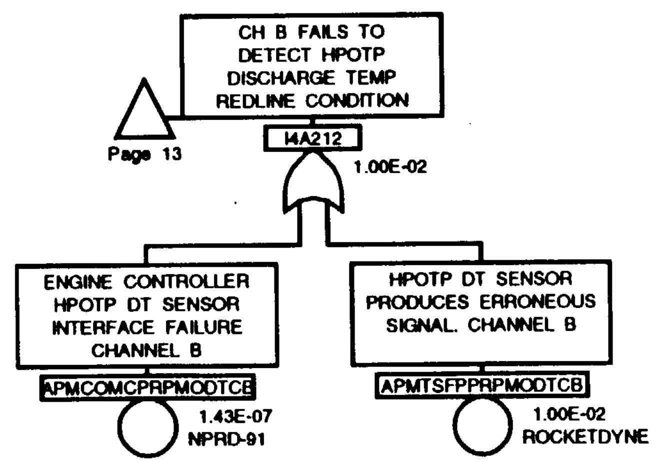

FAILURE TO CONTROL THE POSITION (INDEPENDENT FAILURES)
I1A2111O
8.67E-11
Page 11
FAILURES ON CHANNEL A
I1A21111O
5.68E-06
FAILURES ON TRANSFER TO CHANNEL B
I1A21112O
1.53E-05
OPOV SERVO-VALVE A FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFOSVA1
4
5.58E-06
NPRD-3
FAILURE ON CHANNEL A TO CONTROL OPOV POSITION (ENGINE 1)
ASMCOFPBCFOCHA1
4
1.00E-07
HYPOTHESIS
OPOV SERVO-VALVE B FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFOSVB1
4
5.58E-06
NPRD-3
OPOV SERVO-SWITCH A FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFOPHFOSWA1
4.02E-06
NPRD-3

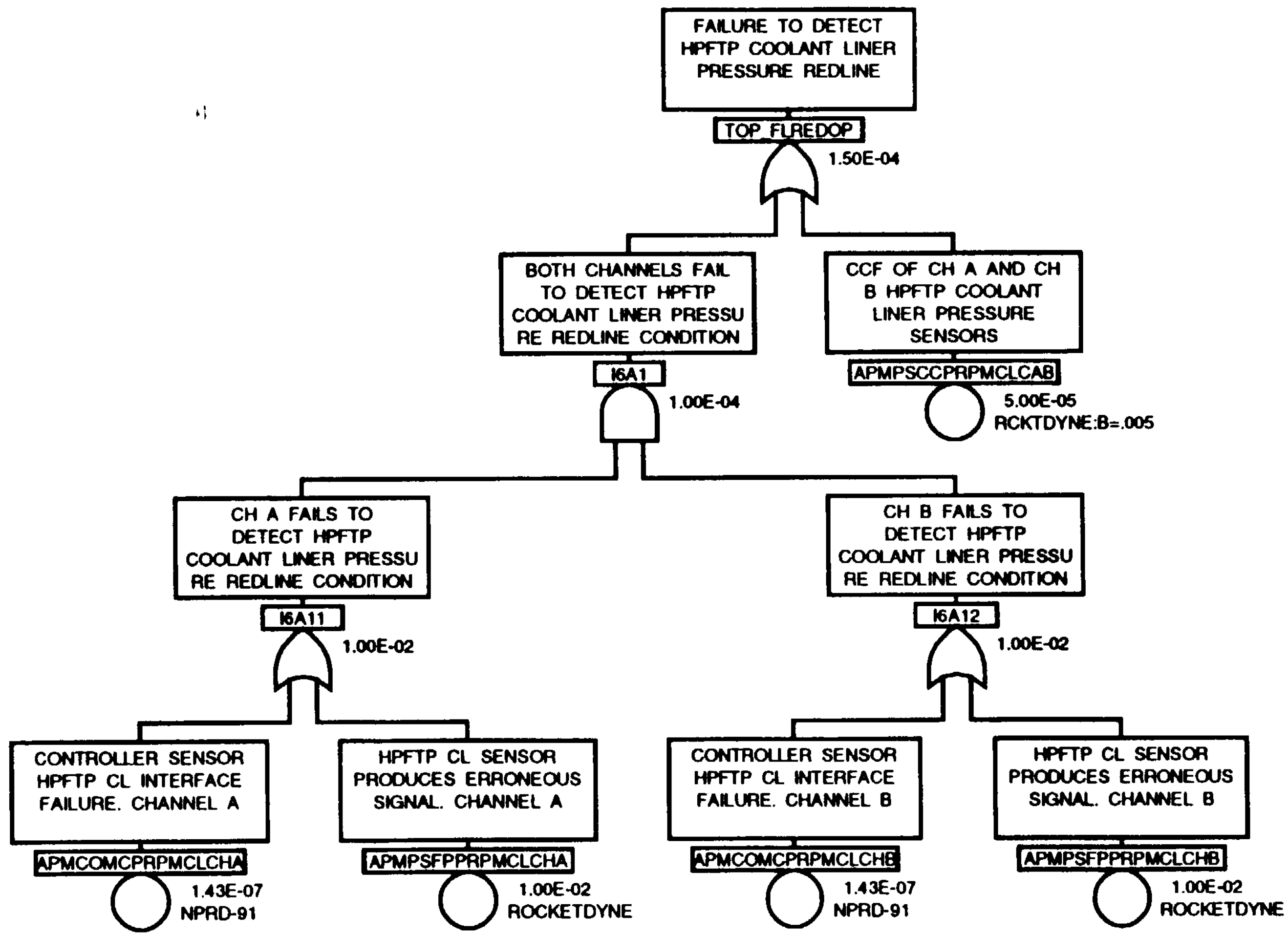

FAILURE TO DETECT DT REDLINE FOR BOTH TURBOPUMP TURBINES
TOP_FLREDHPFO
2.25E-08
FAILURE TO DETECT HPFTP TURBINE EXHAUST TEMP REDLINE
TOP_FLREDHPF
1.50E-04
FAILURE TO DETECT HPOTP EXHAUST TEMP REDLINE
TOP_FLREDHPO
1.50E-04
BOTH SENSOR CHANNELS FAIL TO DETECT HPFTP DT REDLINE CONDITION
I4A11
1.00E-04
CCF OF CHANNEL A AND CHANNEL B HPFTP DT SENSORS
APMTSCCPRPMFDTAB
5.00E-05
RCKTDYNE:B=.005
BOTH SENSOR CHANNELS FAIL TO DETECT REDLINE CONDITION
I4A21
1.00E-04
CCF OF CHANNEL A CHANNEL B HPOTP DT SENSORS
APMTSCCPRPMODTAB
5.00E-05
RCKTDYNE:B=.005
CH A FAILS TO DETECT HPFTP DISCHARGE TEMP REDLINE CONDITION
I4A111
1.00E-02
Page 14
CH B FAILS TO DETECT HPFTP DISCHARGE TEMP REDLINE CONDITION
I4A112
1.00E-02
Page 15
CH A FAILS TO DETECT HPOTP DISCHARGE TEMP REDLINE CONDITION
I4A211
1.00E-02
Page 16
CH B FAILS TO DETECT HPOTP DISCHARGE TEMP REDLINE CONDITION
I4A212
1.00E-02
Page 17

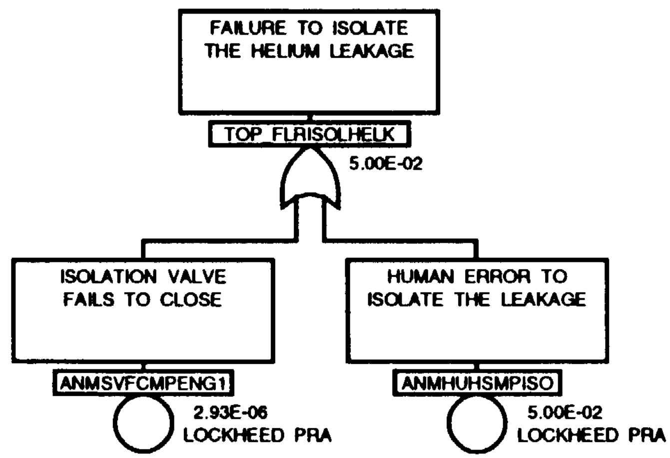

CH A FAILS TO DETECT HPFTP DISCHARGE TEMP REDLINE CONDITION
I4A111
1.00E-02
Page 13
CONTROLLER SENSOR HPFTP DT INTERFACE FAILURE. CHANNEL A
APMCOMCPRPMFDTCA
1.43E-07
NPRD-91
HPFTP DT SENSOR PRODUCES ERRONEOUS SIGNAL. CHANNEL A
APMTSFPPRPMFDTCA
1.00E-02
ROCKETDYNE

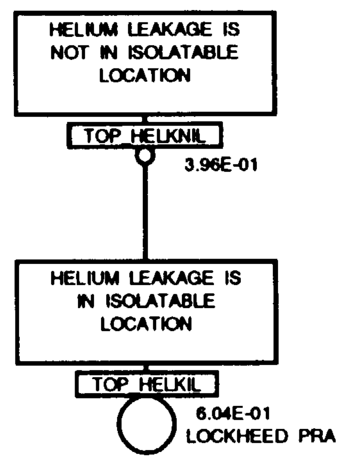

CH B FAILS TO DETECT HPFTP DISCHARGE TEMP REDLINE CONDITION
Page 13
I4A112
1.00E-02
CONTROLLER SENSOR HPFTP DT INTERFACE FAILURE. CHANNEL B
APMCOMCPRPMFDTCB
1.43E-07
NPRD-91
HPFTP DT SENSOR PRODUCES ERRONEOUS SIGNAL. CHANNEL B
APMTSFPPRPMFDTCB
1.00E-02
ROCKETDYNE

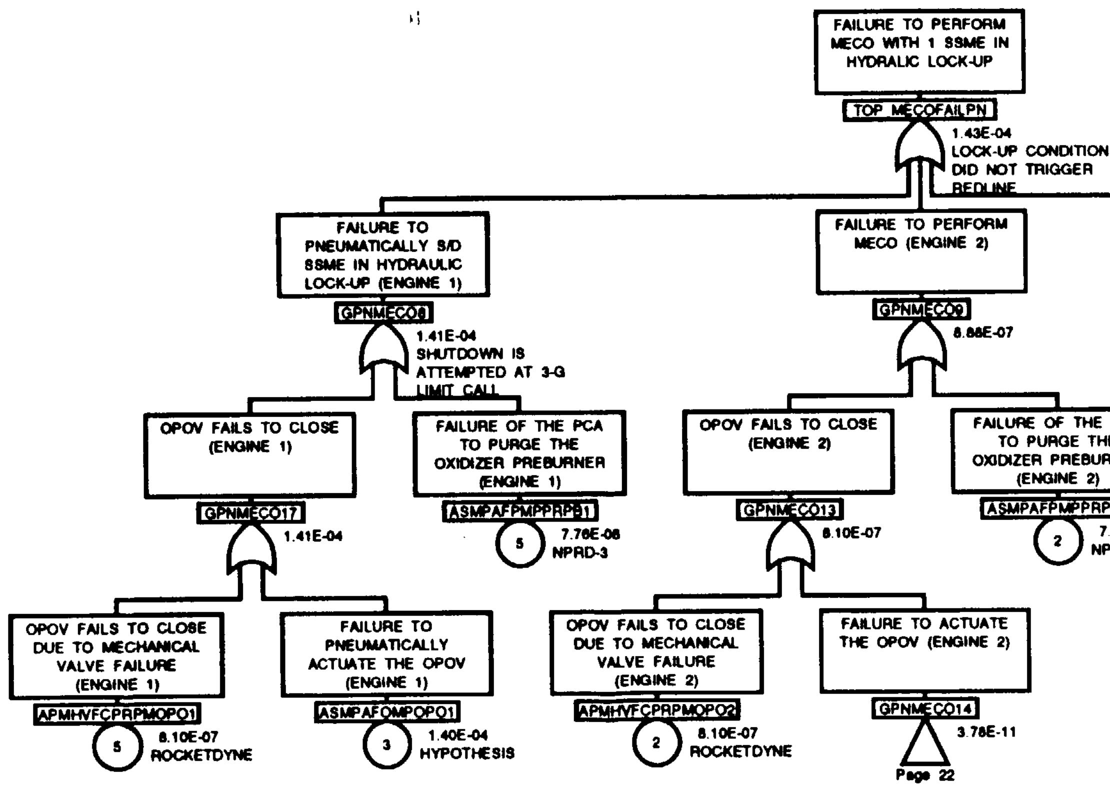

CH A FAILS TO DETECT HPOTP DISCHARGE TEMP REDLINE CONDITION
Page 13
I4A211
1.00E-02
ENGINE CONTROLLER HPOTP DT SENSOR INTERFACE FAILURE CHANNEL A
APMCOMCPRPMODTCA
1.43E-07
NPRD-91
HPOTP DT SENSOR PRODUCES ERRONEOUS SIGNAL. CHANNEL A
APMTSFPPRPMODTCA
1.00E-02
ROCKETDYNE

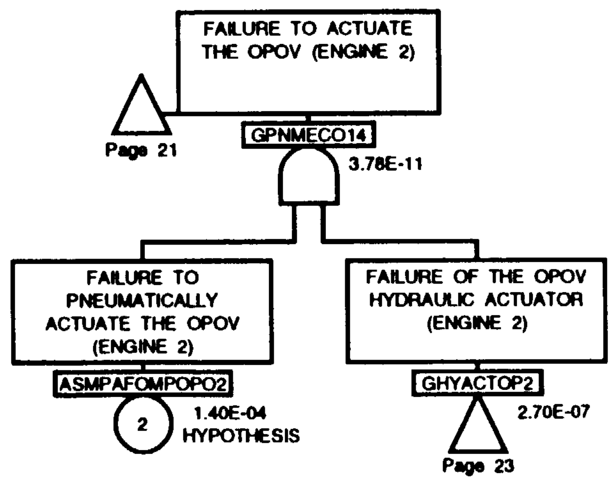

CH B FAILS TO DETECT HPOTP DISCHARGE TEMP REDLINE CONDITION
Page 13
I4A212
1.00E-02
ENGINE CONTROLLER HPOTP DT SENSOR INTERFACE FAILURE CHANNEL B
APMCOMCPRPMODTCB
1.43E-07
NPRD-91
HPOTP DT SENSOR PRODUCES ERRONEOUS SIGNAL. CHANNEL B
APMTSFPPRPMODTCB
1.00E-02
ROCKETDYNE

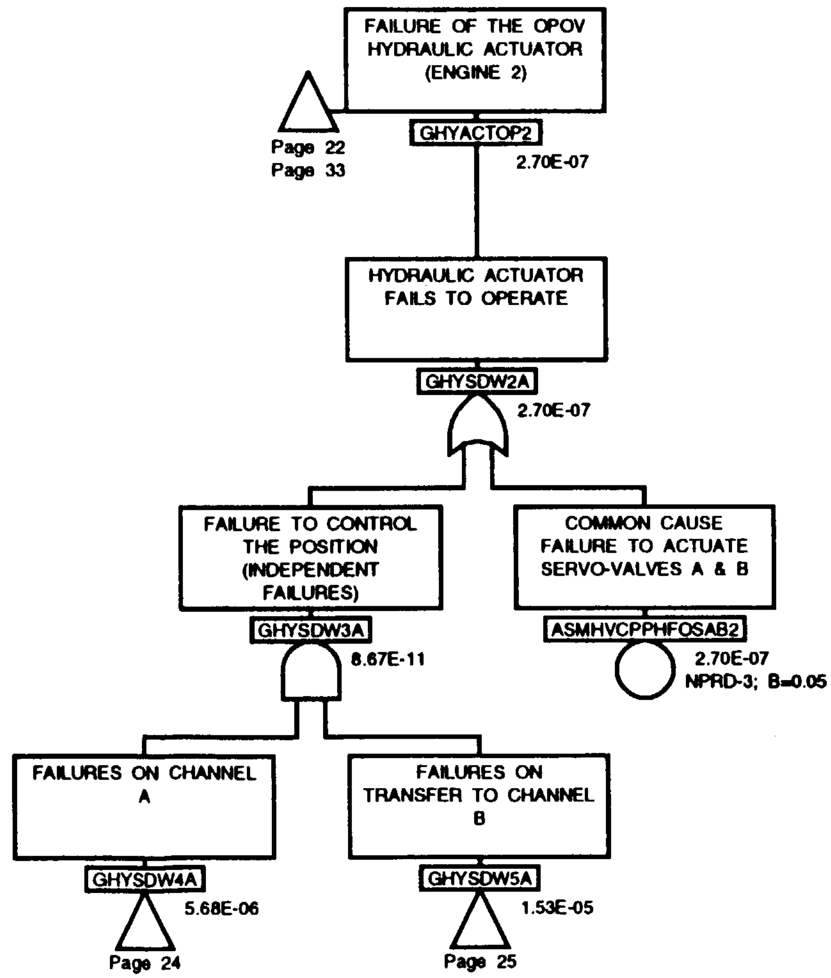

FAILURE TO DETECT HPFTP COOLANT LINER PRESSURE REDLINE
TOP FLREDOP
1.50E-04
BOTH CHANNELS FAIL TO DETECT HPFTP COOLANT LINER PRESSU RE REDLINE CONDITION
I6A1
1.00E-04
CCF OF CH A AND CH B HPFTP COOLANT LINER PRESSURE SENSORS
APMPSCCPRPMCLCAB
5.00E-05
RCKTDYNE:B=.005
CH A FAILS TO DETECT HPFTP COOLANT LINER PRESSU RE REDLINE CONDITION
I6A11
1.00E-02
CH B FAILS TO DETECT HPFTP COOLANT LINER PRESSU RE REDLINE CONDITION
I6A12
1.00E-02
CONTROLLER SENSOR HPFTP CL INTERFACE FAILURE. CHANNEL A
APMCOMCPRPMCLCHA
1.43E-07
NPRD-91
HPFTP CL SENSOR PRODUCES ERRONEOUS SIGNAL. CHANNEL A
APMPSFPPRPMCLCHA
1.00E-02
ROCKETDYNE
CONTROLLER SENSOR HPFTP CL INTERFACE FAILURE. CHANNEL B
APMCOMCPRPMCLCHB
1.43E-07
NPRD-91
HPFTP CL SENSOR PRODUCES ERRONEOUS SIGNAL. CHANNEL B
APMPSFPPRPMCLCHB
1.00E-02
ROCKETDYNE

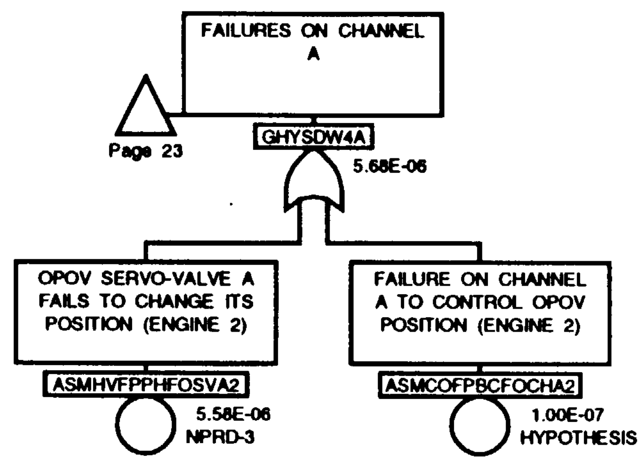

FAILURE TO ISOLATE THE HELIUM LEAKAGE
TOP FLRISOLHELK
5.00E-02
ISOLATION VALVE FAILS TO CLOSE
ANMSVFCMPENG1
2.93E-06
LOCKHEED PRA
HUMAN ERROR TO ISOLATE THE LEAKAGE
ANMHUHSMPISO
5.00E-02
LOCKHEED PRA

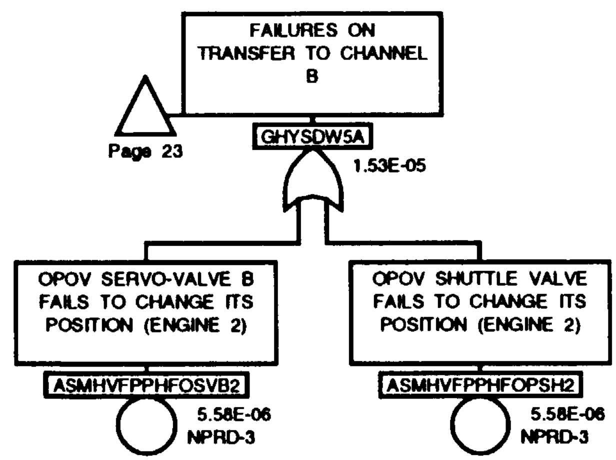

HELIUM LEAKAGE IS NOT IN ISOLATABLE LOCATION
TOP HELKNIL
3.96E-01
HELIUM LEAKAGE IS IN ISOLATABLE LOCATION
TOP HELKIL
6.04E-01
LOCKHEED PRA

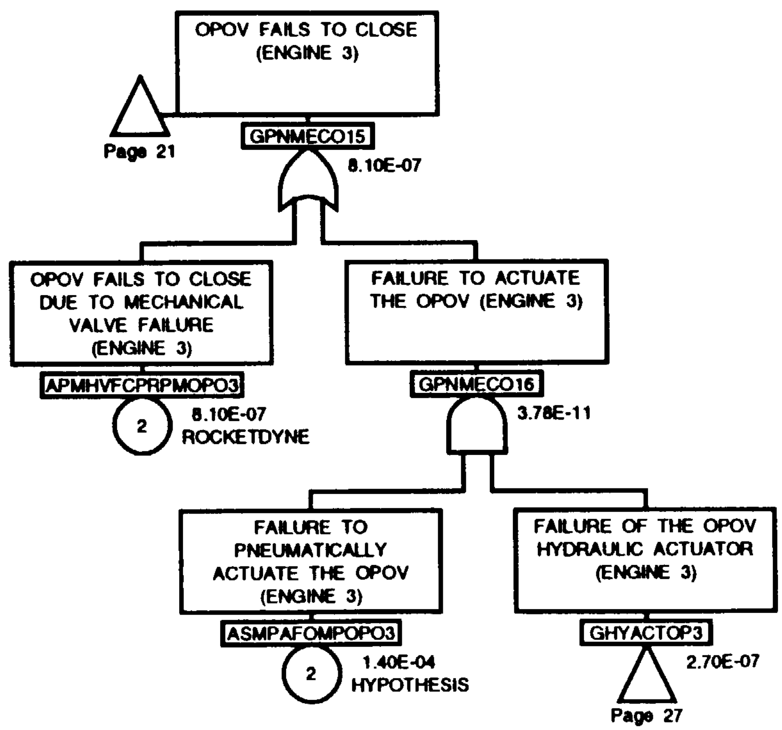

FAILURE TO PERFORM MECO WITH 1 SSME IN HYDRALIC LOCK-UP
TOP MECOFAILPN
1.43E-04
LOCK-UP CONDITION DID NOT TRIGGER REDLINE
FAILURE TO PNEUMATICALLY S/D SSME IN HYDRAULIC LOCK-UP (ENGINE 1)
GPNMECO8
1.41E-04
SHUTDOWN IS ATTEMPTED AT 3-G LIMIT CALL
FAILURE TO PERFORM MECO (ENGINE 2)
GPNMECO9
8.88E-07
FAILURE TO PERFORM MECO (ENGINE 3)
GPNMECO10
8.88E-07
OPOV FAILS TO CLOSE (ENGINE 1)
GPNMECO17
1.41E-04
FAILURE OF THE PCA TO PURGE THE OXIDIZER PREBURNER (ENGINE 1)
ASMPAFPMPPRPB1
5
7.76E-08
NPRD-3
OPOV FAILS TO CLOSE (ENGINE 2)
GPNMECO13
8.10E-07
FAILURE OF THE PCA TO PURGE THE OXIDIZER PREBURNER (ENGINE 2)
ASMPAFPMPPRPB2
2
7.76E-08
NPRD-3
OPOV FAILS TO CLOSE (ENGINE 3)
GPNMECO15
8.10E-07
Page 26
FAILURE OF THE PCA TO PURGE THE OXIDIZER PREBURNER (ENGINE 3)
ASMPAFPMPPRPB3
2
7.76E-08
NPRD-3
OPOV FAILS TO CLOSE DUE TO MECHANICAL VALVE FAILURE (ENGINE 1)
APMHVFCPRPMOPO1
5
8.10E-07
ROCKETDYNE
FAILURE TO PNEUMATICALLY ACTUATE THE OPOV (ENGINE 1)
ASMPAFOMPOPO1
3
1.40E-04
HYPOTHESIS
OPOV FAILS TO CLOSE DUE TO MECHANICAL VALVE FAILURE (ENGINE 2)
APMHVFCPRPMOPO2
2
8.10E-07
ROCKETDYNE
FAILURE TO ACTUATE THE OPOV (ENGINE 2)
GPNMECO14
3.78E-11
Page 22

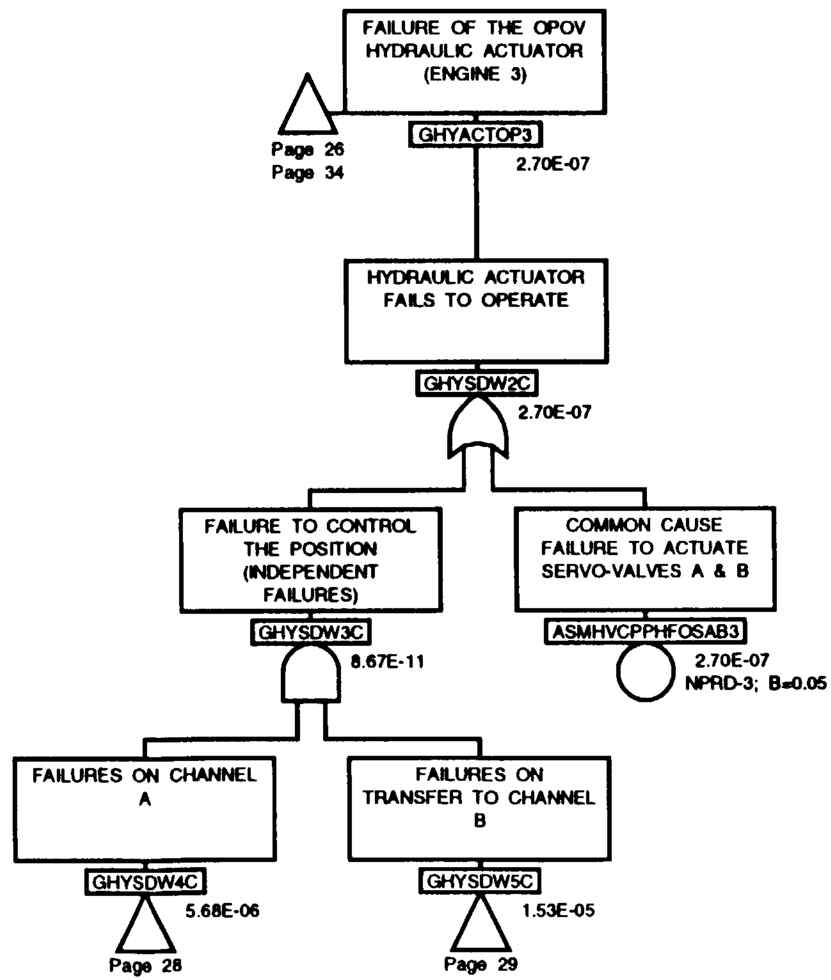

FAILURE TO ACTUATE THE OPOV (ENGINE 2)
GPNMECO14
3.78E-11
Page 21
FAILURE TO PNEUMATICALLY ACTUATE THE OPOV (ENGINE 2)
ASMPAFOMPOPO2
2
1.40E-04
HYPOTHESIS
FAILURE OF THE OPOV HYDRAULIC ACTUATOR (ENGINE 2)
GHYACTOP2
2.70E-07
Page 23

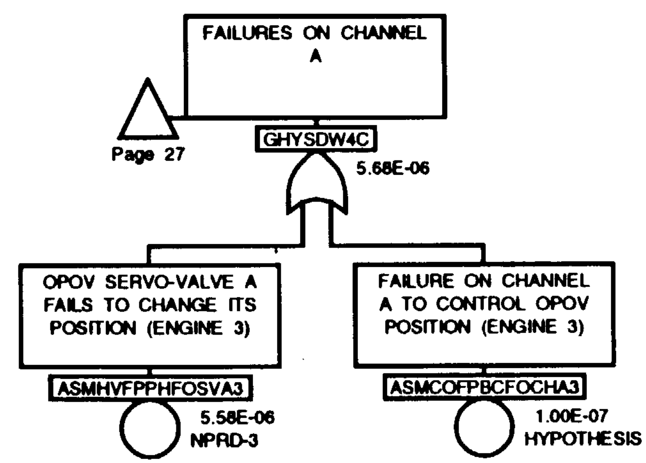

FAILURE OF THE OPOV HYDRAULIC ACTUATOR (ENGINE 2)
GHYACTOP2
2.70E-07
Page 22
Page 33
HYDRAULIC ACTUATOR FAILS TO OPERATE
GHYSDW2A
2.70E-07
FAILURE TO CONTROL THE POSITION (INDEPENDENT FAILURES)
GHYSDW3A
8.67E-11
COMMON CAUSE FAILURE TO ACTUATE SERVO-VALVES A & B
ASMHVCPPHFOSAB2
2.70E-07
NPRD-3; B=0.05
FAILURES ON CHANNEL A
GHYSDW4A
5.68E-06
Page 24
FAILURES ON TRANSFER TO CHANNEL B
GHYSDW5A
1.53E-05
Page 25

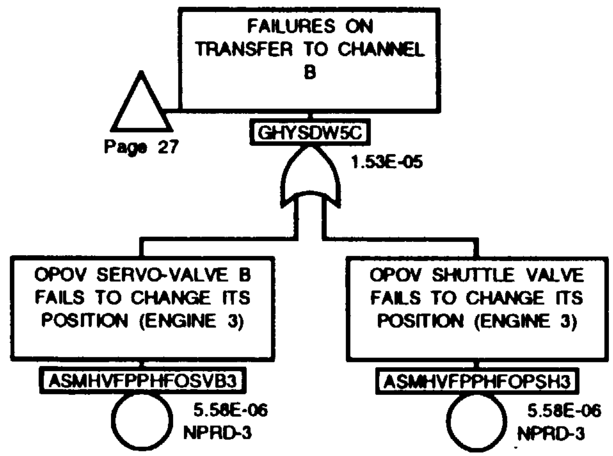

FAILURES ON CHANNEL A
Page 23
GHYSDW4A
5.68E-06
OPOV SERVO-VALVE A FAILS TO CHANGE ITS POSITION (ENGINE 2)
ASMHVFPPHFOSVA2
5.58E-06
NPRD-3
FAILURE ON CHANNEL A TO CONTROL OPOV POSITION (ENGINE 2)
ASMCOFPBCFOCHA2
1.00E-07
HYPOTHESIS

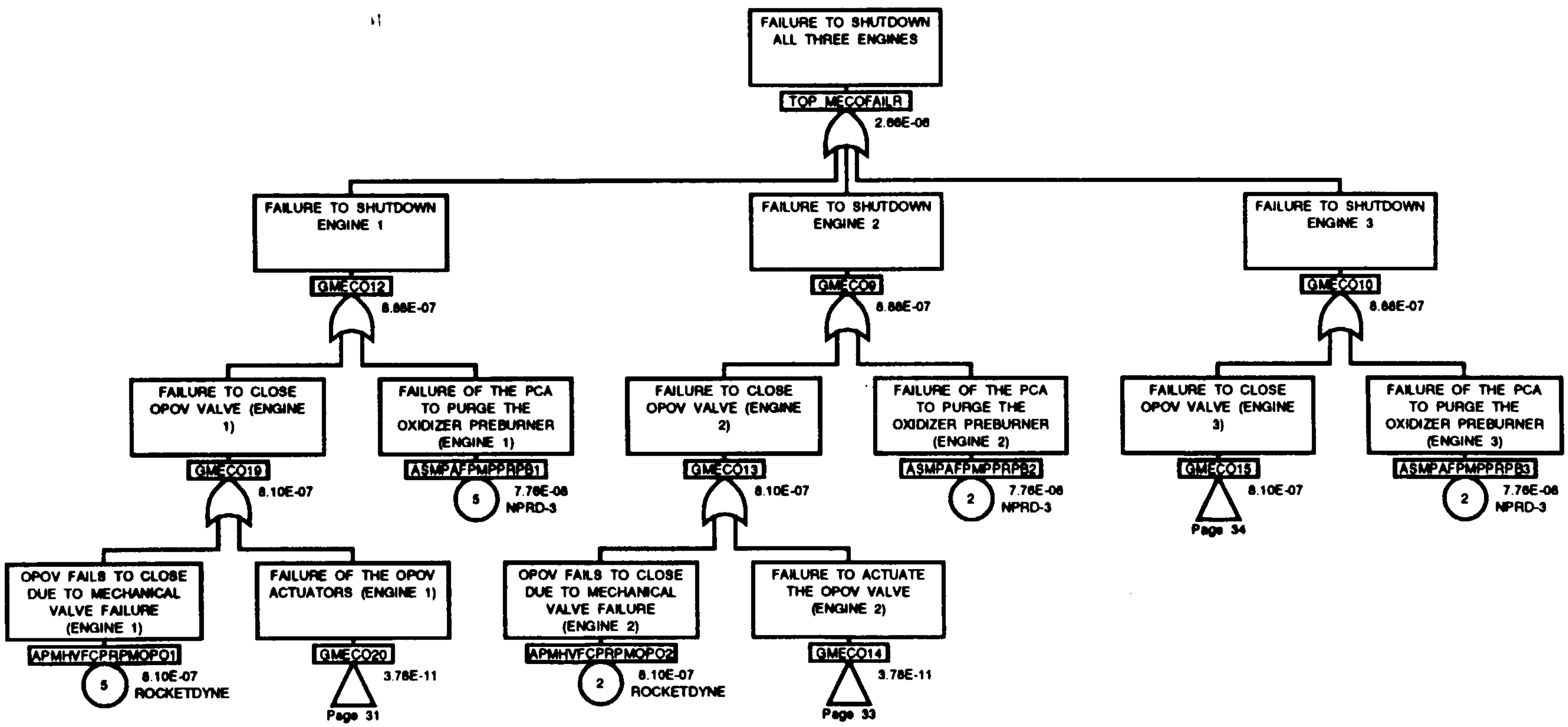

FAILURES ON TRANSFER TO CHANNEL B
GHYSDW5A
1.53E-05
Page 23
OPOV SERVO-VALVE B FAILS TO CHANGE ITS POSITION (ENGINE 2)
ASMHVFPPHFOSVB2
5.58E-06
NPRD-3
OPOV SHUTTLE VALVE FAILS TO CHANGE ITS POSITION (ENGINE 2)
ASMHVFPPHFOPSH2
5.58E-06
NPRD-3


OPOV FAILS TO CLOSE (ENGINE 3)
Page 21
GPNMECO15
8.10E-07
OPOV FAILS TO CLOSE DUE TO MECHANICAL VALVE FAILURE (ENGINE 3)
APMHVFCPRPMOPO3
2
8.10E-07
ROCKETDYNE
FAILURE TO ACTUATE THE OPOV (ENGINE 3)
GPNMECO16
3.78E-11
FAILURE TO PNEUMATICALLY ACTUATE THE OPOV (ENGINE 3)
ASMPAFOMPOPO3
2
1.40E-04
HYPOTHESIS
FAILURE OF THE OPOV HYDRAULIC ACTUATOR (ENGINE 3)
GHYACTOP3
2.70E-07
Page 27

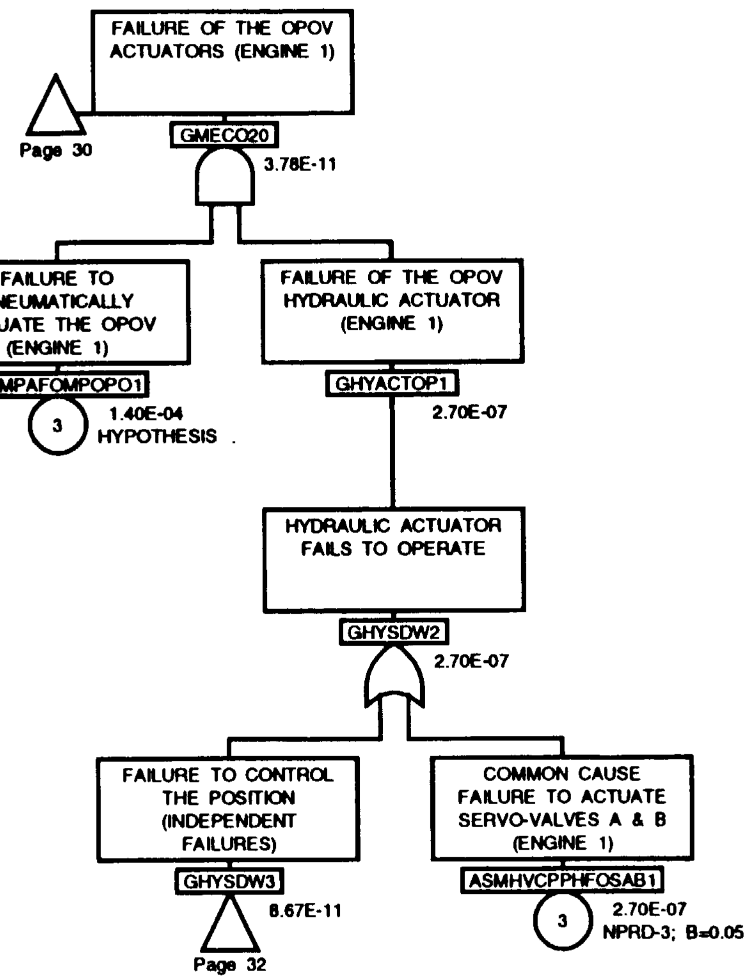

FAILURE OF THE OPOV HYDRAULIC ACTUATOR (ENGINE 3)
GHYACTOP3
2.70E-07
Page 26
Page 34
HYDRAULIC ACTUATOR FAILS TO OPERATE
GHYSDW2C
2.70E-07
FAILURE TO CONTROL THE POSITION (INDEPENDENT FAILURES)
GHYSDW3C
8.67E-11
COMMON CAUSE FAILURE TO ACTUATE SERVO-VALVES A & B
ASMHVCPPHFOSAB3
2.70E-07
NPRD-3; B=0.05
FAILURES ON CHANNEL A
GHYSDW4C
5.68E-06
Page 28
FAILURES ON TRANSFER TO CHANNEL B
GHYSDW5C
1.53E-05
Page 29

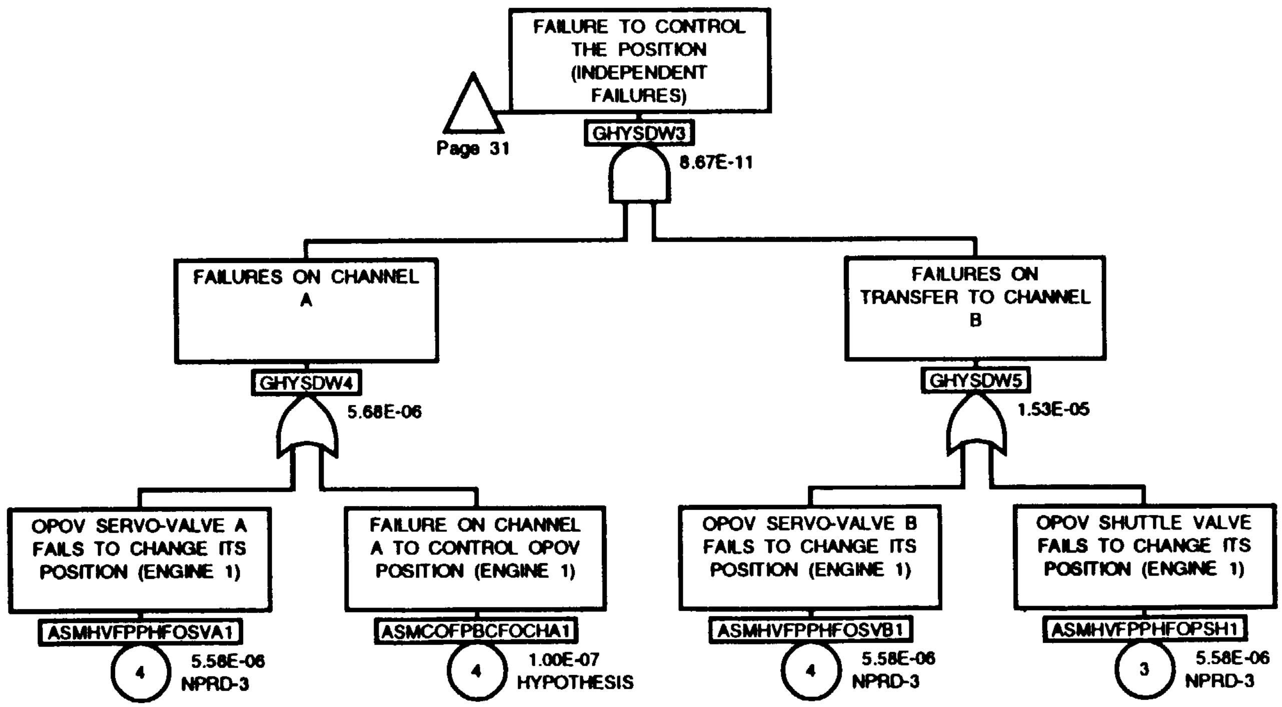

FAILURES ON CHANNEL A
GHYSDW4C
5.68E-06
Page 27
OPOV SERVO-VALVE A FAILS TO CHANGE ITS POSITION (ENGINE 3)
ASMHVFPPHFOSVA3
5.58E-06
NPRD-3
FAILURE ON CHANNEL A TO CONTROL OPOV POSITION (ENGINE 3)
ASMCOFPBCFOCHA3
1.00E-07
HYPOTHESIS

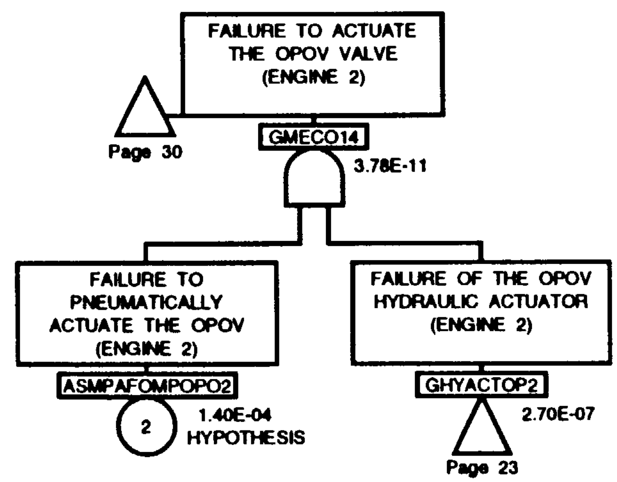

FAILURES ON TRANSFER TO CHANNEL B
GHYSDW5C
1.53E-05
Page 27
OPOV SERVO-VALVE B FAILS TO CHANGE ITS POSITION (ENGINE 3)
ASMHVFPPHFOSVB3
5.58E-06
NPRD-3
OPOV SHUTTLE VALVE FAILS TO CHANGE ITS POSITION (ENGINE 3)
ASMHVFPPHFOPSH3
5.58E-06
NPRD-3

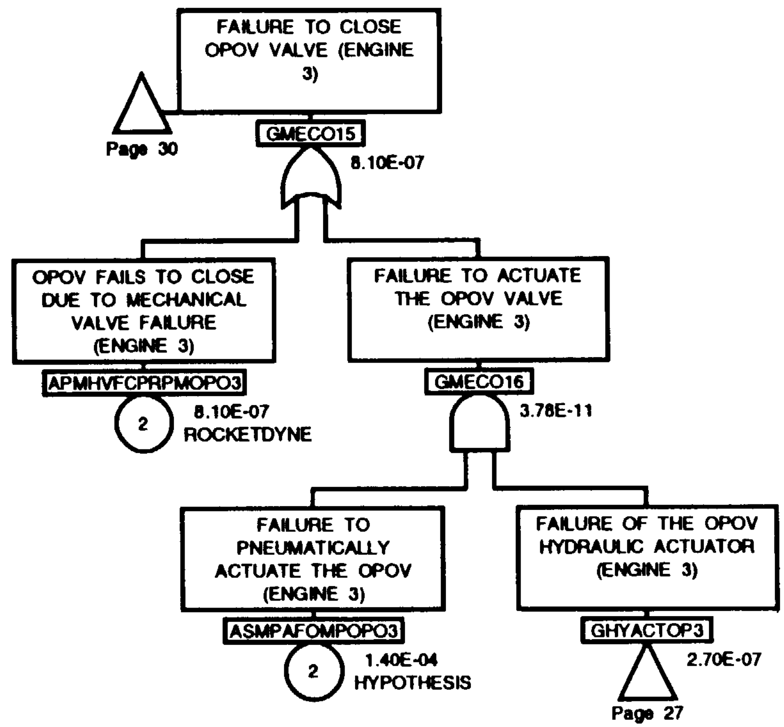


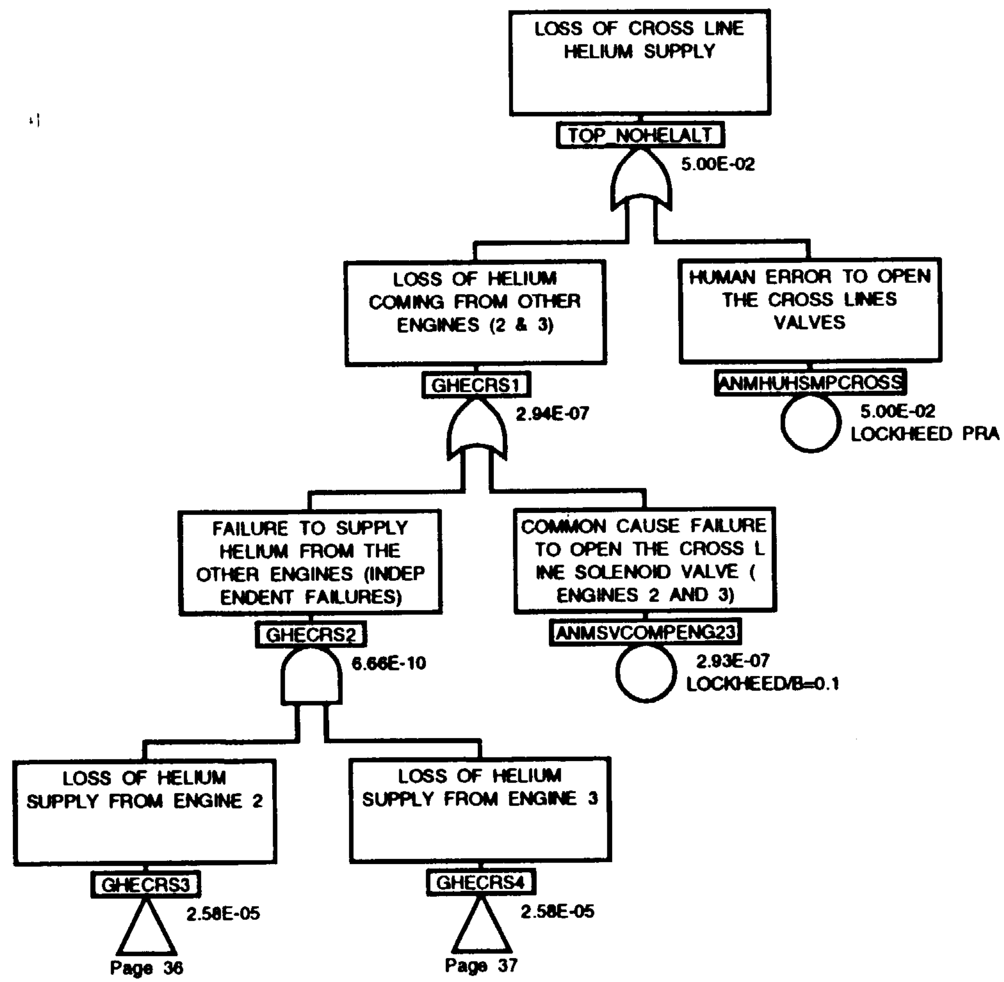
FAILURE TO SHUTDOWN ALL THREE ENGINES
TOP MECOFAILR
2.06E-06
FAILURE TO SHUTDOWN ENGINE 1
GMECO12
6.88E-07
FAILURE TO SHUTDOWN ENGINE 2
GMECO9
6.88E-07
FAILURE TO SHUTDOWN ENGINE 3
GMECO10
6.88E-07
FAILURE TO CLOSE OPOV VALVE (ENGINE 1)
GMECO19
6.10E-07
FAILURE OF THE PCA TO PURGE THE OXIDIZER PREBURNER (ENGINE 1)
ASMPAFPMPPRPB1
5
7.76E-08
NPRD-3
FAILURE TO CLOSE OPOV VALVE (ENGINE 2)
GMECO13
6.10E-07
FAILURE OF THE PCA TO PURGE THE OXIDIZER PREBURNER (ENGINE 2)
ASMPAFPMPPRPB2
2
7.76E-08
NPRD-3
FAILURE TO CLOSE OPOV VALVE (ENGINE 3)
GMECO15
6.10E-07
Page 34
FAILURE OF THE PCA TO PURGE THE OXIDIZER PREBURNER (ENGINE 3)
ASMPAFPMPPRPB3
2
7.76E-08
NPRD-3
OPOV FAILS TO CLOSE DUE TO MECHANICAL VALVE FAILURE (ENGINE 1)
APMHVFCPRPMOPO1
5
6.10E-07
ROCKETDYNE
FAILURE OF THE OPOV ACTUATORS (ENGINE 1)
GMECO20
3.78E-11
Page 31
OPOV FAILS TO CLOSE DUE TO MECHANICAL VALVE FAILURE (ENGINE 2)
APMHVFCPRPMOPO2
2
6.10E-07
ROCKETDYNE
FAILURE TO ACTUATE THE OPOV VALVE (ENGINE 2)
GMECO14
3.78E-11
Page 33

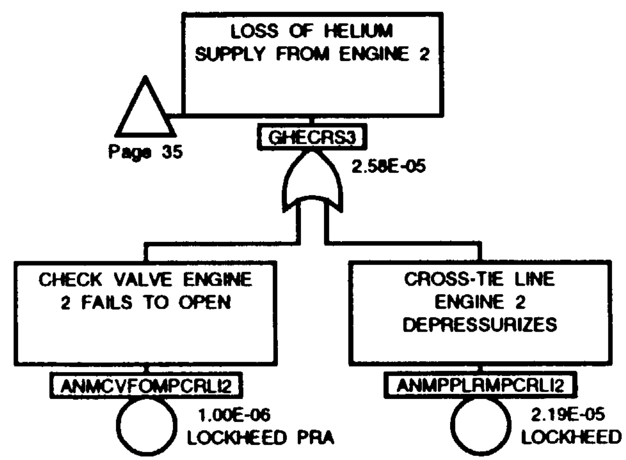

FAILURE OF THE OPOV ACTUATORS (ENGINE 1)
Page 30
GMECO20
3.78E-11
FAILURE TO PNEUMATICALLY ACTUATE THE OPOV (ENGINE 1)
ASMPAFOMPOPO1
3
1.40E-04
HYPOTHESIS
FAILURE OF THE OPOV HYDRAULIC ACTUATOR (ENGINE 1)
GHYACTOP1
2.70E-07
HYDRAULIC ACTUATOR FAILS TO OPERATE
GHYSDW2
2.70E-07
FAILURE TO CONTROL THE POSITION (INDEPENDENT FAILURES)
GHYSDW3
8.67E-11
Page 32
COMMON CAUSE FAILURE TO ACTUATE SERVO-VALVES A & B (ENGINE 1)
ASMHVCPPHFOSAB1
3
2.70E-07
NPRD-3; B=0.05

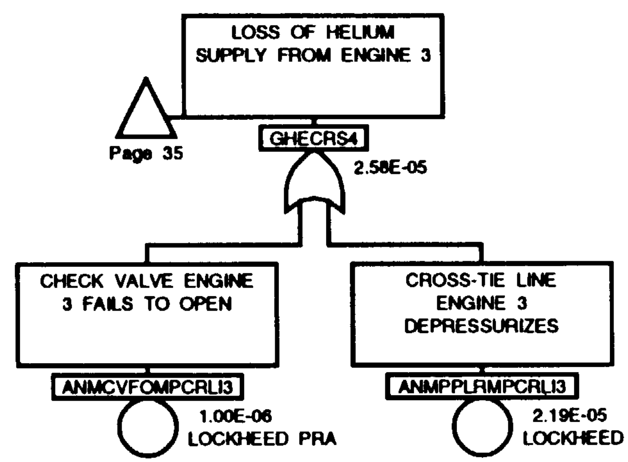

FAILURE TO CONTROL THE POSITION (INDEPENDENT FAILURES)
Page 31
GHYSDW3
8.67E-11
FAILURES ON CHANNEL A
GHYSDW4
5.68E-06
FAILURES ON TRANSFER TO CHANNEL B
GHYSDW5
1.53E-05
OPOV SERVO-VALVE A FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFOSVA1
4
5.58E-06
NPRD-3
FAILURE ON CHANNEL A TO CONTROL OPOV POSITION (ENGINE 1)
ASMCOFPBCFOCHA1
4
1.00E-07
HYPOTHESIS
OPOV SERVO-VALVE B FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFOSVB1
4
5.58E-06
NPRD-3
OPOV SHUTTLE VALVE FAILS TO CHANGE ITS POSITION (ENGINE 1)
ASMHVFPPHFOPSH1
3
5.58E-06
NPRD-3

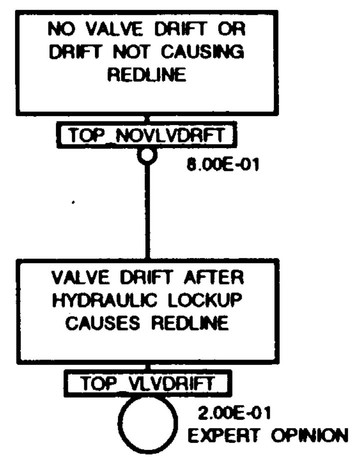

FAILURE TO ACTUATE THE OPOV VALVE (ENGINE 2)
Page 30
GMECO14
3.78E-11
FAILURE TO PNEUMATICALLY ACTUATE THE OPOV (ENGINE 2)
ASMPAFOMPOPO2
2
1.40E-04
HYPOTHESIS
FAILURE OF THE OPOV HYDRAULIC ACTUATOR (ENGINE 2)
GHYACTOP2
2.70E-07
Page 23

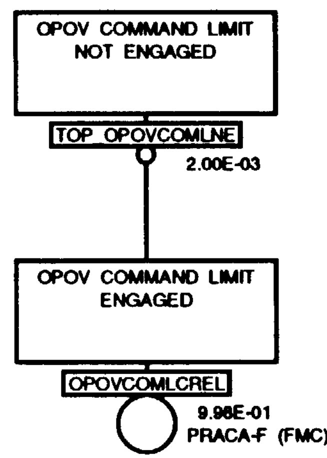

FAILURE TO CLOSE OPOV VALVE (ENGINE 3)
GMECO15
8.10E-07
Page 30
OPOV FAILS TO CLOSE DUE TO MECHANICAL VALVE FAILURE (ENGINE 3)
APMHVFCPRPMOPO3
2
8.10E-07
ROCKETDYNE
FAILURE TO ACTUATE THE OPOV VALVE (ENGINE 3)
GMECO16
3.78E-11
FAILURE TO PNEUMATICALLY ACTUATE THE OPOV (ENGINE 3)
ASMPAFOMPOPO3
2
1.40E-04
HYPOTHESIS
FAILURE OF THE OPOV HYDRAULIC ACTUATOR (ENGINE 3)
GHYACTOP3
2.70E-07
Page 27

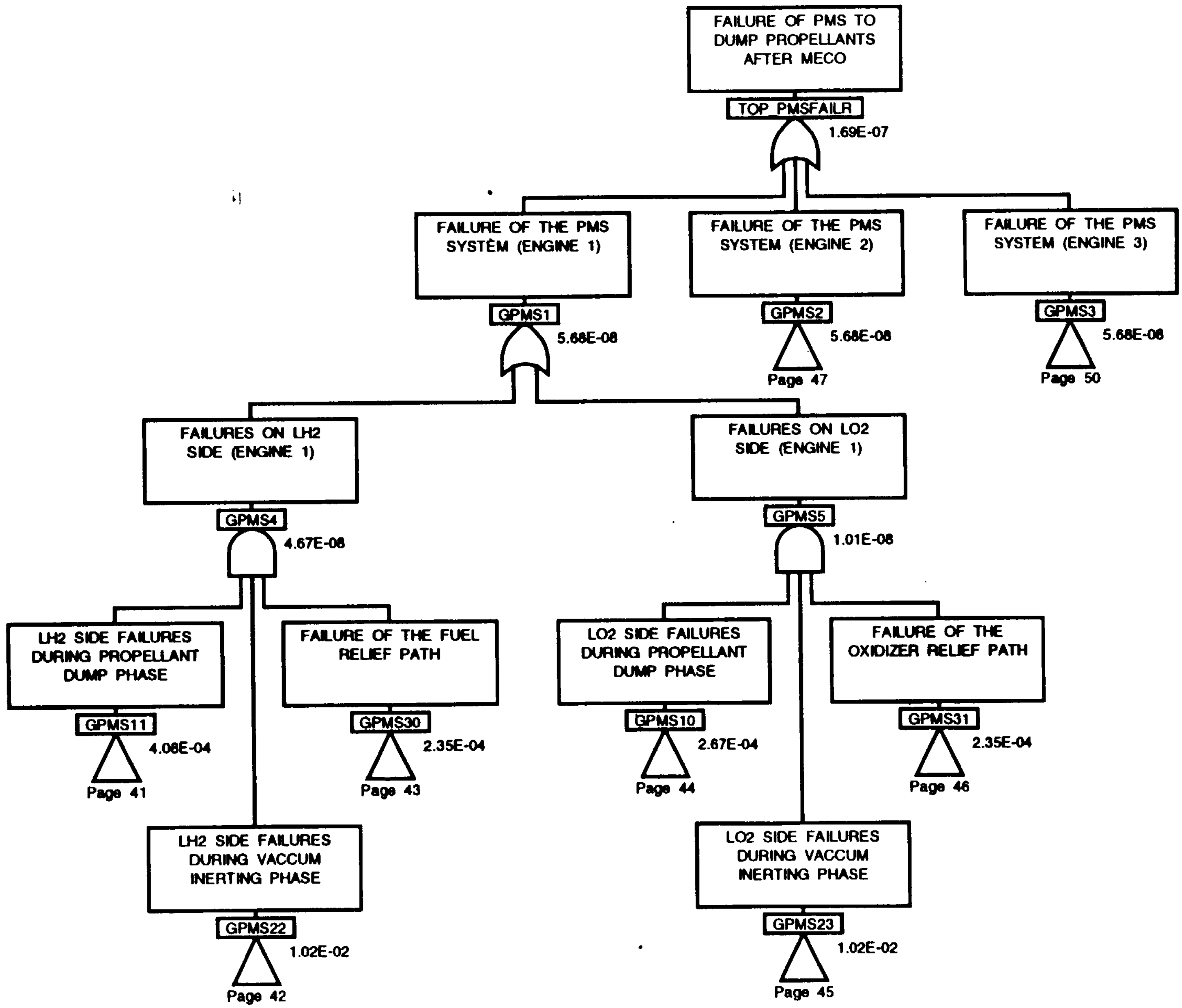

LOSS OF CROSS LINE HELIUM SUPPLY
TOP_NOHELALT
5.00E-02
LOSS OF HELIUM COMING FROM OTHER ENGINES (2 & 3)
GHECRS1
2.94E-07
HUMAN ERROR TO OPEN THE CROSS LINES VALVES
ANMHUHSMPCROSS
5.00E-02
LOCKHEED PRA
FAILURE TO SUPPLY HELIUM FROM THE OTHER ENGINES (INDEP ENDENT FAILURES)
GHECRS2
6.66E-10
COMMON CAUSE FAILURE TO OPEN THE CROSS L INE SOLENOID VALVE (ENGINES 2 AND 3)
ANMSVCOMPENG23
2.93E-07
LOCKHEED/B=0.1
LOSS OF HELIUM SUPPLY FROM ENGINE 2
GHECRS3
2.58E-05
Page 36
LOSS OF HELIUM SUPPLY FROM ENGINE 3
GHECRS4
2.58E-05
Page 37

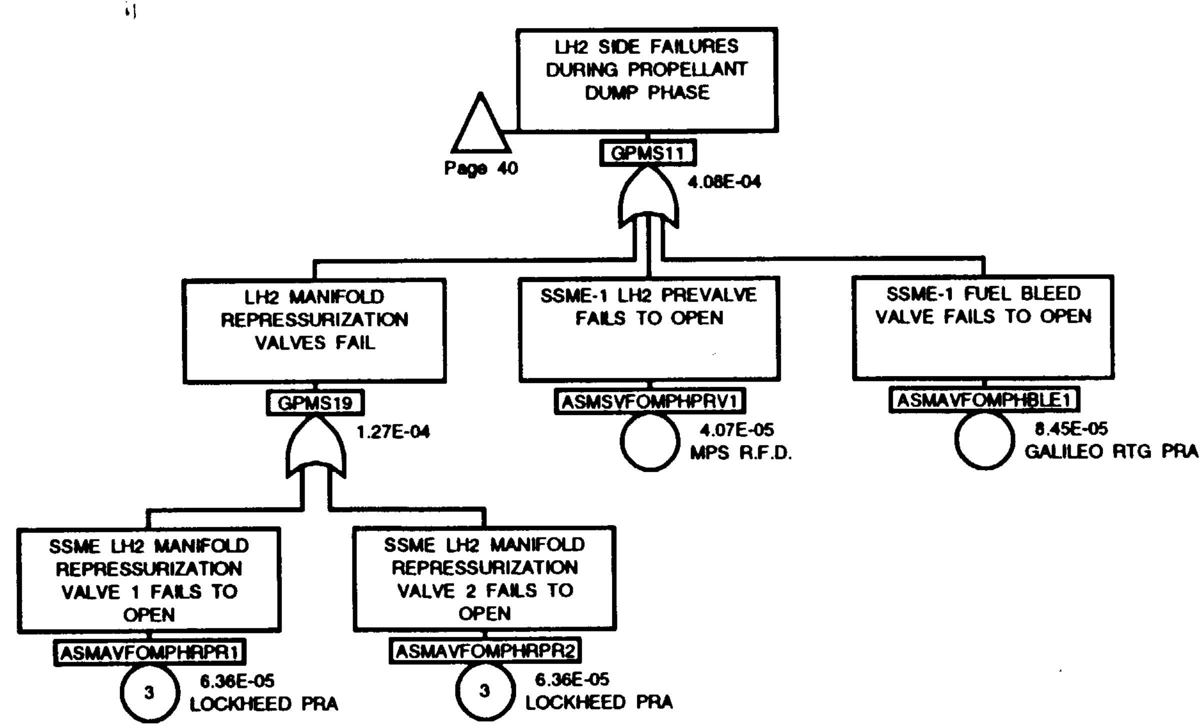

LOSS OF HELIUM SUPPLY FROM ENGINE 2
GHECRS3
2.58E-05
Page 35
CHECK VALVE ENGINE 2 FAILS TO OPEN
ANMCVFOMPCRLI2
1.00E-06
LOCKHEED PRA
CROSS-TIE LINE ENGINE 2 DEPRESSURIZES
ANMPPLRMPCRLI2
2.19E-05
LOCKHEED

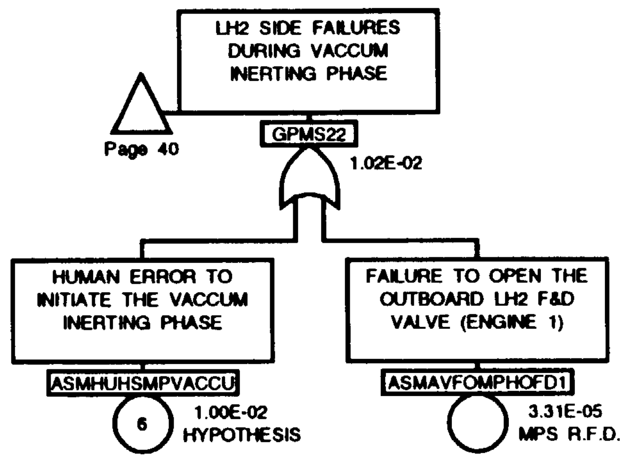

LOSS OF HELIUM SUPPLY FROM ENGINE 3
Page 35
GHECRS4
2.58E-05
CHECK VALVE ENGINE 3 FAILS TO OPEN
ANMCVFOMPCRLI3
1.00E-06
LOCKHEED PRA
CROSS-TIE LINE ENGINE 3 DEPRESSURIZES
ANMPPLRMPCRLI3
2.19E-05
LOCKHEED

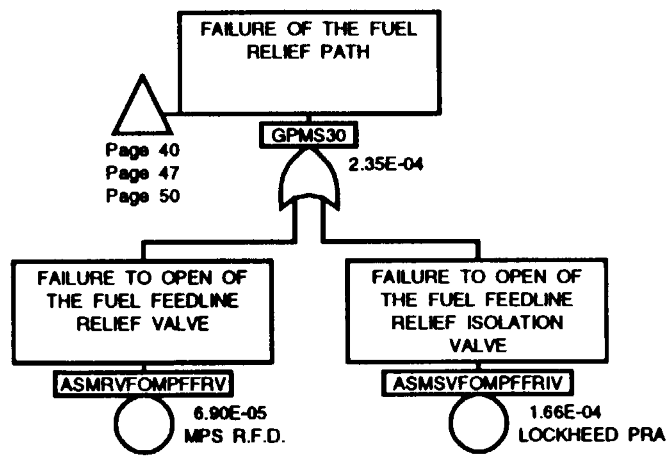

NO VALVE DRIFT OR DRIFT NOT CAUSING REDLINE
TOP_NOVLVDRFT
8.00E-01
VALVE DRIFT AFTER HYDRAULIC LOCKUP CAUSES REDLINE
TOP_VLVDRIFT
2.00E-01
EXPERT OPINION


OPOV COMMAND LIMIT NOT ENGAGED
TOP_OPOVCOMLNE
2.00E-03
OPOV COMMAND LIMIT ENGAGED
OPOVCOMLCREL
9.98E-01
PRACA-F (FMC)


FAILURE OF PMS TO DUMP PROPELLANTS AFTER MECO
TOP PMSFAILR
1.69E-07
FAILURE OF THE PMS SYSTEM (ENGINE 1)
GPMS1
5.68E-08
FAILURE OF THE PMS SYSTEM (ENGINE 2)
GPMS2
5.68E-08
Page 47
FAILURE OF THE PMS SYSTEM (ENGINE 3)
GPMS3
5.68E-08
Page 50
FAILURES ON LH2 SIDE (ENGINE 1)
GPMS4
4.67E-08
FAILURES ON LO2 SIDE (ENGINE 1)
GPMS5
1.01E-08
LH2 SIDE FAILURES DURING PROPELLANT DUMP PHASE
GPMS11
4.08E-04
Page 41
FAILURE OF THE FUEL RELIEF PATH
GPMS30
2.35E-04
Page 43
LH2 SIDE FAILURES DURING VACCUM INERTING PHASE
GPMS22
1.02E-02
Page 42
LO2 SIDE FAILURES DURING PROPELLANT DUMP PHASE
GPMS10
2.67E-04
Page 44
FAILURE OF THE OXIDIZER RELIEF PATH
GPMS31
2.35E-04
Page 46
LO2 SIDE FAILURES DURING VACCUM INERTING PHASE
GPMS23
1.02E-02
Page 45


LH2 SIDE FAILURES DURING PROPELLANT DUMP PHASE
GPMS11
4.08E-04
Page 40
LH2 MANIFOLD REPRESSURIZATION VALVES FAIL
GPMS19
1.27E-04
SSME-1 LH2 PREVALVE FAILS TO OPEN
ASMSVFOMPHPRV1
4.07E-05
MPS R.F.D.
SSME-1 FUEL BLEED VALVE FAILS TO OPEN
ASMAVFOMPHBLE1
8.45E-05
GALILEO RTG PRA
SSME LH2 MANIFOLD REPRESSURIZATION VALVE 1 FAILS TO OPEN
ASMAVFOMPHRPR1
3
6.36E-05
LOCKHEED PRA
SSME LH2 MANIFOLD REPRESSURIZATION VALVE 2 FAILS TO OPEN
ASMAVFOMPHRPR2
3
6.36E-05
LOCKHEED PRA


LH2 SIDE FAILURES DURING VACCUM INERTING PHASE
Page 40
GPMS22
1.02E-02
HUMAN ERROR TO INITIATE THE VACCUM INERTING PHASE
ASMHUHSMPVACCU
6
1.00E-02
HYPOTHESIS
FAILURE TO OPEN THE OUTBOARD LH2 F&D VALVE (ENGINE 1)
ASMAVFOMPHOFD1
3.31E-05
MPS R.F.D.


FAILURE OF THE FUEL RELIEF PATH
GPMS30
2.35E-04
Page 40
Page 47
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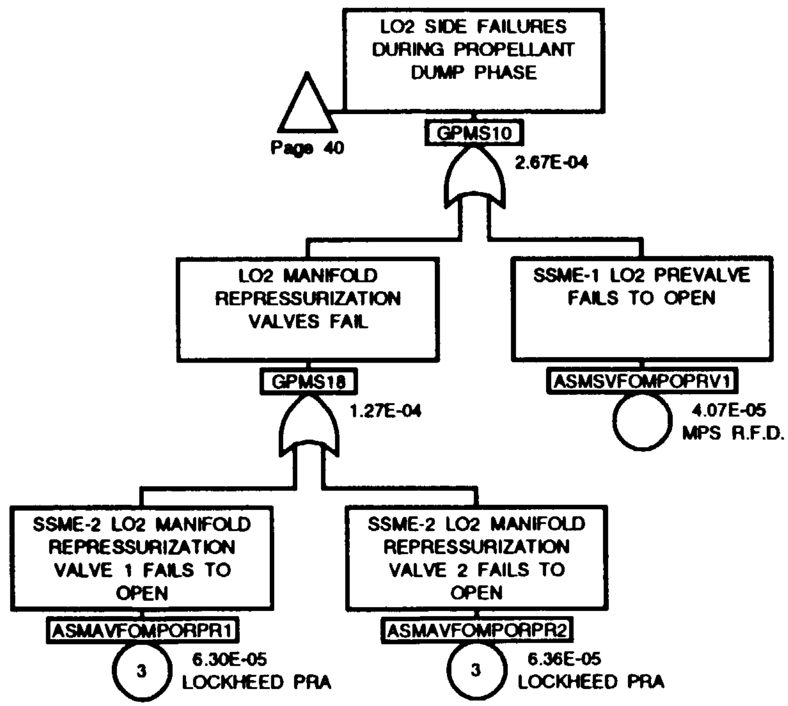
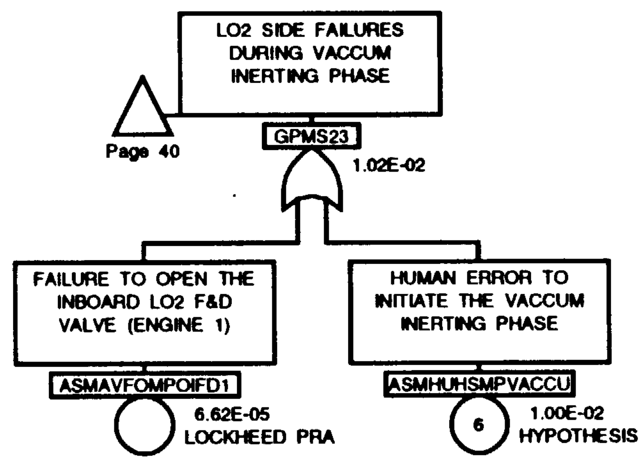
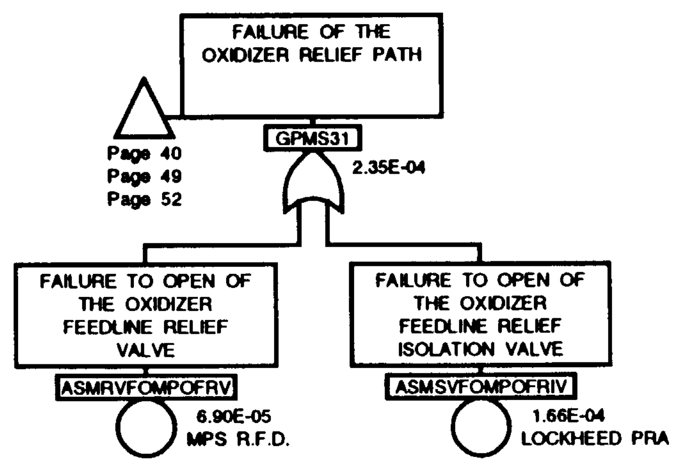
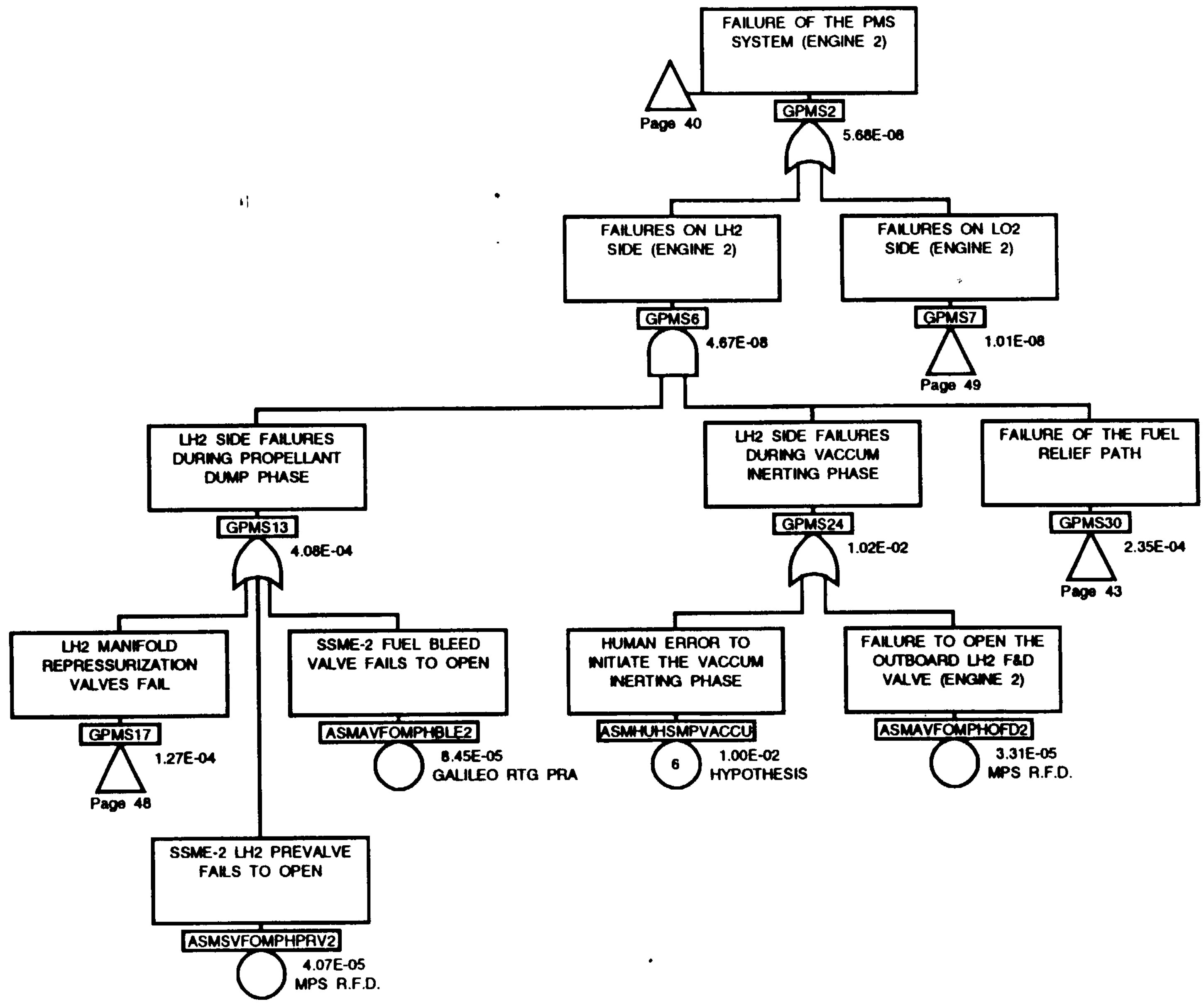
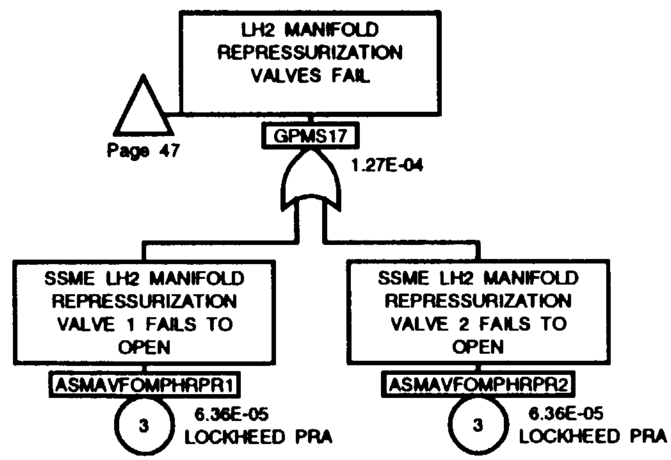
FAILURE TO OPEN OF THE FUEL FEEDLINE RELIEF VALVE
ASMRVFOMPFFRV
6.90E-05
MPS R.F.D.
FAILURE TO OPEN OF THE FUEL FEEDLINE RELIEF ISOLATION VALVE
ASMSVFOMPFFRIV
1.66E-04
LOCKHEED PRA

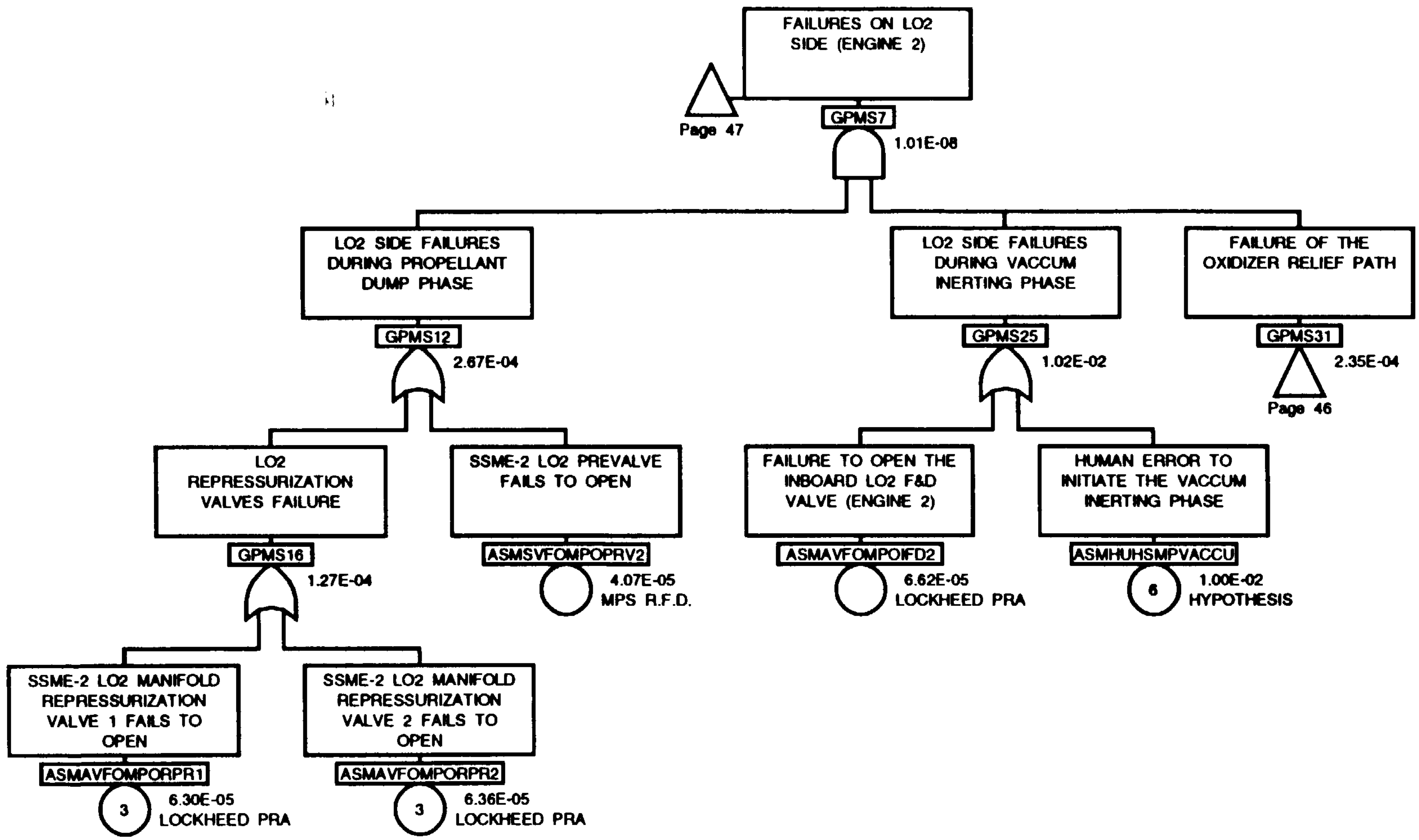

LO2 SIDE FAILURES DURING PROPELLANT DUMP PHASE
Page 40
GPMS10
2.67E-04
LO2 MANIFOLD REPRESSURIZATION VALVES FAIL
GPMS18
1.27E-04
SSME-1 LO2 PREVALVE FAILS TO OPEN
ASMSVFOMPOPRV1
4.07E-05
MPS R.F.D.
SSME-2 LO2 MANIFOLD REPRESSURIZATION VALVE 1 FAILS TO OPEN
ASMAVFOMPORPR1
3
6.30E-05
LOCKHEED PRA
SSME-2 LO2 MANIFOLD REPRESSURIZATION VALVE 2 FAILS TO OPEN
ASMAVFOMPORPR2
3
6.36E-05
LOCKHEED PRA

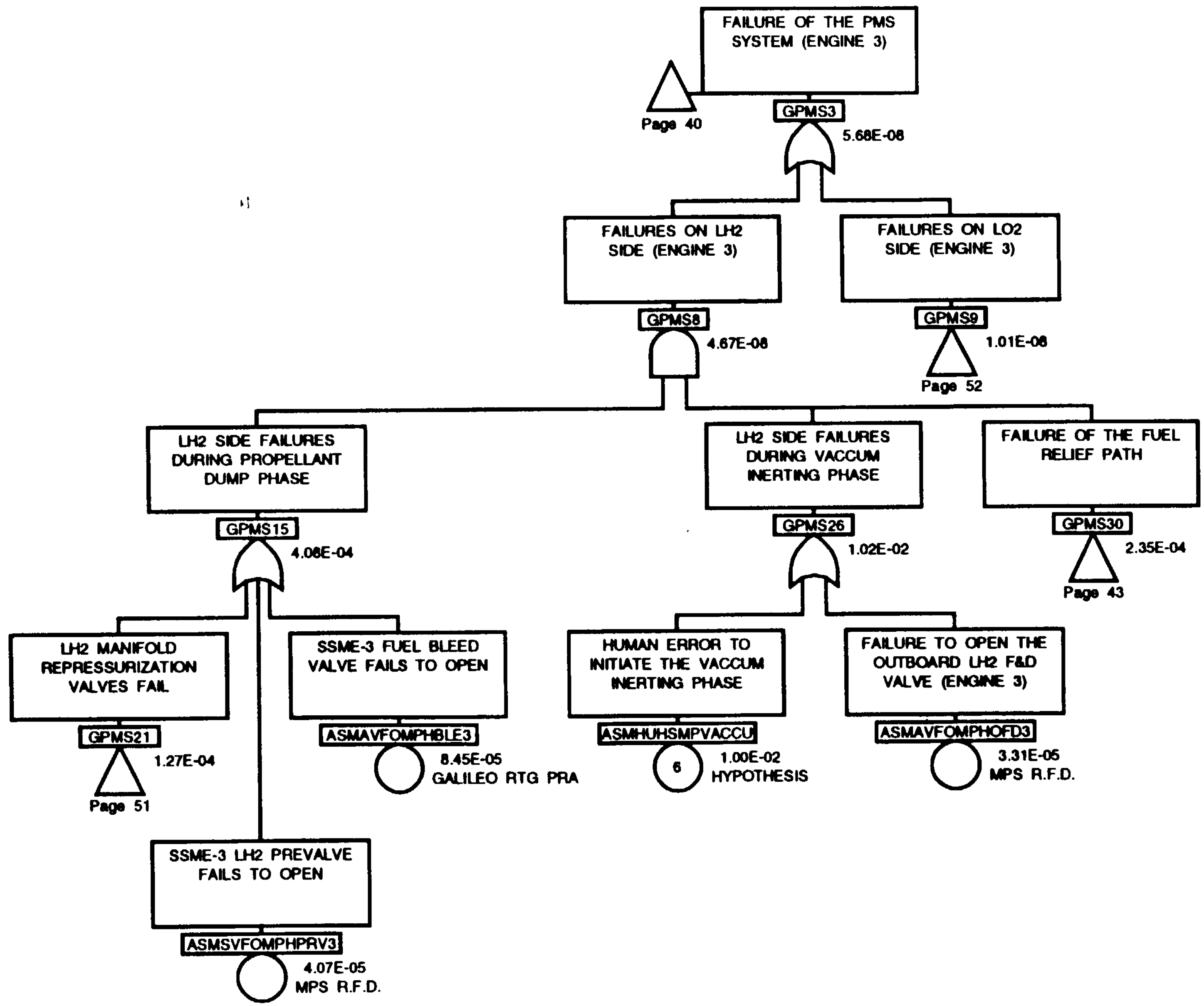

LO2 SIDE FAILURES DURING VACCUM INERTING PHASE
Page 40
GPMS23
1.02E-02
FAILURE TO OPEN THE INBOARD LO2 F&D VALVE (ENGINE 1)
ASMAVFOMPOIFD1
6.62E-05
LOCKHEED PRA
HUMAN ERROR TO INITIATE THE VACCUM INERTING PHASE
ASMHUHSMPVACCU
6
1.00E-02
HYPOTHESIS

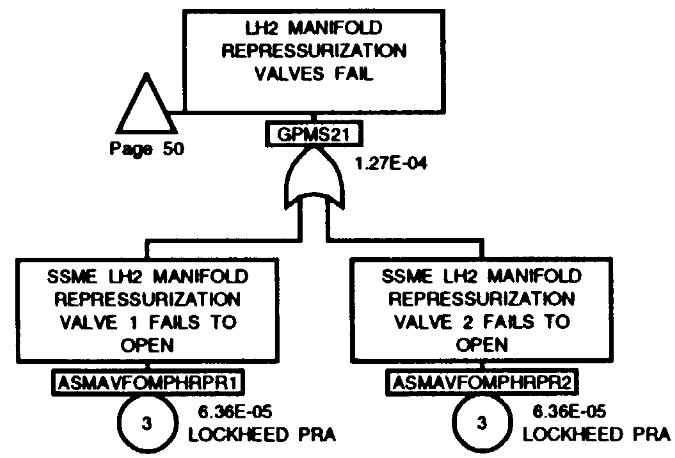

FAILURE OF THE OXIDIZER RELIEF PATH
GPMS31
2.35E-04
Page 40
Page 49
Page 52
FAILURE TO OPEN OF THE OXIDIZER FEEDLINE RELIEF VALVE
ASMRVFOMPOFRV
6.90E-05
MPS R.F.D.
FAILURE TO OPEN OF THE OXIDIZER FEEDLINE RELIEF ISOLATION VALVE
ASMSVFOMPOFRIV
1.66E-04
LOCKHEED PRA

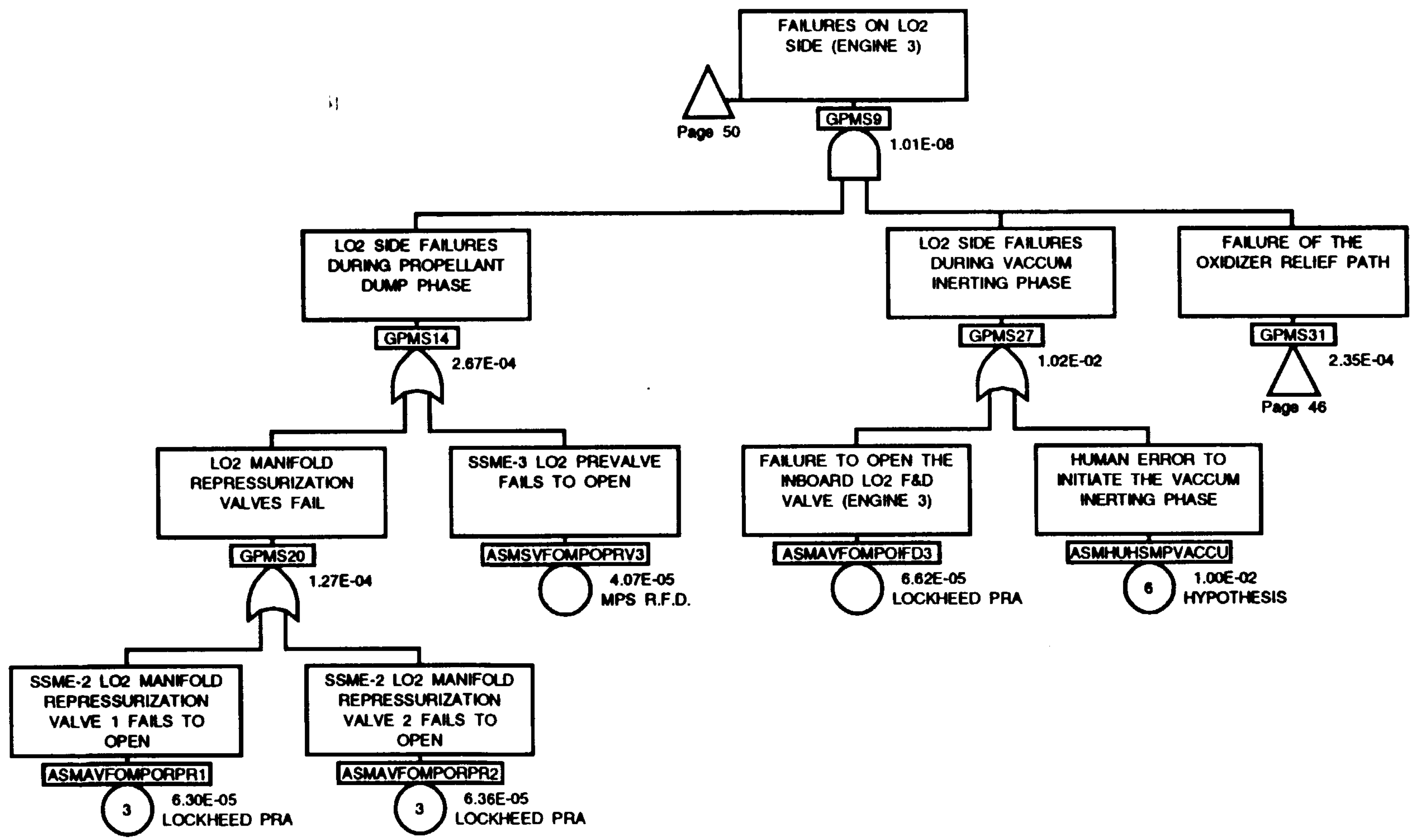

FAILURE OF THE PMS SYSTEM (ENGINE 2)
Page 40
GPMS2
5.68E-08
FAILURES ON LH2 SIDE (ENGINE 2)
FAILURES ON LO2 SIDE (ENGINE 2)
GPMS6
4.67E-08
GPMS7
1.01E-08
Page 49
LH2 SIDE FAILURES DURING PROPELLANT DUMP PHASE
LH2 SIDE FAILURES DURING VACCUM INERTING PHASE
FAILURE OF THE FUEL RELIEF PATH
GPMS13
4.08E-04
GPMS24
1.02E-02
GPMS30
2.35E-04
Page 43
LH2 MANIFOLD REPRESSURIZATION VALVES FAIL
SSME-2 FUEL BLEED VALVE FAILS TO OPEN
HUMAN ERROR TO INITIATE THE VACCUM INERTING PHASE
FAILURE TO OPEN THE OUTBOARD LH2 F&D VALVE (ENGINE 2)
GPMS17
1.27E-04
Page 48
ASMAVFOMPHBLE2
8.45E-05
GALILEO RTG PRA
ASMHUHSMPVACCU
6
1.00E-02
HYPOTHESIS
ASMAVFOMPHOFD2
3.31E-05
MPS R.F.D.
SSME-2 LH2 PREVALVE FAILS TO OPEN
ASMSVFOMPHPRV2
4.07E-05
MPS R.F.D.

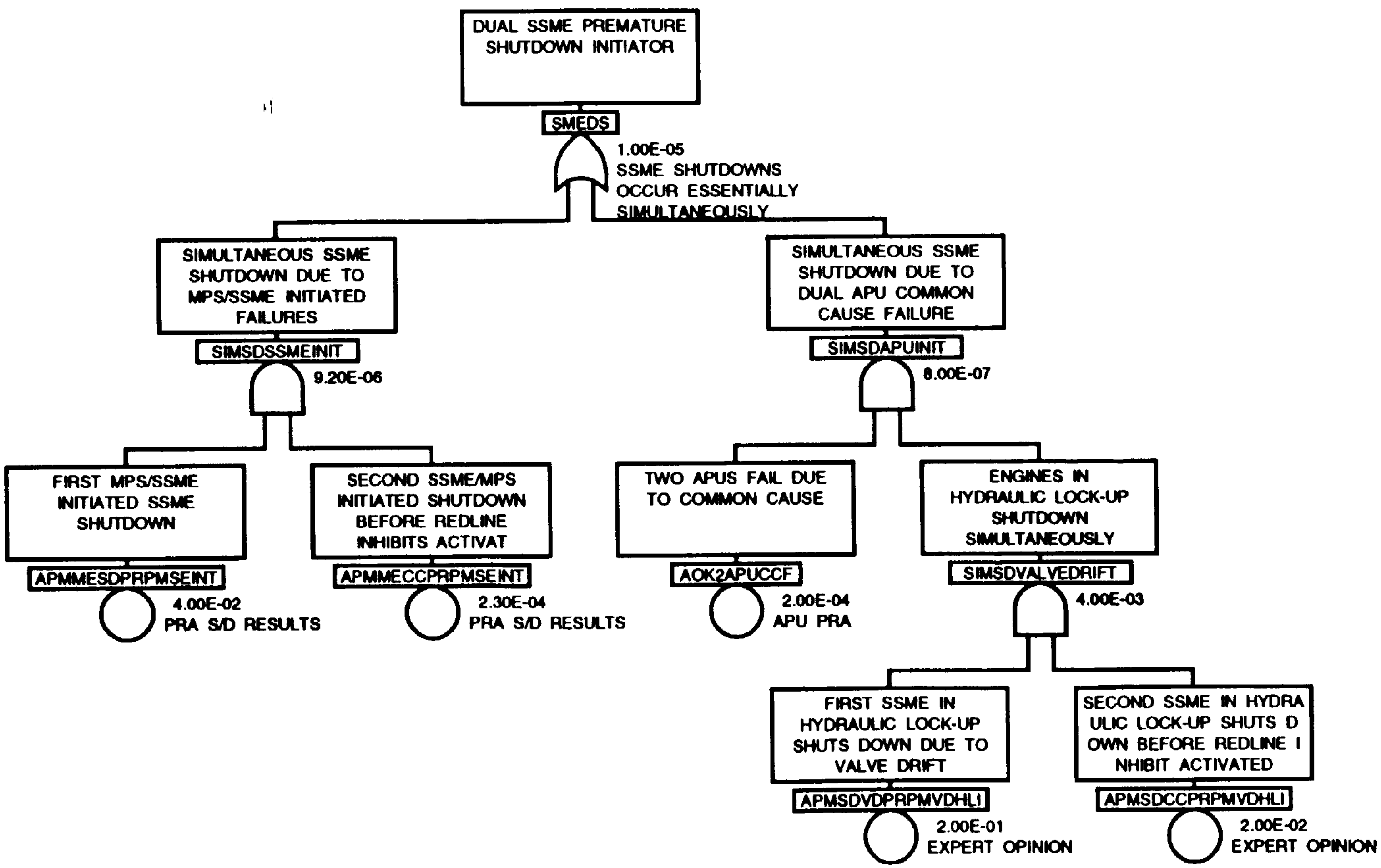

LH2 MANIFOLD REPRESSURIZATION VALVES FAIL
Page 47
GPMS17
1.27E-04
SSME LH2 MANIFOLD REPRESSURIZATION VALVE 1 FAILS TO OPEN
ASMAVFOMPHRPR1
3
6.36E-05
LOCKHEED PRA
SSME LH2 MANIFOLD REPRESSURIZATION VALVE 2 FAILS TO OPEN
ASMAVFOMPHRPR2
3
6.36E-05
LOCKHEED PRA

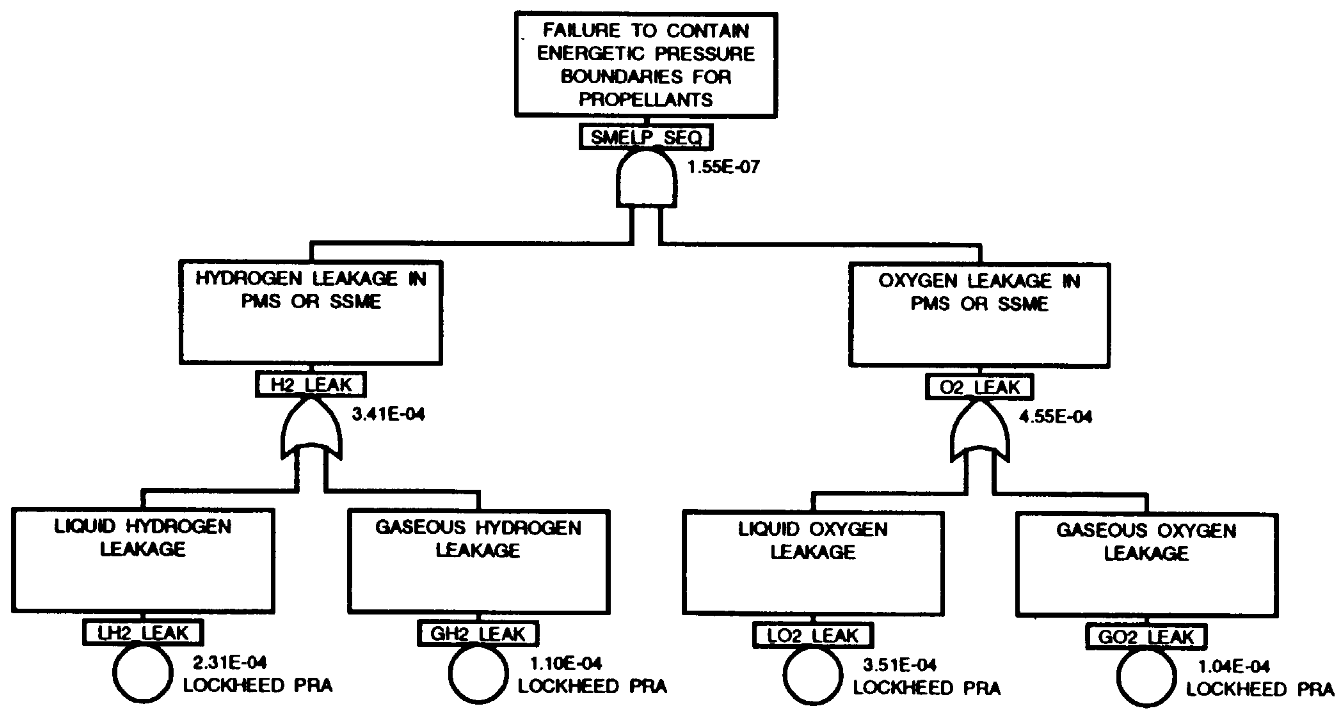

FAILURES ON LO2 SIDE (ENGINE 2)
Page 47
GPMS7
1.01E-08
LO2 SIDE FAILURES DURING PROPELLANT DUMP PHASE
GPMS12
2.67E-04
LO2 SIDE FAILURES DURING VACCUM INERTING PHASE
GPMS25
1.02E-02
FAILURE OF THE OXIDIZER RELIEF PATH
GPMS31
2.35E-04
Page 46
LO2 REPRESSURIZATION VALVES FAILURE
GPMS16
1.27E-04
SSME-2 LO2 PREVALVE FAILS TO OPEN
ASMSVFOMPOPRV2
4.07E-05
MPS R.F.D.
FAILURE TO OPEN THE INBOARD LO2 F&D VALVE (ENGINE 2)
ASMAVFOMPOIFD2
6.62E-05
LOCKHEED PRA
HUMAN ERROR TO INITIATE THE VACCUM INERTING PHASE
ASMHUHSMPVACCU
6
1.00E-02
HYPOTHESIS
SSME-2 LO2 MANIFOLD REPRESSURIZATION VALVE 1 FAILS TO OPEN
ASMAVFOMPORPR1
3
6.30E-05
LOCKHEED PRA
SSME-2 LO2 MANIFOLD REPRESSURIZATION VALVE 2 FAILS TO OPEN
ASMAVFOMPORPR2
3
6.36E-05
LOCKHEED PRA

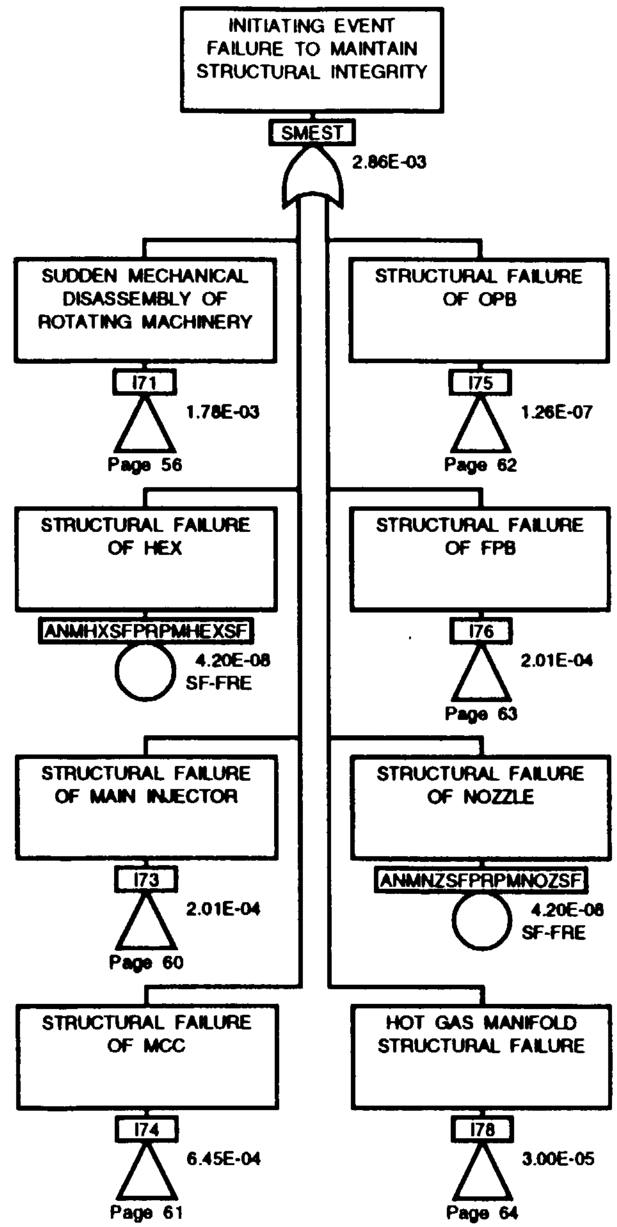

FAILURE OF THE PMS SYSTEM (ENGINE 3)
Page 40
GPMS3
5.68E-08
FAILURES ON LH2 SIDE (ENGINE 3)
FAILURES ON LO2 SIDE (ENGINE 3)
GPMS8
4.67E-08
GPMS9
1.01E-08
Page 52
LH2 SIDE FAILURES DURING PROPELLANT DUMP PHASE
LH2 SIDE FAILURES DURING VACCUM INERTING PHASE
FAILURE OF THE FUEL RELIEF PATH
GPMS15
4.08E-04
GPMS26
1.02E-02
GPMS30
2.35E-04
Page 43
LH2 MANIFOLD REPRESSURIZATION VALVES FAIL
SSME-3 FUEL BLEED VALVE FAILS TO OPEN
HUMAN ERROR TO INITIATE THE VACCUM INERTING PHASE
FAILURE TO OPEN THE OUTBOARD LH2 F&D VALVE (ENGINE 3)
GPMS21
1.27E-04
Page 51
ASMAVFOMPHBLE3
8.45E-05
GALILEO RTG PRA
ASMHUHSMPVACCU
6
1.00E-02
HYPOTHESIS
ASMAVFOMPHOFD3
3.31E-05
MPS R.F.D.
SSME-3 LH2 PREVALVE FAILS TO OPEN
ASMSVFOMPHPRV3
4.07E-05
MPS R.F.D.

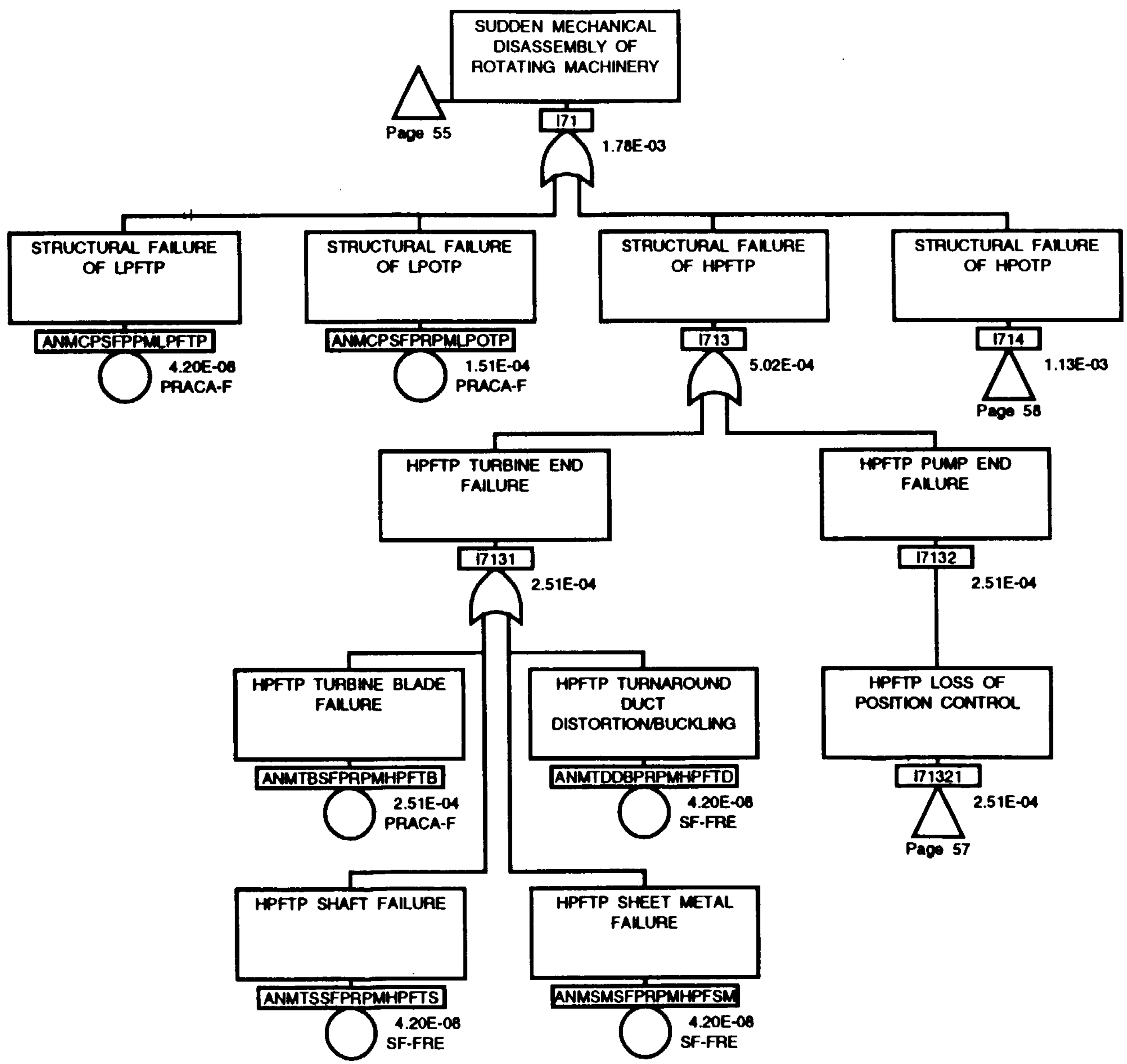

LH2 MANIFOLD REPRESSURIZATION VALVES FAIL
Page 50
GPMS21
1.27E-04
SSME LH2 MANIFOLD REPRESSURIZATION VALVE 1 FAILS TO OPEN
ASMAVFOMPHRPR1
3
6.36E-05
LOCKHEED PRA
SSME LH2 MANIFOLD REPRESSURIZATION VALVE 2 FAILS TO OPEN
ASMAVFOMPHRPR2
3
6.36E-05
LOCKHEED PRA


FAILURES ON LO2 SIDE (ENGINE 3)
Page 50
GPMS9
1.01E-08
LO2 SIDE FAILURES DURING PROPELLANT DUMP PHASE
GPMS14
2.67E-04
LO2 SIDE FAILURES DURING VACCUM INERTING PHASE
GPMS27
1.02E-02
FAILURE OF THE OXIDIZER RELIEF PATH
GPMS31
2.35E-04
Page 46
LO2 MANIFOLD REPRESSURIZATION VALVES FAIL
GPMS20
1.27E-04
SSME-3 LO2 PREVALVE FAILS TO OPEN
ASMSVFOMPOPRV3
4.07E-05
MPS R.F.D.
FAILURE TO OPEN THE INBOARD LO2 F&D VALVE (ENGINE 3)
ASMAVFOMPOIFD3
6.62E-05
LOCKHEED PRA
HUMAN ERROR TO INITIATE THE VACCUM INERTING PHASE
ASMHUHSMPVACCU
6
1.00E-02
HYPOTHESIS
SSME-2 LO2 MANIFOLD REPRESSURIZATION VALVE 1 FAILS TO OPEN
ASMAVFOMPORPR1
3
6.30E-05
LOCKHEED PRA
SSME-2 LO2 MANIFOLD REPRESSURIZATION VALVE 2 FAILS TO OPEN
ASMAVFOMPORPR2
3
6.36E-05
LOCKHEED PRA

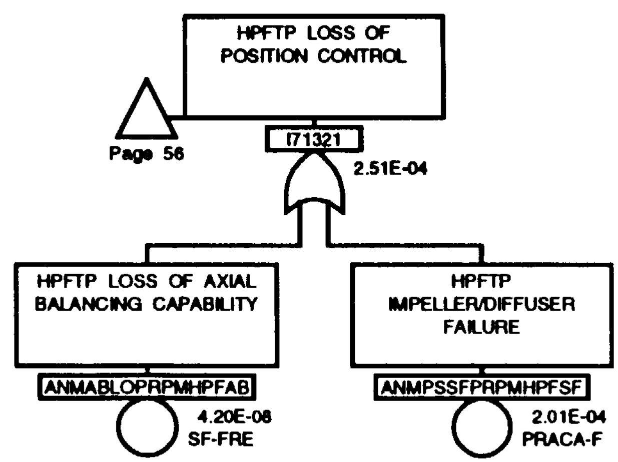

DUAL SSME PREMATURE SHUTDOWN INITIATOR
SMEDS
1.00E-05
SSME SHUTDOWNS OCCUR ESSENTIALLY SIMULTANEOUSLY
SIMULTANEOUS SSME SHUTDOWN DUE TO MPS/SSME INITIATED FAILURES
SIMSDSSMEINIT
9.20E-06
SIMULTANEOUS SSME SHUTDOWN DUE TO DUAL APU COMMON CAUSE FAILURE
SIMSDAPUINIT
8.00E-07
FIRST MPS/SSME INITIATED SSME SHUTDOWN
APMMESDPRPMSEINT
4.00E-02
PRA S/D RESULTS
SECOND SSME/MPS INITIATED SHUTDOWN BEFORE REDLINE INHIBITS ACTIVAT
APMMECCPRPMSEINT
2.30E-04
PRA S/D RESULTS
TWO APUS FAIL DUE TO COMMON CAUSE
AOK2APUCCF
2.00E-04
APU PRA
ENGINES IN HYDRAULIC LOCK-UP SHUTDOWN SIMULTANEOUSLY
SIMSDVALVEDRIFT
4.00E-03
FIRST SSME IN HYDRAULIC LOCK-UP SHUTS DOWN DUE TO VALVE DRIFT
APMSDVDPRPMVDHLI
2.00E-01
EXPERT OPINION
SECOND SSME IN HYDRA ULIC LOCK-UP SHUTS D OWN BEFORE REDLINE I NHIBIT ACTIVATED
APMSDCCPRPMVDHLI
2.00E-02
EXPERT OPINION

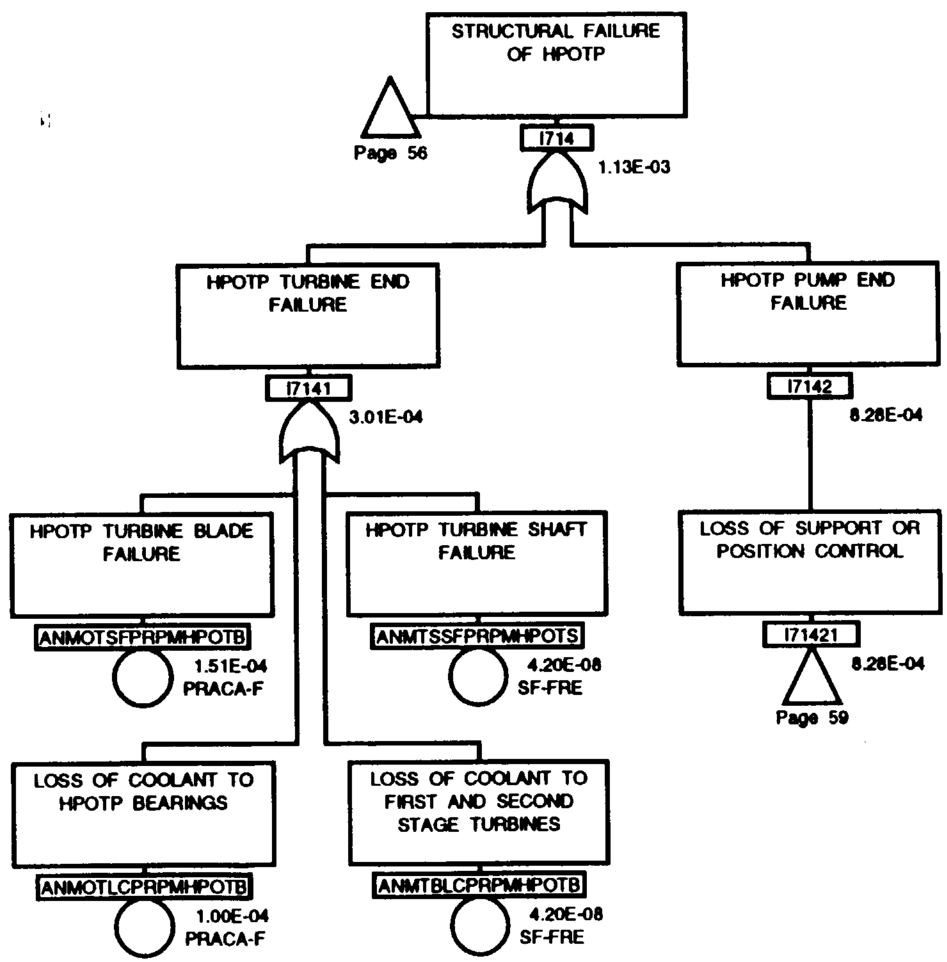

FAILURE TO CONTAIN ENERGETIC PRESSURE BOUNDARIES FOR PROPELLANTS
SMELP SEQ
1.55E-07
HYDROGEN LEAKAGE IN PMS OR SSME
H2 LEAK
3.41E-04
OXYGEN LEAKAGE IN PMS OR SSME
O2 LEAK
4.55E-04
LIQUID HYDROGEN LEAKAGE
LH2 LEAK
2.31E-04
LOCKHEED PRA
GASEOUS HYDROGEN LEAKAGE
GH2 LEAK
1.10E-04
LOCKHEED PRA
LIQUID OXYGEN LEAKAGE
LO2 LEAK
3.51E-04
LOCKHEED PRA
GASEOUS OXYGEN LEAKAGE
GO2 LEAK
1.04E-04
LOCKHEED PRA

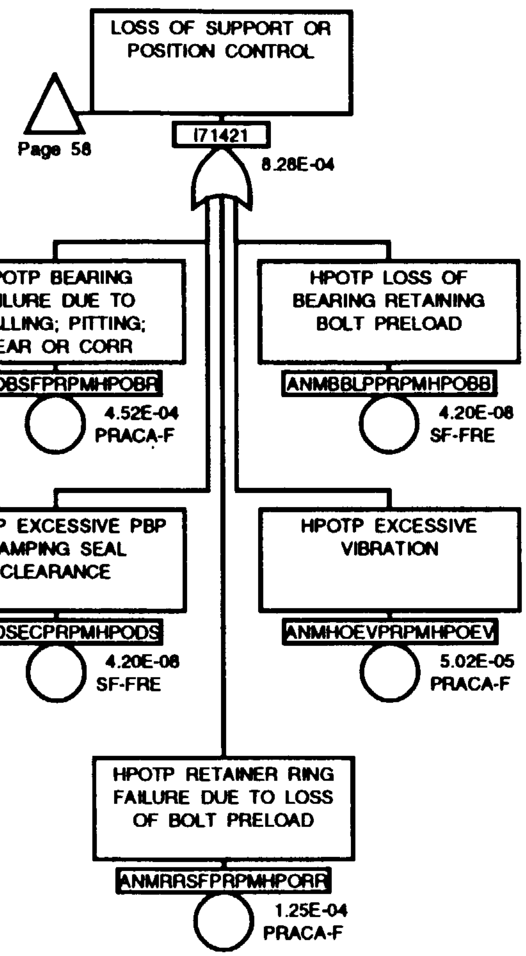

INITIATING EVENT
FAILURE TO MAINTAIN
STRUCTURAL INTEGRITY
SMEST
2.86E-03
SUDDEN MECHANICAL
DISASSEMBLY OF
ROTATING MACHINERY
I71
1.78E-03
Page 56
STRUCTURAL FAILURE
OF OPB
I75
1.26E-07
Page 62
STRUCTURAL FAILURE
OF HEX
ANMHXSFPRPMHEXSF
4.20E-08
SF-FRE
STRUCTURAL FAILURE
OF FPB
I76
2.01E-04
Page 63
STRUCTURAL FAILURE
OF MAIN INJECTOR
I73
2.01E-04
Page 60
STRUCTURAL FAILURE
OF NOZZLE
ANMNZSFPRPMNOZSF
4.20E-08
SF-FRE
STRUCTURAL FAILURE
OF MCC
I74
6.45E-04
Page 61
HOT GAS MANIFOLD
STRUCTURAL FAILURE
I78
3.00E-05
Page 64

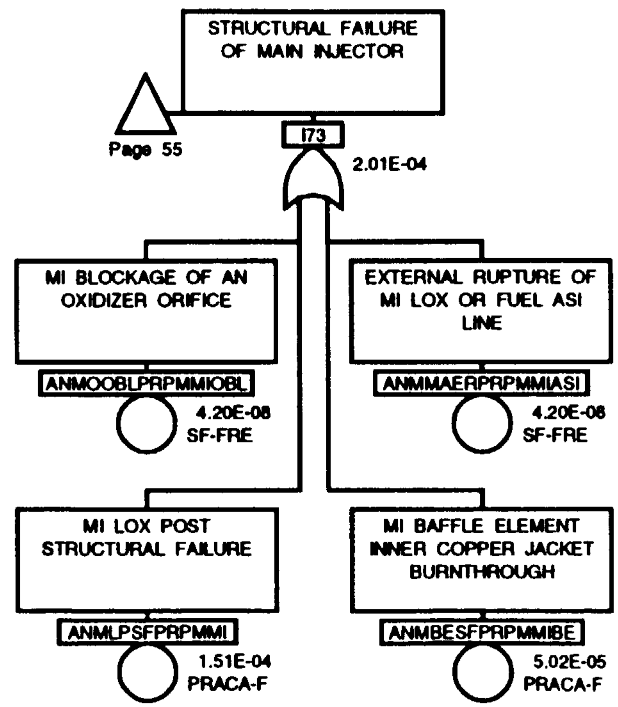


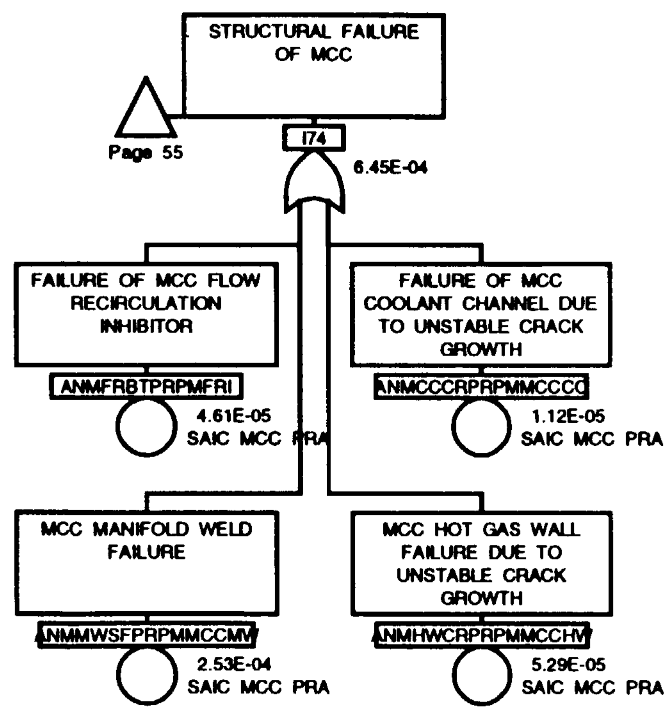
SUDDEN MECHANICAL DISASSEMBLY OF ROTATING MACHINERY
Page 55
I71
1.78E-03
STRUCTURAL FAILURE OF LPFTP
ANMCPSFPPMLPFTP
4.20E-08
PRACA-F
STRUCTURAL FAILURE OF LPOTP
ANMCPSFPRPMLPOTP
1.51E-04
PRACA-F
STRUCTURAL FAILURE OF HPFTP
I713
5.02E-04
STRUCTURAL FAILURE OF HPOTP
I714
1.13E-03
Page 58
HPFTP TURBINE END FAILURE
I7131
2.51E-04
HPFTP PUMP END FAILURE
I7132
2.51E-04
HPFTP TURBINE BLADE FAILURE
ANMTBSFPRPMHPFTB
2.51E-04
PRACA-F
HPFTP TURNAROUND DUCT DISTORTION/BUCKLING
ANMTDDBPRPMHPFTD
4.20E-08
SF-FRE
HPFTP LOSS OF POSITION CONTROL
I71321
2.51E-04
Page 57
HPFTP SHAFT FAILURE
ANMTSSFPRPMHPFTS
4.20E-08
SF-FRE
HPFTP SHEET METAL FAILURE
ANMSMSFPRPMHPFSM
4.20E-08
SF-FRE

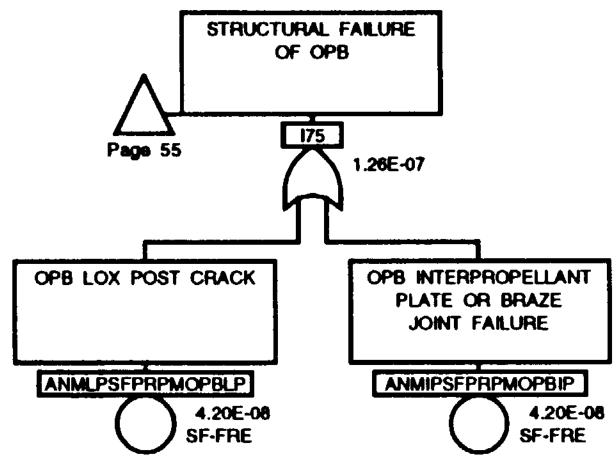

HPFTP LOSS OF POSITION CONTROL
Page 56
I71321
2.51E-04
HPFTP LOSS OF AXIAL BALANCING CAPABILITY
ANMABLOPRPMHPFAB
4.20E-08
SF-FRE
HPFTP IMPELLER/DIFFUSER FAILURE
ANMPSSFPRPMHPFSF
2.01E-04
PRACA-F

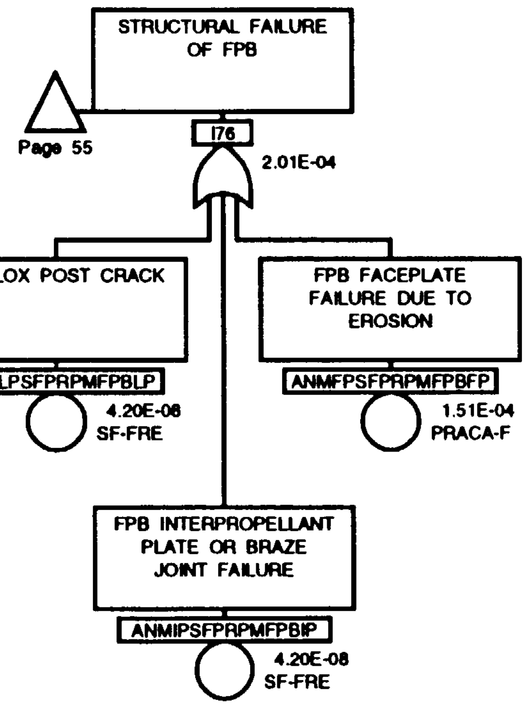

STRUCTURAL FAILURE OF HPOTP
Page 56
I714
1.13E-03
HPOTP TURBINE END FAILURE
I7141
3.01E-04
HPOTP PUMP END FAILURE
I7142
8.28E-04
HPOTP TURBINE BLADE FAILURE
ANMOTSFPRPMHPOTB
1.51E-04
PRACA-F
HPOTP TURBINE SHAFT FAILURE
ANMTSSFPRPMHPOTS
4.20E-08
SF-FRE
LOSS OF SUPPORT OR POSITION CONTROL
I71421
8.28E-04
Page 59
LOSS OF COOLANT TO HPOTP BEARINGS
ANMOTLCPRPMHPOTB
1.00E-04
PRACA-F
LOSS OF COOLANT TO FIRST AND SECOND STAGE TURBINES
ANMTBLCPRPMHPOTB
4.20E-08
SF-FRE

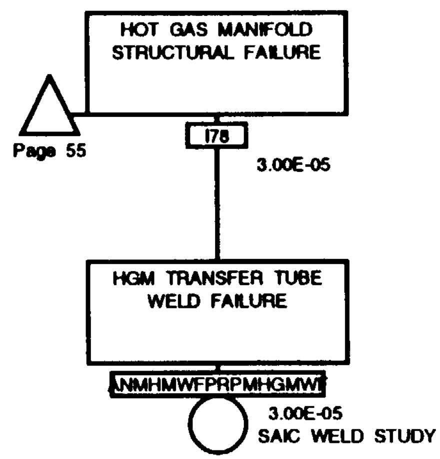

LOSS OF SUPPORT OR POSITION CONTROL
Page 58
I71421
8.28E-04
HPOTP BEARING FAILURE DUE TO SPALLING; PITTING; WEAR OR CORR
ANMOBSFPRPMHPOBR
4.52E-04
PRACA-F
HPOTP LOSS OF BEARING RETAINING BOLT PRELOAD
ANMBBLPPRPMHPOBB
4.20E-08
SF-FRE
HPOTP EXCESSIVE PBP DAMPING SEAL CLEARANCE
ANMDSECPRPMHPODS
4.20E-08
SF-FRE
HPOTP EXCESSIVE VIBRATION
ANMHOEVPRPMHPOEV
5.02E-05
PRACA-F
HPOTP RETAINER RING FAILURE DUE TO LOSS OF BOLT PRELOAD
ANMRRSFPRPMHPORR
1.25E-04
PRACA-F

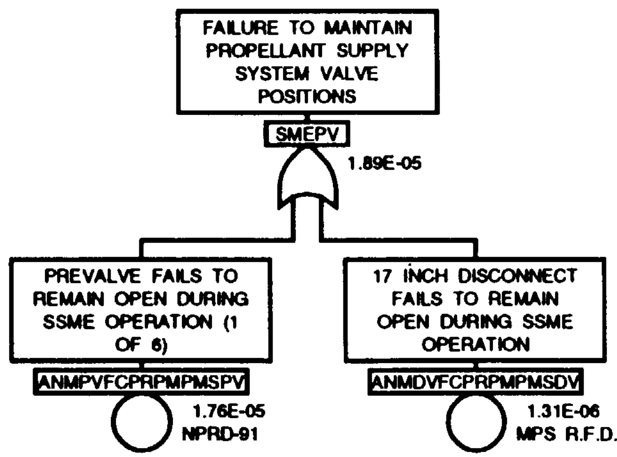

STRUCTURAL FAILURE OF MAIN INJECTOR
Page 55
I73
2.01E-04
MI BLOCKAGE OF AN OXIDIZER ORIFICE
ANMOOBLPRPMMIOBL
4.20E-08
SF-FRE
EXTERNAL RUPTURE OF MI LOX OR FUEL ASI LINE
ANMMAERPRPMMIASI
4.20E-08
SF-FRE
MI LOX POST STRUCTURAL FAILURE
ANMLPSFPRPMMI
1.51E-04
PRACA-F
MI BAFFLE ELEMENT INNER COPPER JACKET BURNTHROUGH
ANMBESFPRPMMIBE
5.02E-05
PRACA-F


STRUCTURAL FAILURE OF MCC
Page 55
I74
6.45E-04
FAILURE OF MCC FLOW RECIRCULATION INHIBITOR
ANMFRBTPRPMFRI
4.61E-05
SAIC MCC PRA
FAILURE OF MCC COOLANT CHANNEL DUE TO UNSTABLE CRACK GROWTH
ANMCCCRPRPMMCCCC
1.12E-05
SAIC MCC PRA
MCC MANIFOLD WELD FAILURE
ANMMWSFPRPMMCCMV
2.53E-04
SAIC MCC PRA
MCC HOT GAS WALL FAILURE DUE TO UNSTABLE CRACK GROWTH
ANMHWCRPRPMMCCHV
5.29E-05
SAIC MCC PRA


STRUCTURAL FAILURE OF OPB
Page 55
I75
1.26E-07
OPB LOX POST CRACK
ANMLPSFPRPMOPBLP
4.20E-08
SF-FRE
OPB INTERPROPELLANT PLATE OR BRAZE JOINT FAILURE
ANMIPSFPRPMOPBIP
4.20E-08
SF-FRE


STRUCTURAL FAILURE OF FPB
Page 55
I76
2.01E-04
FPB LOX POST CRACK
ANMLPSFPRPMFPBLP
4.20E-08
SF-FRE
FPB FACEPLATE FAILURE DUE TO EROSION
ANMFPSFPRPMFPBFP
1.51E-04
PRACA-F
FPB INTERPROPELLANT PLATE OR BRAZE JOINT FAILURE
ANMIPSFPRPMFPBIP
4.20E-08
SF-FRE


HOT GAS MANIFOLD STRUCTURAL FAILURE
Page 55
I78
3.00E-05
HGM TRANSFER TUBE WELD FAILURE
ANMHMWFPRPMHGMWF
3.00E-05
SAIC WELD STUDY


FAILURE TO MAINTAIN PROPELLANT SUPPLY SYSTEM VALVE POSITIONS
SMEPV
1.89E-05
PREVALVE FAILS TO REMAIN OPEN DURING SSME OPERATION (1 OF 6)
ANMPVFCPRPMPMSPV
1.76E-05
NPRD-91
17 INCH DISCONNECT FAILS TO REMAIN OPEN DURING SSME OPERATION
ANMDVFCPRPMPMSDV
1.31E-06
MPS R.F.D.

FUEL TURBINE TEMPERATURE REDLINE
SENSOR RELIABILITY ASSESSMENT

SENSOR FAILURE DATA - FUEL SIDE ONLY

PART NUMBER	7004-91	7013	TOTAL
TOTAL SECONDS	264,000	158,000	422,000
FAILURES	3	2	5

BOTH PART NUMBERS EXHIBIT THE SAME FAILURE RATE

MISSION RELIABILITY VALUES - SINGLE SENSOR (50%CONFIDENCE)

FAILURE (HIGH OR LOW)	0.993104
FAIL HIGH - DISQUALIFY	0.9943159
FAIL HIGH - VOTE FOR CUTOFF	0.9967419
FAIL LOW - DISQUALIFY	0.9979538

HISTORICAL SSME RELIABILITY DATA

SINGLE ENGINE - 104% MISSION	0.9924918
EXCEED FUEL TURBINE REDLINE	0.9984938

ERRONEOUS SHUTDOWN PROBABILITY

FIRST FAILURE HIGH OR LOW (1 OF 2)	0.0137444
SECOND FAILURE HIGH AND VOTE	0.0032581
COMBINED	4.478E-05
THREE ENGINE PROBABILITY	0.0001343
MTBF	7,440

LOSS OF PROTECTION PROBABILITY

FIRST FAILURE HIGH OR LOW (1 OF 2)	0.0137444
SECOND FAILURE - NO VOTE	0.0056841
COMBINED	7.812E-05
THREE ENGINE PROBABILITY	0.0002344
MTBF	4,270

REDLINE EXCEEDED PROBABILITY

SINGLE ENGINE	0.0015062
THREE ENGINE PROBABILITY	0.0045117
MTBF	220

REDLINE PROVIDES NEEDED PROTECTION

SAFE SHUT DOWN FOR 20 PERCENT OF HISTORICAL FAILURES

EXPECTED NEED	1 IN 220 FLIGHTS
EXPECTED ERRONEOUS	1 IN 7,440 FLIGHTS
RATIO	34 TO 1

SENSOR CATASTROPHIC POTENTIAL

LOSS OF REDLINE	7.812E-05
ENGINE EXCEEDS REDLINE	0.0015062
COMBINED	1.177E-07
THREE ENGINE PROBABILITY	3.53E-07
MTBF	2,832,780

ERRONEOUS SHUTDOWN (3 ENGINES)	0.0001343
SECOND ENGINE SHUTDOWN	0.0075082
COMBINED	1.009E-06
MTBF	991,450

UNABLE TO ASSESS ORBITER ABORT RISK

CUTOFF CODES

CODE	ID	DESCRIPTION
CADS	1	COMMAND AND DATA SIMULATOR COMMAND (SIMULATES ORBITER COMPUTER)
CADS ELU	2	CADS - ELECTRONIC LOCKUP
CADS FTD	3	CADS - HPFTP TURBINE DISCHARGE TEMPERATURE REDLINE LOST
CONT	4	ENGINE CONTROLLER INITIATED
CONT FD	5	CONTROLLER - FUEL DENSITY (OBSOLETE)
CONT IEA	6	CONTROLLER - INPUT ELECTRONICS CHANNEL A
ENG RDY	7	LOSS OF ENGINE READY
F SPD IC	8	HPFTP SPEED IGNITION CONFIRM
F TD T	9	HPFTP TURBINE DISCHARGE TEMPERATURE
F TD T E	10	HPFTP TURBINE DISCHARGE TEMPERATURE - ERRONEOUS
F TI T	11	HPFTP TURBINE INLET TEMPERATURE (OBSOLETE)
FAC	12	FACILITY INITIATED CUTOFF (NOT AN ENGINE PROBLEM)
FAC E	13	FACILITY INITIATED CUTOFF - ERRONEOUS
H2O PR	14	FACILITY WATER PRESSURE
HEX DP	15	HEAT EXCHANGER DELTA PRESSURE (OBSOLETE)
HEX PR	16	HEAT EXCHANGER PRESSURE (OBSOLETE)
HEX PR E	17	HEAT EXCHANGER PRESSURE - ERRONEOUS
HF ACC	18	HPFTP ACCELEROMETERS
HF ACC A	19	HPFTP ACCELEROMETERS - AXIAL (OBSOLETE)
HF ACC E	20	HPFTP ACCELEROMETERS - ERRONEOUS
HF ACC N	21	HPFTP ACCELEROMETERS - NON STANDARD MONITOR (OBSOLETE)
HF SPD	22	HPFTP SPEED (OBSOLETE)
HGM	23	HOT GAS MANIFOLD DELTA PRESSURE
HO ACC	24	HPOTP ACCELEROMETERS
HO ACC A	25	HPOTP ACCELEROMETERS - AXIAL (OBSOLETE)
HO ACC C	26	HPOTP ACCELEROMETERS - CROSSFEED FROM HPFTP
HO ACC E	27	HPOTP ACCELEROMETERS - ERRONEOUS
HO ACC N	28	HPOTP ACCELEROMETERS - NON STANDARD MONITOR (OBSOLETE)
HO BRG T	29	HPOTP BEARING COOLANT TEMPERATURE
HO SPD	30	HPOTP SPEED (OBSOLETE)
HO SPD E	31	HPOTP - ERRONEOUS
INJ ACC	32	MAIN INJECTOR ACCELEROMETERS
LF ACC	33	LPFTP ACCELEROMETERS
LF ACC E	34	LPFTP ACCELEROMETERS - ERRONEOUS
LO ACC E	35	LPOTP ACCELEROMETERS - ERRONEOUS
LOX T E	36	HPOTP LOX DISCHARGE TEMP RISE - ERRONEOUS (OBSOLETE)
LPF TURB	37	LPFTP TURBINE INLET PRESSURE (OBSOLETE)
MCC	38	MCC LINER CAVITY PRESSURE
MCC ACC E	39	MAIN COMBUSTION CHAMBER ACCELEROMETERS - ERRONEOUS
MCC PC	40	MAIN CHAMBER PRESSURE
MCF ACT	41	MAJOR COMPONENT FAIL REPORT - ACTUATOR
MCF CL	42	MCF - COMMAND LIMIT
MCF DCU	43	MCF - DIGITAL COMPUTER UNIT
MCF FD	44	MCF - FUEL DENSITY
MCF FTD	45	MCF - HPFTP TURBINE DISCHARGE TEMPERATURE
MCF F/M	46	MCF - FUEL FLOWMETER
MCF OTD	47	MCF - HPOTP TURBINE DISCHARGE TEMPERATURE
MCF PC	48	MCF - MAIN CHAMBER PRESSURE
MOV ACC	49	MAIN OXIDIZER VALVE ACCELEROMETER (OBSOLETE)
O DR DP	50	HPOTP PRIMARY OXIDIZER SEAL DRAIN DELTA PRESSURE (OBSOLETE)
O DR P	51	HPOTP PRIMARY OXIDIZER SEAL DRAIN PRESSURE (OBSOLETE)
O DR P E	52	HPOTP PRIMARY OXIDIZER SEAL DRAIN PRESSURE - ERRONEOUS
O DR T	53	HPOTP PRIMARY OXIDIZER SEAL DRAIN TEMPERATURE (OBSOLETE)
O IS PRG	54	HPOTP INTERMEDIATE SEAL PURGE PRESSURE
O ISCDP	55	HPOTP INTERMEDIATE SEAL CAVITY DELTA PRESSURE (OBSOLETE)
O ISCP	56	HPOTP INTERMEDIATE SEAL CAVITY PRESSURE (OBSOLETE)
O ISCP E	57	HPOTP INTERMEDIATE SEAL CAVITY PRESSURE ERRONEOUS
O TD T	58	HPOTP TURBINE DISCHARGE TEMPERATURE
O TD T E	59	HPOTP TURBINE DISCHARGE TEMPERATURE - ERRONEOUS
O TI T	60	HPOTP TURBINE INLET TEMPERATURE (OBSOLETE)
O TI T E	61	HPOTP TURBINE INLET TEMPERATURE - ERRONEOUS (OBSOLETE)
OBS	62	MANUAL CUTOFF BY OBSERVER
OBS E	63	ERRONEOUS OBSERVER CUTOFF
OBS FIRE	64	OBSERVER CUTOFF - FIRE
PB PG IC	65	PREBURNER PURGE IGNITION CONFIRM
PB PRG	66	PREBURNER PURGE FAILED ON
PBP PR	67	PREBURNER PUMP DISCHARGE PRESSURE (OBSOLETE)
PC IC H	68	CHAMBER PRESSURE IGNITION CONFIRM - HIGH
PC IC L	69	CHAMBER PRESSURE IGNITION CONFIRM - LOW
PC MS	70	CHAMBER PRESSURE MAINSTAGE
PH/T	71	POWERHEAD AREA ENVIRONMENT TEMPERATURE
PIF	72	LOW FUEL INLET PRESSURE (FACILITY)
PIO	73	LOW OXIDIZER INLET PRESSURE (FACILITY)
SATS	74	SHUTTLE AVIONICS TEST SET (CLUSTER GROUND TEST ORBITER COMPUTER SIMULATO
TH BNG	75	HPFTP THRUST BEARING SPEED (OBSOLETE)
TH BNG E	76	HPFTP THRUST BEARING SPEED - SENSOR MALFUNCTION (OBSOLETE)
VEH	77	VEHICLE (ORBITER) COMMAND

SSME PREMATURE CUTOFFS (Duration > 2.4 seconds)

TEST NUMBER	ENGINE	REDLINE	COMP	MAJOR INCID	DATE	COMMENT	DURATION	POWER LEVEL	FAILURE MODE FROM UCR	UCR	CONFIGURATION	CUTOFF ID	DISCOUNTING RATIONALE
ASTS68-C	2032	MCF OTD	SYSTEM		18-Aug-94	CHANNEL A HPOTP TEMP EXCEEDED 1560	4.72	100		A033147	5 FPL/PH2	47	Case Open
901.674	2032	MCF FD	CCV		06-Nov-91	HIGH LPFTP DISCHARGE PRESSURE	3.72	95	FAILED TO INSTALL CCV COUPLING	A031266	5 FPL/PH2	44	Random Human Event
902.465	2107	O TD T	F/M KI		02-Mar-89	OFF M/R-DUE TO BAD FLOWMETER CONST	447.40	109	KI PREDICTION NOT PER WATER FLOW	A021548	5 FPL/PH2	58	
901.578	0211	O TD T	SYSTEM		28-Jul-88	THROTTLE DOWN IN THRUST LIMIT +200F	596.40	109	CROSS FEED GAIN BAD AT HIGH VLV POSITIONS	A020646	5 FPL/PH2	58	
902.428	2106	CADS FTD	OPB		01-Jul-87	HPOTP BELLOWS BURNTHRU-(HYD L/U)	204.12	104	BOTH F TD T DISQUAL,LOW TEMP-CADS S/D	A018425	5 FPL/PH2	3	Sensor Failure
750.288	0210	O TD T	SYSTEM		25-Jun-87	1560 PRELIFTOFF R/L -CHANGED TO 1660	4.40	100	HPOTP TURB TEMP EXCD R/L	A015718	5 FPL/PH2	58	
902.386	2026	O TD T	S/W KI		11-Dec-85	INCORRECT FLOWMETER CONSTANT	18.21	108	PREMATURE C/O: OXID TURB TEMP R/L	A008918	5 FPL/PH2	58	
STS51F-A	2023	F TD T E	SENSOR		29-Jul-85	BOTH F TD T SENSORS FAILED	349.75	104	FID-SENSOR DISQUALIFIED	A006762	4 FPL	10	Sensor Failure
901.485	2105	O TD T	SYSTEM		24-Jul-85	HIGH EFF HPFTURB/ 2 NOZ TUBE RUPT	28.53	109	PREM. C/O: HPOTP TURB. DISC.TEMP	A014574	5 FPL/PH2	58	
750.245	2308	HF ACC	HPFTP		23-Aug-84	FIRST STAGE IMPELLER FAILED UN 2608R2	25.61	109	PREM C/O BY HPFT RADIAL ACCELS	A017091	5 FPL/PH2	18	FASCOS Not Active
901.421	2010	HF ACC	HPFTP		25-Sep-83	CAVITATION/KEEP NSS BELOW 7350	148.49	104	R/L CUTOFF DUE TO EXCV VIBRATION	A012593	4 FPL	18	FASCOS Not Active
901.412	2018	MCF OTD	F/M KI		21-May-83	OFF M/R HPOTP CHAN B TEMP MCF	5.22	100	F/M CALIBRATION CONSTANT ESTIMATE LOW	A013370	4 FPL	47	LOR Cutoff
902.309	2011	O TD T	F/M KI		14-Apr-83	HIGH MIXTURE RATIO DUE TO KI	4.95	100	F/M CALIBRATION CONSTANT ESTIMATE LOW	A006684	4 FPL	58	
901.388	2011	MCF OTD	F/M KI		21-Sep-82	OFF M/R HPOTP CHAN A TEMP MCF	5.40	100	HPOT-TURB DIS TEMP, F/M CONST	A008321	4 FPL	47	LOR Cutoff
902.292	2010	O TD T	SYSTEM		09-Aug-82	OVERSHOOT DURING THROTTLE	146.02	111	C/O BY TURB TEMP OPOV DEADBND AT 111%	A015121	4 FPL	58	111% PL
901.376	2014	MCF CL	F/M KI		10-Jul-82	OPOV COMMAND LIMIT	5.12	98	OPOV COMMAND LIMIT - F/M CONST HIGHOPEN)	A015962	4 FPL	42	No Effect SW
901.356	0107	HO ACC	HPOTP		25-Jan-82	SUB SYNC VIBRATION UN 2011R1	37.16	111	SUB SYNC VIB - #2 & #4 BALL WEAR	A013571	4 FPL	24	111% PL
750.151	0110	MCF OTD	SYSTEM		04-Dec-81	HPOT TDT LOW/DELAYED OPB IGN	3.61	20	LOW HPOT TEMP,ENG BAL-NOZ CHANGE	A016034	4 FPL	47	LOR Cutoff
901.347	0107	OBS	F/M KI		30-Nov-81	OBS C/O HPOT TEMP LOW - F/M	95.40	100	OBS C/O HPOT TURB DIS TEMP LOW, F/M CONS	A017574	4 FPL	62	Manual Cutoff
901.340	0107	F TD T	HPFTP		15-Oct-81	HPFTP T/A DUCT S/M BULGED	405.50	109	FAC HPFT TURB R/L-TURNAROUND DUCT FAIL	A018305	4 FPL	9	Facility R/L
750.148	0110	O TD T	MINJ		02-Sep-81	MINJ BURN OUT/REPLACED MINJ	16.00	105	SEV EROSION OF PRIM/SEC FACE PLATES	A016031	4 FPL	58	
901.331	2108	O TD T	MINJ		15-Jul-81	MINJ BURN OUT EXT DAM	233.14	100	SEVERE DAMGD TO THE PRIM/SEC F PLATES	A013786	4 FPL	58	
750.119	0007	MCF CL	SYSTEM		28-Jan-81	OPOV LIMIT RESET MCF	5.25	100	PREMATURE CUTOFF;OPOV POSITION	A018563	2 MPTA	42	
750.107	0007	MCF OTD	SYSTEM		13-Nov-80	LOW LOX TURB TEMP DELAYED OPB	3.64	20	IMPROPER PWR BLD UP DURING START SEQ	A018562	2 MPTA	47	Delayed Ignition
SF1101-B	2003	F TD T	NOZZLE		03-Nov-80	NOZZLE TUBE RUPTURES	19.50	100	TUBES 125 THRU 146 BLOWN INWARD	A015578	2 MPTA	9	
902.198	2004	O TD T	MINJ		23-Jul-80	HOLE IN INJ/LOX POST FAIL	8.53	102	R/L C/O - HPOT TURB DISC TEMP, MAIN INJ	A017566	3 FMOF	58	
SF0901-B	2003	F TD T	HPFTP		16-Apr-80	TURNAROUND MAN COLLAPSED	4.72	100	HI FUEL TURB DISC TEMP VOTING LOGIC C/O	A011269	2 MPTA	9	
SF0701-C	0006	O TD T	SYSTEM		01-Feb-80	OPB DELAY/OVERSHOOT	4.61	100	PREMATURE C/O-HPOT DISC TEMP EXCEEDED RL	A011139	2 MPTA	58	Delayed Ignition
SF0603-C	0006	O ISCP	HPOTP		04-Nov-79	SECONDARY TURBINE SEAL FAILURE	8.69	100	AMCERMET SEALS CHANGED TO CARBON	A010994	2 MPTA	56	Obsolete Redline
750.047	0105	O TD T	SYSTEM		22-Sep-79	OVERSHOOT AT THROTTLE DOWN	10.43	95	C/O-LOX TURBINE TEMP EXCEEDED REDLINE	A018555	3 FMOF	58	
901.25	0007	O ISCP	HPOTP		11-Aug-79	HPOTP 2ND SL CAV PR HIGH	6.48	100	FAILED MATING RING - ICE/RUBBING	A014075	2 MPTA	56	Obsolete Redline
901.246	2007	PC MS	SYSTEM		12-Jul-79	MCC PC LOW DELAYED OPB IGN	3.73	20	LOW P/C,PARTIAL IGNITION IN OPB FAC.CUT	A018993	3 FMOF	70	Delayed Ignition
902.162	2004	O TD T	NOZZLE		13-Jun-79	TUBE RUPTURE (12) DOGGY DOORS	4.45	100	NOZZLE TUBE RUPTURES-HPOT R/L	A018955	3 FMOF	58	
902.158	2004	O TD T	NOZZLE		22-May-79	TUBE LEAKS (13)	27.67	100	NUMEROUS TUBE LEAKS	A009345	3 FMOF	58	
750.041	0201	F TD T	NOZZLE	YES	14-May-79	NOZZLE STEERHORN FAILED	4.32	100	HPFT OVERTEMP REDLINE CUTOFF	A006466	2 MPTA	9	
902.157	2004	O TD T	NOZZLE		10-May-79	COLD WALL TUBE LEAKS (3)	90.50	100	NOZZLE TUBE SPLITS -COOLANT LOSS	A009316	3 FMOF	58	
902.145	2002	HF ACC	HPFTP		08-Dec-78	HIGH SYN VIB HPFP UN 2103R2	68.61	100	3rd TEST IN A ROW - PUMP REMOVED	A017976	2 MPTA	18	FASCOS Not Active
902.144	2002	HO ACC C	HPFTP		04-Dec-78	HPF CROSS FEED /CHANGED PROFILE	36.29	70	TEST CUT BY HPOT TURBINE RADIAL ACCEL	A017971	2 MPTA	26	FASCOS Not Active
902.143	2002	HO ACC C	HPFTP		03-Dec-78	HPF CROSS FEED /CHANGE R/L	2.81	20	TEST CUT BY HPOT TURBINE RADIAL ACCEL	A017968	2 MPTA	26	FASCOS Not Active
901.216	0005	O TD T	SYSTEM		02-Nov-78	R/L INCREASED TO 1810	3.57	20	DAMAGED HPOT TURBINE FROM ENG. 0006 (MOV)	A009298	2 MPTA	58	Damaged HPOT
901.208	0005	O TD T	HPOTP		17-Oct-78	LOW TURB EFF-CHANGED M/R	4.88	90	DAMAGED HPOT TURBINE FROM ENG. 0006 (MOV)	A009269	2 MPTA	58	Damaged HPOT
902.127	2002	HO ACC A	HPOTP		05-Sep-78	PBP ACCLS (AXIAL)	111.56	100	SHORT DELAY TIME - RAISED REDLINE	A019144	2 MPTA	25	FASCOS Not Active
901.190	0005	LF ACC	LPFTP		26-Aug-78	DELETE FUEL VENT	137.83	100	HIGH LPFT VIB. (NOISE) - MISUNDERSTOOD	A019171	2 MPTA	33	FASCOS Not Active
901.186	0005	LOX T E	SENSOR		13-Aug-78	CH A CONN FELL OFF - CH B SENSOR FAIL	240.39	100	OPEN CIRCUIT BRG #1 (RISE RATE Redline)	A019136	2 MPTA	36	Sensor Failure
902.118	0101	F TD T	HPFTP		10-Jul-78	BULGE IN TURBINE TURN MANIFOLD	6.84	92	EXTREME BULGING IN TURNAROUND MANIFOLD	A003283	2 MPTA	9	
902.116	0101	HO ACC	HPOTP		29-Jun-78	TURBINE SEAL FAILURE HPOP 0005	10.85	92	SUB SYNC VIB - PUMP BRG CAGE FAIL	A018853	2 MPTA	24	FASCOS Not Active
902.114	0101	HO ACC C	HPFTP		24-Jun-78	ACTIVATED RASCOS-CROSSFEED FROM HP	281.03	100	RAISED PBP REDLINE	A019242	2 MPTA	26	FASCOS Not Active
902.111	0101	HO ACC	HPOTP		08-Jun-78	PBP ACCL	4.53	92	6.4 MR CAUSED BY LOX F/M COIL	A019201	2 MPTA	24	FASCOS Not Active
901.183	0005	HF ACC	MINJ		05-Jun-78	MINJ BURN THRO/REPLACE P/H	51.00	100	HPFT RADIAL CUTOFF UN 0103R8	A019050	2 MPTA	18	FASCOS Not Active
901.182	0005	HO ACC	HPOTP		02-Jun-78	TURB SL RUBBED SHAFT - CHANGE PROFILE	7.82	100	PB PUMP RADIAL ACCEL REDLINE CUTOFF	A003295	2 MPTA	24	FASCOS Not Active
901.178	0005	F TD T	HPFTP		13-May-78	PRESS LOX TANK TO 105 PSI	4.27	100	START DAMAGE BY FPOV D/S SEAL(BELVILLE)	A018789	2 MPTA	9	Facility Related
901.176	0005	CONT IEA	SENSOR		08-May-78	CHB LOX FLOW/DCUA IP ELECT	32.03	100	TEMP SENSOR SHORT SATURATED MPX.SHUTDOWN	A019009	2 MPTA	6	Sensor Failure
901.173	0002	F TD T	MINJ		31-Mar-78	MINJ BURN THRO/REPLACED ENG	201.17	92	MAIN INJECTOR -HPFT R/L	A018710	1 PRE MPTA	9	PRE MPTA
901.171	0002	F TD T	NOZZLE		27-Mar-78	NOZZLE TUBE SPLITS-REPAIRED	10.71	100	HPFTP DISCHARGE TEMP REDLINE CUTOFF	A018742	1 PRE MPTA	9	PRE MPTA
901.169	0002	HF ACC	HPF LPF		21-Mar-78	LOW PERF LPFTP-CAVITATED HPFTP	210.97	93	HPFTP RADIAL ACCEL REDLINE CUTOFF	A018688	1 PRE MPTA	18	PRE MPTA
901.167	0002	F TD T	NOZZLE		17-Mar-78	22 NOZZLE TUBE SPLITS / CAVITATION	3.83	50	HPFT TURBINE DISCHARGE TEMP 2 REDLINE	A018666	1 PRE MPTA	9	PRE MPTA
901.164	0002	O TD T	SYSTEM		21-Feb-78	OLD START SEQ EARLY OPB PRIME	6.08	91	HPOT TURBINE DAMANGED BY START TEMP SPIKE	A005177	1 PRE MPTA	58	PRE MPTA
901.163	0002	HO ACC	HPOTP		17-Feb-78	DELAYED R/L	3.57	50	HPOTP SYNCHRONOUS WITH HOUSING RESONANCE	A005176	1 PRE MPTA	24	PRE MPTA
901.162	0002	HF ACC	HPFTP		15-Feb-78	LIMIT P/L & RAISE TK PR-CAV	11.32	100	HPFT RADIAL ACCEL REDLINE CUTOFF	A008619	1 PRE MPTA	18	PRE MPTA
901.161	0002	HF ACC	HPFTP		14-Feb-78	LIMIT P/L & OPEN FUEL REPR-CAV	4.25	100	HPFT RADIAL ACCEL REDLINE CUTOFF	A008614	1 PRE MPTA	18	PRE MPTA
901.160	0002	HO ACC	HPOTP		12-Feb-78	TURBINE RADIAL 9 G CHANGE R/L	4.04	90	HPOTP SYNCHRONOUS WITH HOUSING RESONANCE	A008617	1 PRE MPTA	24	PRE MPTA
902.101	2002	CONT	CONT		09-Feb-78	PNEUMATIC S/D DCUA HALT	26.64	90	PWR OSC.- SINGLE POINT FAILURE	A005167	2 MPTA	4	Controller Initiated
902.1	2002	HO ACC C	HPFTP		02-Feb-78	CROSS FEED FROM HPFTP	2.89	20	HPFT INTERSTAGE SEAL RUB	A003271	2 MPTA	26	FASCOS Not Active

SSME PREMATURE CUTOFFS (Duration > 2.4 seconds)

TEST NUMBER	ENGINE	REDLINE	COMP	MAJOR INCID	DATE	COMMENT	DURATION	POWER LEVEL	FAILURE MODE FROM UCR	UCR	CONFIGURATION	CUTOFF ID	DISCOUNTING RATIONALE
901.15	0002	O ISCP	HPOTP		15-Dec-77	HPOTP I/S CAV PR R/L >80 PSIG	9.83	90	HPOT INTER SEAL CAVITY PRESSURE REDLINE	A008612	1 PRE MPTA	56	PRE MPTA
901.147	0103	HO ACC C	HPFTP	YES	01-Dec-77	HPFTURB BL FAILURE	31.36	81	SEVERE EROSION OF TURBINE AREA	A005094	1 PRE MPTA	26	PRE MPTA
902.095	0002	HO ACC C	HPFTP		17-Nov-77	HPFT TURBINE BLADE FAILURE-CROSSFEED	51.09	70	HPOT RADIAL CUTOFF-HPFP UN 0101R17	A008624	1 PRE MPTA	26	PRE MPTA
901.139	0103	HO ACC	HPOTP		07-Nov-77	HPOT R/L 9 G - REDUCE P/L & SL FLOW	54.83	94	HPOT RADIAL ACCEL RLCD -ROTOR BALANCE	A008611	1 PRE MPTA	24	PRE MPTA
902.09	0002	CONT	SYSTEM		01-Nov-77	ICE IN PC PORT - RUNAWAY THROTTLE UP	48.63	70	CONTROLLER C/O-FPOVA 6% SWITCH AND S/D	A008620	1 PRE MPTA	4	PRE MPTA
902.083	0002	O DR P	HPOTP		11-Oct-77	HPOTP PR SL DR PR>8 PSIG	34.94	95	HPOT PRI LOX SEAL DR PR EXCEEDED R/L	A008605	1 PRE MPTA	51	PRE MPTA
902.080	0002	O DR P	HPOTP		28-Sep-77	HPOTP PR SL DR PR>13 PSIG	9.05	65	HPOT PRI LOX SEAL DR PR EXCEEDED REDLINE	A008601	1 PRE MPTA	51	PRE MPTA
902.079	0002	O DR P	HPOTP		26-Sep-77	HPOTP PR SL DR PR>8 PSIG	3.05	20	HPOT PRI LOX SEAL DR PR EXCEEDED REDLINE	A008602	1 PRE MPTA	51	PRE MPTA
902.075	0002	O DR T	HPOTP		20-Aug-77	HPOT SL DR T -280 DEGREES R/L	21.71	70	HPOT PRI LOX SEAL DR TEMP EXCEEDED R/L	A005090	1 PRE MPTA	53	PRE MPTA
902.074	0002	O TD T	NOZZLE		18-Aug-77	TUBE SPLITS (31)	7.05	70	NOZZLE TUBE RUPTURES -HPOT R/L	A005066	1 PRE MPTA	58	PRE MPTA
902.073	0002	O TD T	NOZZLE		15-Aug-77	TUBE SPLITS (31)	155.50	64	NOZZLE TUBE RUPTURES -HPOT R/L	A005075	1 PRE MPTA	58	PRE MPTA
902.072	0002	O TD T	NOZZLE		10-Aug-77	TUBE SPLITS (62) WATER	4.41	70	NOZZLE TUBE RUPTURES -HPOT R/L	A005078	1 PRE MPTA	58	PRE MPTA
901.129	0004	PB PRG	PCA		04-Aug-77	PB PURGE 200 PSI MAX (LEAKY SOL VALVE	257.10	75	ERRONEOUS PCA HE PURGE PR R/L CUTOFF	A005080	1 PRE MPTA	66	PRE MPTA
901.124	0004	O ISCP	HPOTP		25-Jul-77	HPOTP I/S CAV PR >55 PSIG	6.64	70	HPOT INTER SEAL CAVITY PRESSURE REDLINE	A005049	1 PRE MPTA	56	PRE MPTA
902.070	0002	O DR P	HPOTP		21-Jul-77	HPOTP PR SL PR -CRACKED BELLOWS	29.31	90	HPOT PRI SL DR LINE	A005389	1 PRE MPTA	51	PRE MPTA
902.068	0002	O TD T	SYSTEM		18-Jul-77	HPOTP TURB TEMP-DELAYED OPB IGN	5.06	90	HPOT TURBINE DISCHARGE TEMP R/L CUTOFF	A005047	1 PRE MPTA	58	PRE MPTA
901.123	0004	O DR P	HPOTP		07-Jul-77	FAILED HPOTP BELLOWS	149.48	70	HPOT PRI SL DR PRESS RLCO	A005382	1 PRE MPTA	51	PRE MPTA
901.122	0004	O DR DP	HPOTP		06-Jul-77	DELETE DR DP R/L	6.06	70	HPOT PRI SEAL DRAIN LINE DELTA PR R/L	A005043	1 PRE MPTA	50	PRE MPTA
901.121	0004	O DR DP	HPOTP		05-Jul-77	HPOT PRI SEAL DRAIN LINE DELTA PR R/L	4.65	70	HPOT PRI SEAL DRAIN LINE DELTA PR R/L	A005042	1 PRE MPTA	50	PRE MPTA
901.120	0004	F TD T	SENSOR		02-Jul-77	PR SENSOR FAILED CAUSING HIGH PL -PC	238.70	70	HPFT TURBINE DISCHARGE TEMP R/L CUTOFF	A005041	1 PRE MPTA	9	PRE MPTA
901.116	0004	O DR P	HPOTP		21-Jun-77	HPOTP BELLOWS FAILED	73.23	90	HPOT PRI SL DR PRESS RLCO	A003441	1 PRE MPTA	51	PRE MPTA
901.114	0004	O DR P	HPOTP		23-May-77	HPOTP PR SL DR PR 2 PSI	7.70	70	HPOT PRIMARY SEAL DRAIN LINE PRESS R1CO	A005022	1 PRE MPTA	51	PRE MPTA
901.113	0004	O DR T	HPOTP		20-May-77	CHANGE R/L	17.34	50	HPOT PRIMARY SEAL DRAIN LINE TEMP RLCO	A005020	1 PRE MPTA	53	PRE MPTA
902.062	0002	O ISCP	HPOTP		05-May-77	HPOTP I/S CAV PR (2 PSIG MIN)	29.93	70	HPOT INTERMEDIATE SEAL CAV PR R/L C/O	A005018	1 PRE MPTA	56	PRE MPTA
902.059	0002	O ISCP	HPOTP		27-Apr-77	HPOTP I/S CAV PR	4.13	51	HPOT INTERMEDIATE SEAL CAV PR R/L C/O	A005006	1 PRE MPTA	56	PRE MPTA
901.107	0003	O TD T	SYSTEM		09-Mar-77	CHANGE MOV START SCHEDULE	8.50	65	HPOT TURBINE DISCHARGE TEMP REDLINE C/O	A003450	1 PRE MPTA	58	PRE MPTA
901.105	0003	HF ACC	HPFTP		03-Mar-77	ADD SHIM AT G6	35.33	100	HPFT RADIAL ACC REDLINE C/O (CAV.)	A003447	1 PRE MPTA	18	PRE MPTA
901.104	0003	OBS	SYSTEM		26-Feb-77	OBSERVER OPOV POS	10.61	65	OPOV VALVE POSITION REDLINE	A003444	1 PRE MPTA	62	PRE MPTA
901.103	0003	HO ACC	HPOTP		18-Feb-77	HPOTP SEVERE EROSION IN SHUTDOWN	23.01	100	HPOT SUB SYNC-TORQUE EXESSSIVE- IMSL RUB	A000661	1 PRE MPTA	24	PRE MPTA
901.101	0003	O TD T	SYSTEM		13-Feb-77	DELAYED OPB IGN	4.31	51	HPOT TURBINE DISCHARGE TEMP REDLINE C/O	A003422	1 PRE MPTA	58	PRE MPTA
902.049	0002	O TIT	SYSTEM		06-Feb-77	OPB OVER TEMP -WATER	3.23	51	OPB R/L EDM WATER IN FUEL MANIFOLD	A003409	1 PRE MPTA	60	PRE MPTA
901.099	0003	CONT FD	SENSOR		31-Jan-77	LPFTP DISH PR SENSORS FAILED	39.80	100	CONTROLLER INITIATED S/D-SENSORS FAILED	A003405	1 PRE MPTA	5	PRE MPTA
901.097	0003	PC MS	SYSTEM		28-Jan-77	MCC PC TOO LOW - CHANGED R/L	4.25	51	MCC PC REDLINE CUTOFF	A003402	1 PRE MPTA	70	PRE MPTA
901.096	0003	F TD T	HPFTP		11-Jan-77	HPFTP BELLOWS SHIELD FAILED	28.63	100	HPFT TURBINE DISCHARGE TEMP R/L CUTOFF	A002650	1 PRE MPTA	9	PRE MPTA
901.090	0003	HF ACC	HPFTP		28-Dec-76	CHANGE R/L	17.69	85	HPFT RADIAL ACCEL RLCO	A002497	1 PRE MPTA	18	PRE MPTA
901.080	0003	HF ACC	HPFTP		27-Oct-76	REPLACE HPFTP,LPFTP,S/W & R/L CHANGE	28.09	75	HPFT RADIAL ACCELEROMETER REDLINE	A002629	1 PRE MPTA	18	PRE MPTA
902.037	0002	HF ACC	HPFTP		01-Oct-76	HPFT RADIAL VIBRATION SAFETY C/O	33.88	90	TEST CUT BY HPFT RAD ACCEL VOTING LOGIC	A002619	1 PRE MPTA	18	PRE MPTA
901.074	0003	HF SPD	SENSOR		20-Sep-76	HPFTP SPD DROP OUT (INSTR)	26.52	75	SENSOR OUTPUT FAILED	A002488	1 PRE MPTA	22	PRE MPTA
901.073	0003	F TIT	SYSTEM		16-Sep-76	DELETE TURB IN T R/L	49.53	75	HPFT TURBINE INLET TEMP REDLINE EXCEEDED	A002484	1 PRE MPTA	11	PRE MPTA
901.072	0003	F TIT	SYSTEM		13-Sep-76	CHANGED F T IN T R/L	17.15	90	HPFT TURBINE INLET TEMP REDLINE EXCEEDED	A002476	1 PRE MPTA	11	PRE MPTA
901.071	0003	O DR P	HPOTP		01-Sep-76	HPOTP PR SL DR PR	18.30	93	HPOT PRI SEAL CAVITY PR REDLINE EXCEEDED	A002468	1 PRE MPTA	51	PRE MPTA
902.027	0002	F TIT	SYSTEM		24-Aug-76	HPFT IN TEMP RLCD	2.96	20	HPFT TURBINE INLET TEMP REDLINE EXCEEDED	A002447	1 PRE MPTA	11	PRE MPTA
902.026	0002	O TIT	SYSTEM		21-Aug-76	OPB OVERTEMP	3.77	60	OPB OVERTEMP	A002445	1 PRE MPTA	60	PRE MPTA
902.024	0002	O TIT	SYSTEM		18-Aug-76	OPB OVER TEMP	3.63	50	OPB OVER TEMP	A002438	1 PRE MPTA	60	PRE MPTA
902.023	0002	F TIT	SYSTEM		17-Aug-76	HPFT TURBINE INLET TEMP REDLINE	3.43	50	HPFT TURBINE INLET TEMP REDLINE EXCEEDED	A002435	1 PRE MPTA	11	PRE MPTA
902.021	0002	O TIT	SYSTEM		11-Aug-76	OPB OVERTEMP	3.73	75	OPB OVERTEMP - CCV SCHEDULE CHANGED	A002431	1 PRE MPTA	60	PRE MPTA
901.067	0001	HF ACC	HPFTP		26-Jul-76	LAST TEST ON 0001D	41.45	63	HPFT RADIAL VIBRATION SAFETY C/O	A002427	1 PRE MPTA	18	PRE MPTA
902.018	0002	HF ACC	HPFTP		14-Jul-76	HPFT RADIAL VIBRATION SAFETY C/O	22.07	85	HPFT RADIAL VIBRATION SAFETY C/O	A002419	1 PRE MPTA	18	PRE MPTA
901.066	0001	HF ACC	HPFTP		09-Jul-76	SUB SYNC VIB	4.24	60	HPFT RADIAL VIBRATION SAFETY C/O	A002415	1 PRE MPTA	18	PRE MPTA
901.065	0001	HF ACC	HPFTP		07-Jul-76	NO COMPONENT CHANGE	16.91	76	HPFT RADIAL VIBRATIN SAFETY C/O	A002412	1 PRE MPTA	18	PRE MPTA
901.062	0001	HF ACC	HPFTP		16-Jun-76	S/W & R/L CHANGES	16.40	75	HPFT RADIAL VIBRATION SAFETY C/O	A002403	1 PRE MPTA	18	PRE MPTA
902.016	0002	HF ACC	HPFTP		15-Jun-76	HPFT RADIAL VIBRATION SAFETY C/O	16.70	65	HPFT RADIAL VIBRATION SAFETY C/O	A002401	1 PRE MPTA	18	PRE MPTA
902.015	0002	HF ACC A	HPFTP		12-Jun-76	HPFT AXIAL VIBRATION SAFETY C/O	3.27	50	HPFT AXIAL VIBRATION SAFETY C/O	A002404	1 PRE MPTA	19	PRE MPTA
902.014	0002	HF ACC A	HPFTP		07-Jun-76	HPFT AXIAL VIBRATION SAFETY C/O	3.16	50	HPFT AXIAL VIBRATION SAFETY C/O	A003390	1 PRE MPTA	19	PRE MPTA
901.059	0001	HF ACC A	HPFTP		05-Jun-76	HPFTP WHIRL	3.97	50	HPFT RADIAL VIBRATION SAFETY C/O(AXIAL)	A003395	1 PRE MPTA	19	PRE MPTA
901.058	0001	HF ACC	HPFTP		03-Jun-76	CHANGED R/L	12.08	75	HPFT RADIAL VIBRATION SAFETY C/O	A003387	1 PRE MPTA	18	PRE MPTA
902.013	0002	HF ACC	HPFTP		01-Jun-76	HPFT RADIAL VIBRATION SAFETY C/O	11.10	65	HPFT RADIAL VIBRATION SAFETY C/O	A003386	1 PRE MPTA	18	PRE MPTA
901.057	0001	HF ACC	HPFTP		26-May-76	SEQ CHANGE	11.86	74	HPFT RADIAL VIBRATION SAFETY C/O	A003376	1 PRE MPTA	18	PRE MPTA
901.056	0001	HF ACC A	HPFTP		21-May-76	CHANGED R/L	7.27	65	HPFT AXIAL VIBRATION SAFETY C/O	A003383	1 PRE MPTA	19	PRE MPTA
901.055	0001	HF ACC A	HPFTP		18-May-76	FPB EROSION & HPFTP CHANGES	6.29	61	HPFT AXIAL VIBRATION SAFETY C/O	A003379	1 PRE MPTA	19	PRE MPTA
901.054	0001	HF ACC	HPFTP		08-May-76	CHANGES TO HPFTURB	7.31	65	HPFT RADIAL VIBRATION SAFETY C/O	A003375	1 PRE MPTA	18	PRE MPTA
901.053	0001	HF ACC	HPFTP		05-May-76	CHANGES TO HPFTURB	6.52	62	HPFT RADIAL VIBRATION SAFETY C/O	A003371	1 PRE MPTA	18	PRE MPTA
901.052	0001	HF ACC	HPFTP		26-Apr-76	NO PUMP CHANGES	7.34	65	HPFT RADIAL VIBRATION SAFETY C/O	A003365	1 PRE MPTA	18	PRE MPTA

SSME PREMATURE CUTOFFS (Duration > 2.4 seconds)

TEST NUMBER	ENGINE	REDLINE	COMP	MAJOR INCID	DATE	COMMENT	DURATION	POWER LEVEL	FAILURE MODE FROM UCR	UCR	CONFIGURATION	CUTOFF ID	DISCOUNTING RATIONALE
901.051	0001	F TIT	SYSTEM		22-Apr-76	HPF TURB IN T R/L	10.32	75	HPFT TURBINE INLET TEMP REDLINE	A003359	1 PRE MPTA	11	PRE MPTA
901.046	0001	HF ACC A	HPFTP		02-Apr-76	EXCESSIVE AXIAL VIBRATION	6.27	61	EXCESSIVE AXIAL VIBRATION	A001428	1 PRE MPTA	19	PRE MPTA
901.044	0001	TH BNG	HPFTP		12-Mar-76	HPFTP BNG SPD	45.18	55	THRUST BEARING WELDED TO HPFT SHAFT	A001422	1 PRE MPTA	75	PRE MPTA
901.041	0001	O TI T	SYSTEM		05-Mar-76	OPB O/T	3.84	50	OPB OVERTEMP	A001413	1 PRE MPTA	60	PRE MPTA
901.040	0001	HGM	SYSTEM		02-Mar-76	HGM LINER DELTA-P R/L	3.39	50	HGM LINER DELTA-P R/L	A001410	1 PRE MPTA	23	PRE MPTA
901.039	0001	O TI T	SYSTEM		27-Feb-76	OPB OVERTEMP	2.88	20	OPB OVERTEMP	A001408	1 PRE MPTA	60	PRE MPTA
901.035	0001	HGM	SYSTEM		24-Jan-76	HGM delta P	3.16	20	HGM LINER DELTA-P R/L - LATE LOX POWER	A007597	1 PRE MPTA	23	PRE MPTA
901.033	0001	TH BNG	HPFTP		19-Jan-76	HPFTP BNG SPEED	2.86	20	HPFTP BNG SPEED	NO UCR	1 PRE MPTA	75	PRE MPTA
901.032	0001	TH BNG	HPFTP		16-Jan-76	HPFTP BNG SPEED	2.76	20	HPFTP BNG SPEED	NO UCR	1 PRE MPTA	75	PRE MPTA
901.031	0001	TH BNG	HPFTP		15-Jan-76	HPFTP BNG SPEED	2.73	20	HPFTP BNG SPEED	NO UCR	1 PRE MPTA	75	PRE MPTA
901.023	0001	HF ACC A	HPFTP		12-Nov-75	HPFTP AX & RAD ACCLS	2.99	20	HPFT AXIAL ACCEL. REDLINE EXCEEDED	A007555	1 PRE MPTA	19	PRE MPTA
901.022	0001	HF ACC A	HPFTP		07-Nov-75	EXCESSIVE AXIAL VIBRATION	2.76	20	HPFT AXIAL ACCEL. REDLINE EXCEEDED	A007552	1 PRE MPTA	19	PRE MPTA

Catastrophic Failures in Entire SSME History

TEST NUMBER	ENGINE	COMP	DATE	COMMENT	DURATION	POWER LEVEL	FAILURE MODE FROM UCR	UCR	CONFIGURATION
904.044	0212	HPOTP	23-Jun-89	HPOTP #2 BEARING FAILURE	1270.72	96	BEARING WEAR WITH OPERATING TIME	A023129	5 FPL/PH2
902.471	2206	DUCT-LPF	02-Jun-89	LPF DUCT BELLOWS TIE BROKE	147.68	104	FLEX JOINT TRIPOD FATIQUE - SMALL RADIUS	A008935	5 FPL/PH2
750.285	0210	NOZZLE	21-May-87	FEED LINE CRACK AT STOP WELD	224.00	109	LEAK IN NO. 3 DOWNCOMMER	A015716	5 FPL/PH2
750.259	2308	MCC	27-Mar-85	DISCH MAN RUPTURE - EXT DAM	101.56	109	PREM C/O, HPFTP ACCELS	A015713	5 FPL/PH2
901.468	0207	FPB	04-Feb-85	CRACK AT F-13 FLANGE-eng retired	203.86	109	CRACK STARTED IN BOSS TO MAN. WELD	A014585	5 FPL/PH2
901.436	0108	HPFTP	14-Feb-84	CLNT LNR PR-MAJOR DAMAGE	611.06	109	EXTENSIVE TURB DAMAGE (RLCO)	A013338	5 FPL/PH2
750.175	2208	DUCT	27-Aug-82	HPO DUCT RUPTURE - ULTRASONIC F/M	116.08	111	PREM C/O P/B BOOST PUMP ACCLES	A011506	4 FPL
750.160	0110	FPB-ICE	12-Feb-82	H2O FROM EDM/EXT DAMAGE (CG1B)	3.16	20	TURB DIS TEMP, WATER IN ENG, EDM OPER	A016045	4 FPL
902.249	0204	HPFTP	21-Sep-81	TURB BL FAIL/VOLUTE RUPTURE/EXT DAM	450.57	109	PREM C/O HPFT TURB BLADE FAILURE	A018288	4 FPL
SF1001-C	0006	FPB	12-Jul-80	HOLE BURNED IN FPB	106.52	102	OBSERVER PREMATURE CUT DUE TO FIRE	A015391	2 MPTA
SF0601-A	2002	MFV	02-Jul-79	MFV BODY FAILURE	18.49	100	VALVE CAP TO BODY BOLTS BROKEN	A009437	2 MPTA
901.225	2001	MOV	27-Dec-78	MOV FRETTING-FIRE-EXT DAM	255.63	100	MOV FIRE - HPFT R/L	A010816	2 MPTA
901.136	0004	HPOTP	08-Sep-77	HPOTP BNG FAILURE - EXT DAM	300.22	90	CUTOFF DUE TO HPOT FIRE OPOVA FID 34-0	A005350	1 PRE MPTA
901.133	0004	FPB	27-Aug-77	HOLE IN FPB BODY	48.21	90	HOLE BURNT THRU FPB BODY OF POWERHEAD	A005072	1 PRE MPTA
901.110	0003	HPOTP	24-Mar-77	HPOTP FIRE EXT DAM	74.07	75	SEVERE INTERNAL FIRE DAMAGE	A005353	1 PRE MPTA

B.2. Integrated Solid
Rocket Booster

ISRB Initiator Frequency Summary

Initiator ID	Initiator Description	One Motor Initiator Freq (per mission)	Pair Initiator Freq (per mission)	Mean # of Missions Between Occurrences	Percent of Non-nominal Initiators	Development
RSRHGLK	RSRM JOINTS: HOT GAS LEAK	1.99E-04	3.98E-04	2513	31.59%	Fault Trees-Page 1
RSRNZRUP	RSRM NOZZLE RUPTURE	4.45E-05	8.90E-05	11236	7.06%	Fault Trees-Page 64
RSRPVRUP	RSRM PRESSURE VESSEL RUPTURE	3.61E-05	7.22E-05	13850	5.73%	Fault Trees-Page 65
RSRWRTHR	RSRM WRONG THRUST	5.00E-09	1.00E-08	100000000	0.00%	Fault Trees-Page 66
SRBNOHLDN	SRB NO, LATE, OR IMPROPER HOLDDOWN RELEASE	1.29E-04	2.58E-04	3876	20.48%	Fault Trees-Page 68
SRBNOIGN	NO OR LATE IGNITION OF 1 SRB/RSRM	1.11E-04	2.22E-04	4505	17.62%	Fault Trees-Page 82
SRBNOSEP	SRB FAILS TO SEPARATE	6.95E-05	1.39E-04	7194	11.03%	Fault Trees-Page 87
SRBPREMHD	SRB HOLDDOWN: PREMATURE RELEASE	8.00E-07	1.60E-06	625000	0.13%	Fault Trees-Page 190
SRBRECPREM	SRB RECOVERY DEVICE: PREMATURE RELEASE	3.00E-06	6.00E-06	166667	0.48%	Fault Trees-Page 191
SRBSTR	SRB STRUCTURAL FAILURES	5.00E-07	1.00E-06	1000000	0.08%	Fault Trees-Page 192
SRBTV	SRB THRUST VECTOR CONTROL SYSTEM FAILURE	3.57E-05	7.13E-05	14025	5.66%	Fault Trees-Page 193

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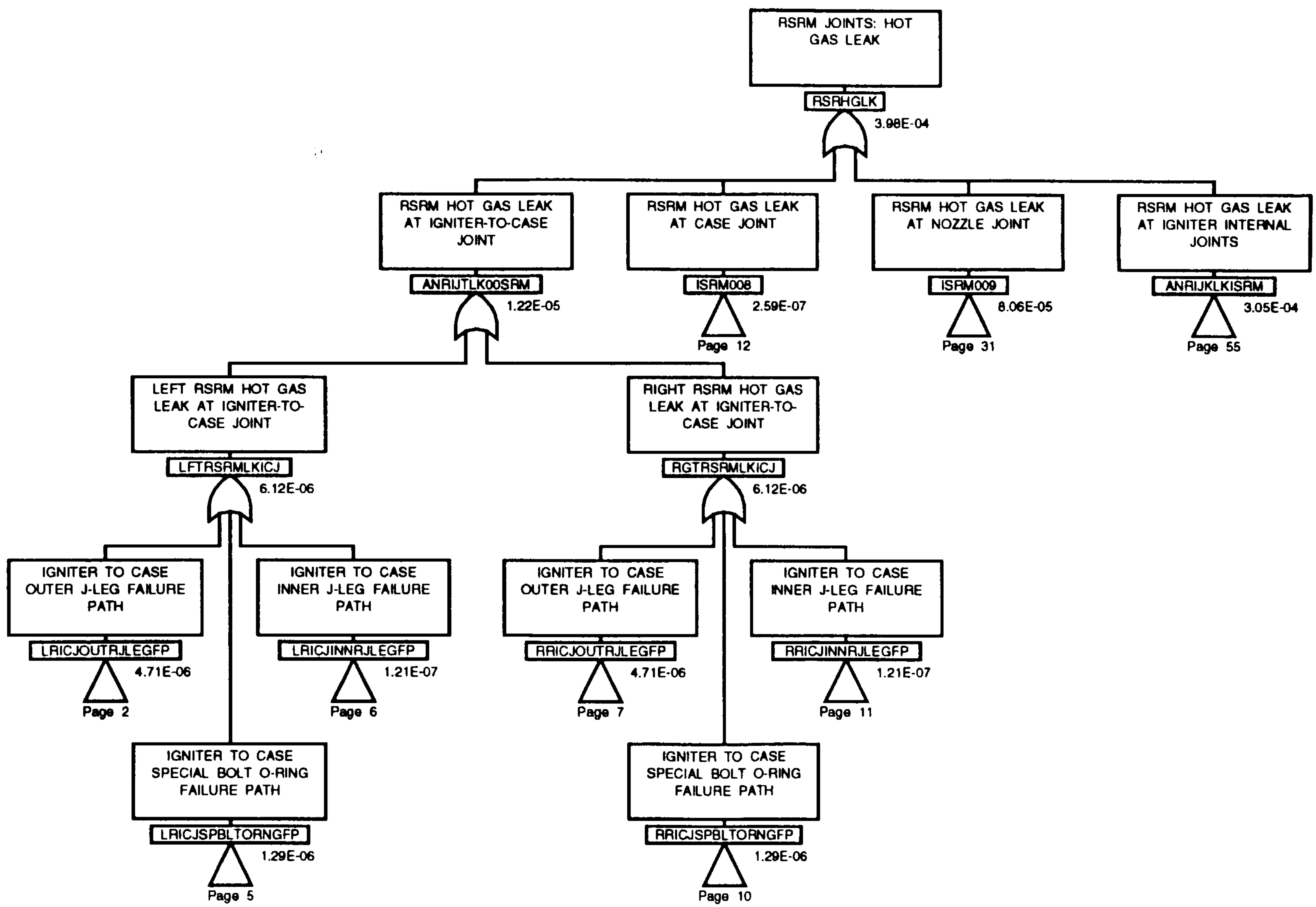
ISRB Hypothesis Descriptions

Hypothesis-1	The analyst made an educated estimate of the anticipated frequency of the event in question. This was deemed necessary when there was insufficient data to support a statistical analysis. The estimation was made after conferring with experts on reliability of the sub-component based on their respective experience.
Hypothesis-2	Insufficient data to support a statistical analysis was available for the NASA Standard Initiators (NSIs) and NASA Standard Detonators (NSDs) however the components were found to be similar in both design and function as the Confined Detonating Fuses (CDFs). However due to additional elements in the NSI and NSD assemblies they were assumed to be 2-3 times more prone to fail than the CDF.
Hypothesis-3	The data available for the Pyrotechnic Initiator Controllers (PICs) indicates that they are extremely reliable components however the fact that no actual failures have occurred makes the estimation of their failure rate difficult. As a conservative assumption, their failure rate was assumed to be on the same order of magnitude as the CDFs.
Hypothesis-4	The ISRB use pyrogenic igniters for which a limited amount of failure data exists. For this reason the analyst made a conservative assumption based on the data available and conversations with USBI personnel.
Hypothesis-5	This estimate concerned the possibility of an explosive device detonating without any external influences; an extremely rare event. A conservative estimate was made which considered such an event to be 10 times less likely than an explosive device (CDF) failing to detonate on command.
Hypothesis-6	The Booster Separation Motors (BSMs) have a limited amount of failure related data however it was agreed (USBI & MSFC) that the failure modes were approximately an order of magnitude (10 times) more likely than an explosive device (CDF) failing to detonate.


RSRM JOINTS: HOT GAS LEAK
RSRHGLK
3.98E-04
RSRM HOT GAS LEAK AT IGNITER-TO-CASE JOINT
ANRIJTLK00SRM
1.22E-05
RSRM HOT GAS LEAK AT CASE JOINT
ISRM008
2.59E-07
Page 12
RSRM HOT GAS LEAK AT NOZZLE JOINT
ISRM009
8.06E-05
Page 31
RSRM HOT GAS LEAK AT IGNITER INTERNAL JOINTS
ANRIJKLKISRM
3.05E-04
Page 55
LEFT RSRM HOT GAS LEAK AT IGNITER-TO-CASE JOINT
LFTRSRMLKICJ
6.12E-06
RIGHT RSRM HOT GAS LEAK AT IGNITER-TO-CASE JOINT
RGTRSRMLKICJ
6.12E-06
IGNITER TO CASE OUTER J-LEG FAILURE PATH
LRICJOUTRJLEGFP
4.71E-06
Page 2
IGNITER TO CASE INNER J-LEG FAILURE PATH
LRICJINNRJLEGFP
1.21E-07
Page 6
IGNITER TO CASE SPECIAL BOLT O-RING FAILURE PATH
LRICJSPBLTORNGFP
1.29E-06
Page 5
IGNITER TO CASE OUTER J-LEG FAILURE PATH
RRICJOUTRJLEGFP
4.71E-06
Page 7
IGNITER TO CASE INNER J-LEG FAILURE PATH
RRICJINNRJLEGFP
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IGNITER TO CASE SPECIAL BOLT O-RING FAILURE PATH
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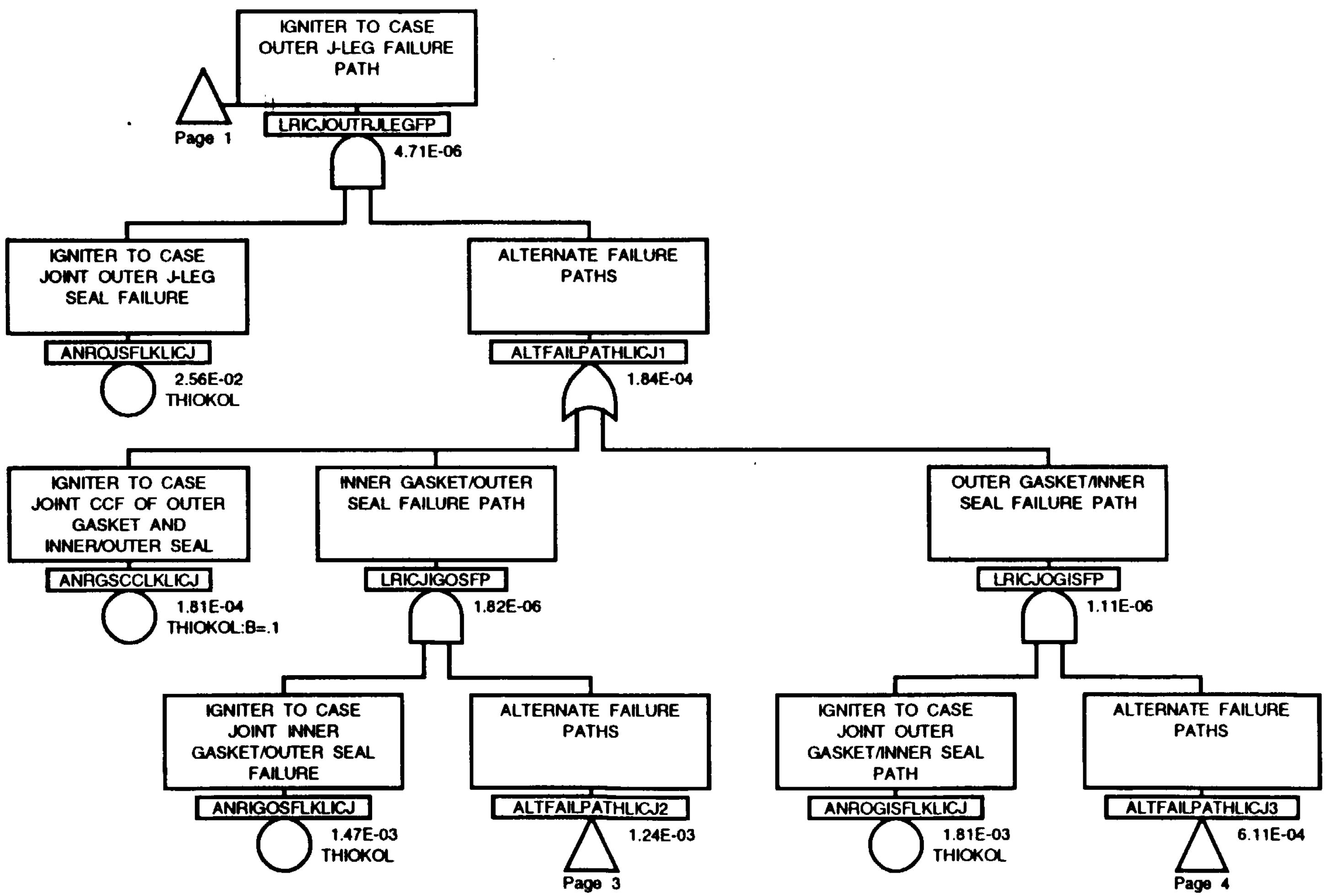
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OUTER GASKET/INNER SEAL FAILURE PATH
LRICJOGISFP
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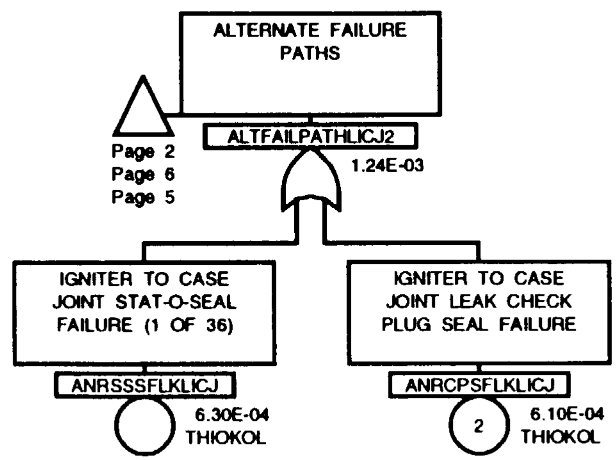
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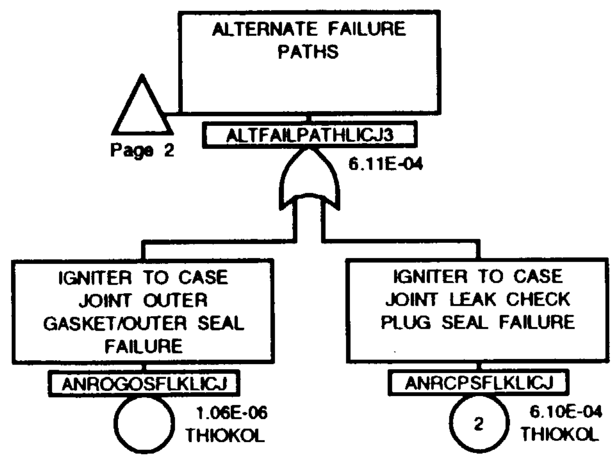
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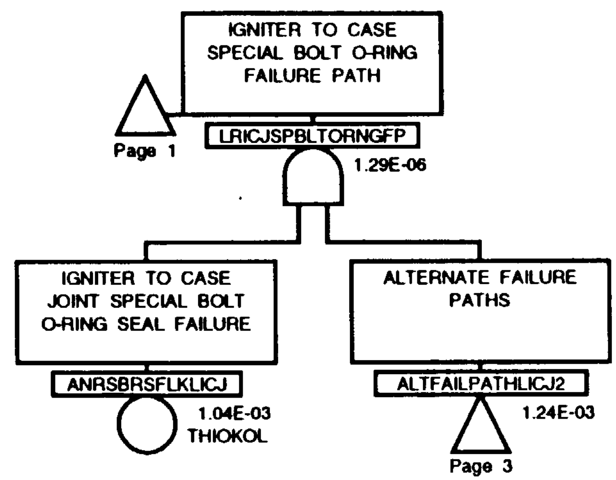
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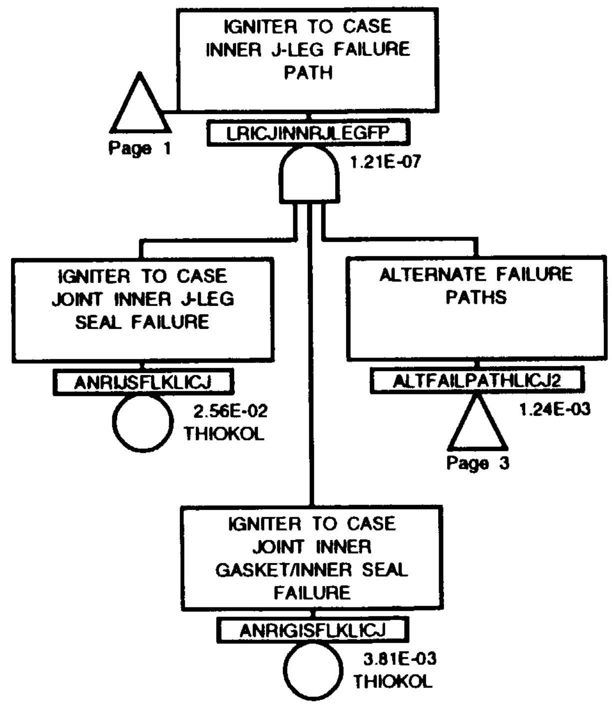
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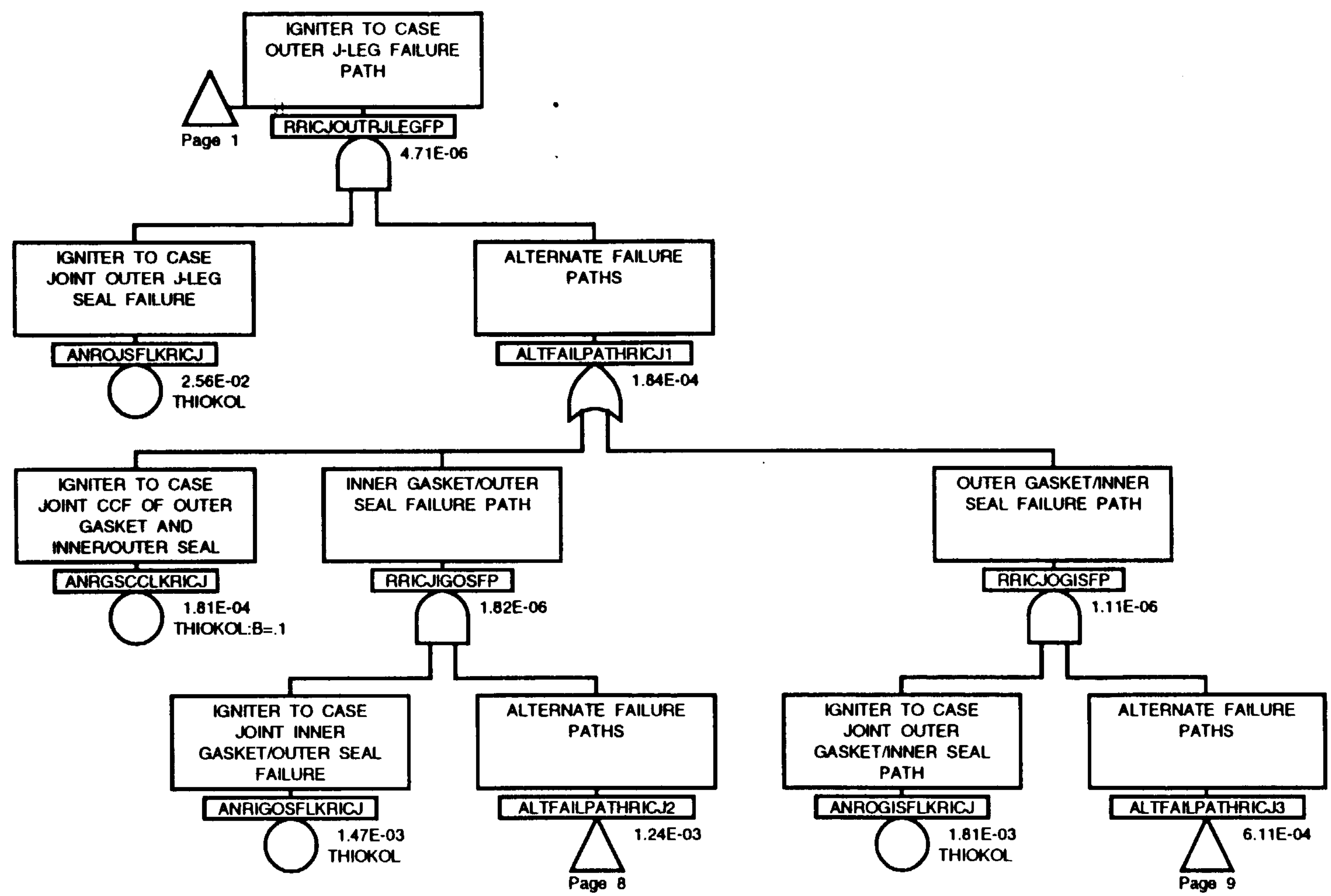
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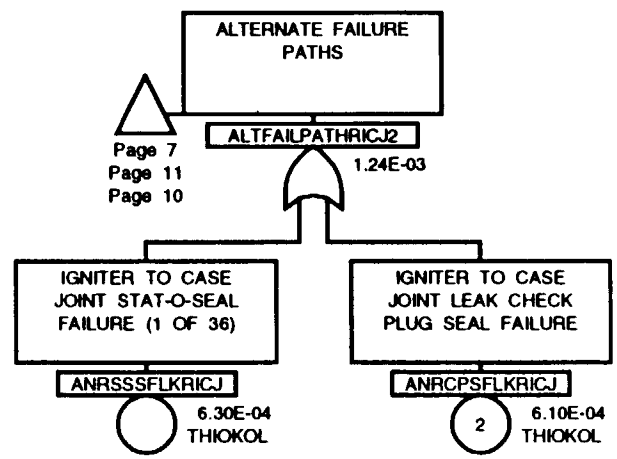
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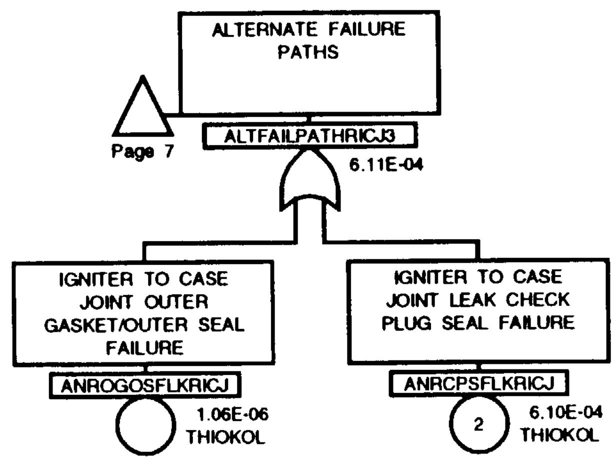
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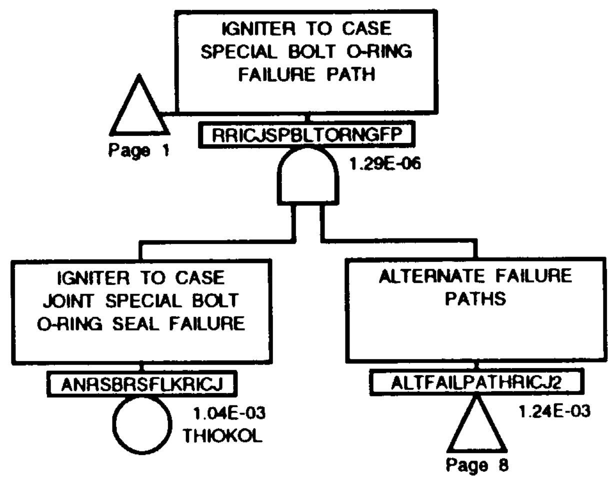
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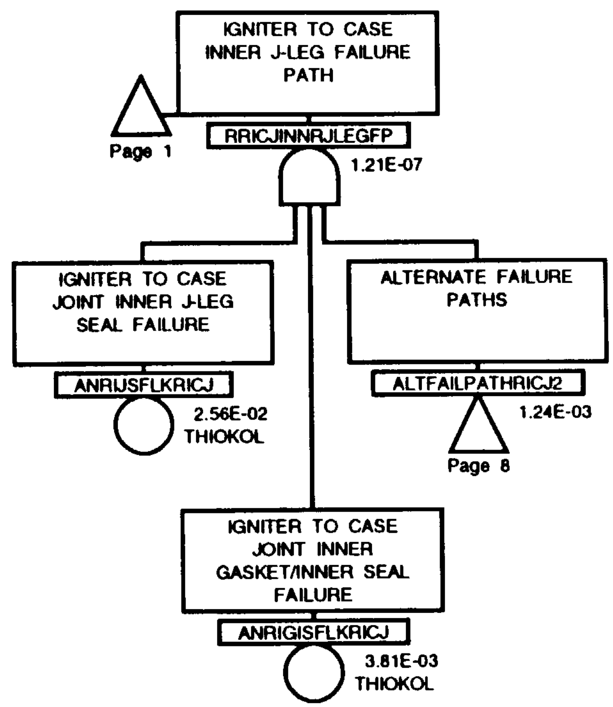
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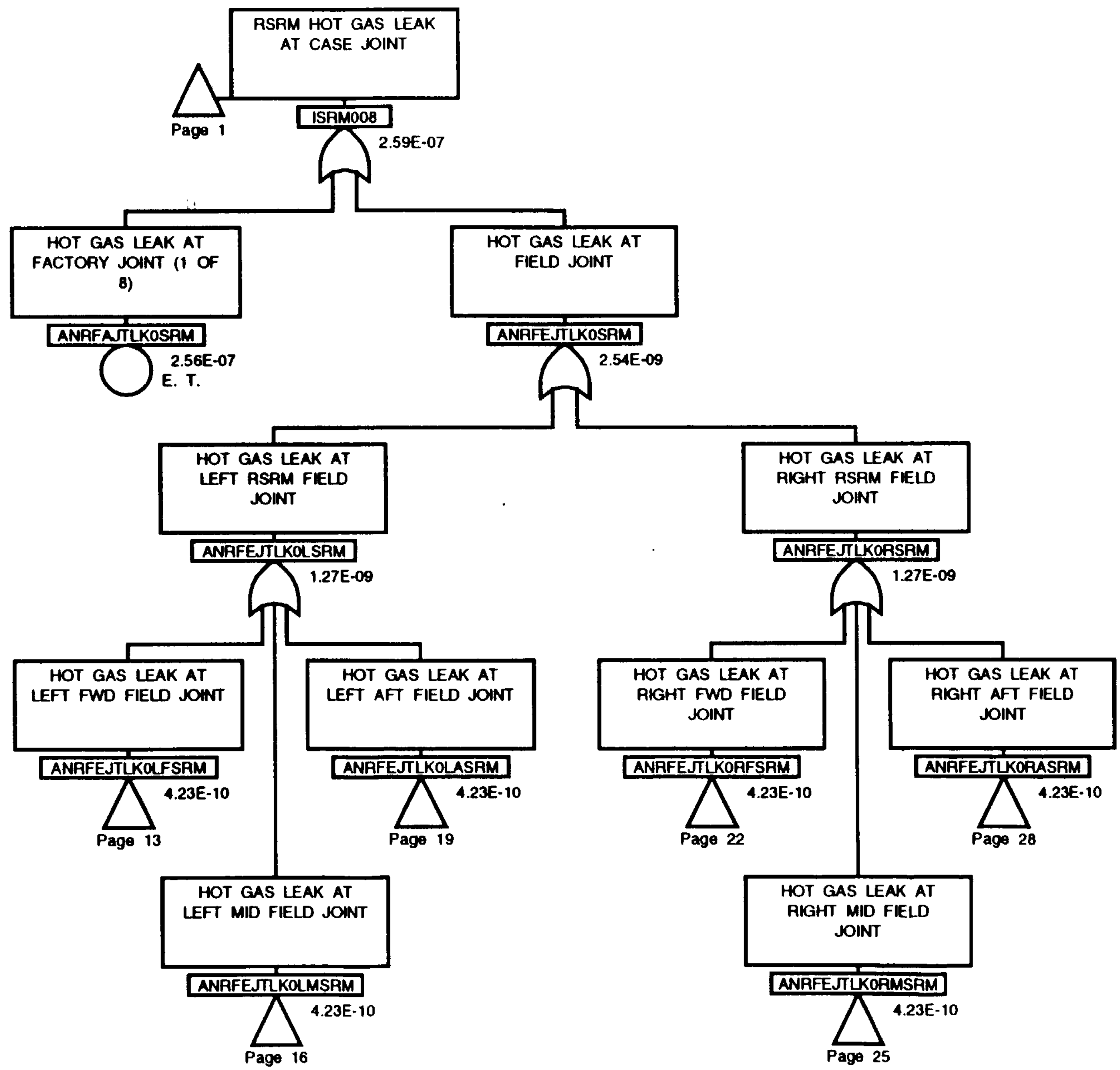
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HOT GAS LEAK AT LEFT AFT FIELD JOINT
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4.23E-10
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HOT GAS LEAK AT RIGHT FWD FIELD JOINT
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4.23E-10
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HOT GAS LEAK AT LEFT MID FIELD JOINT
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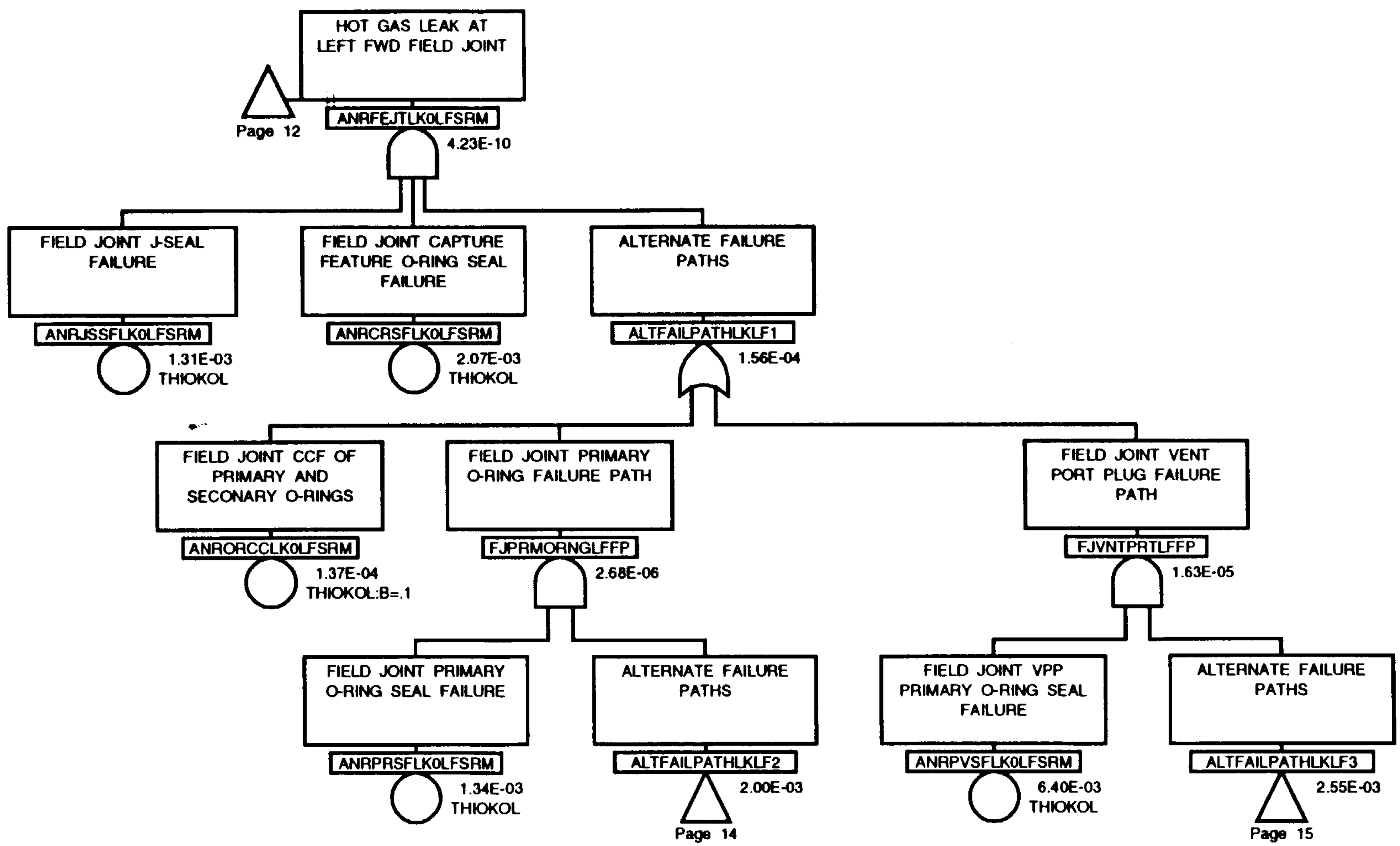
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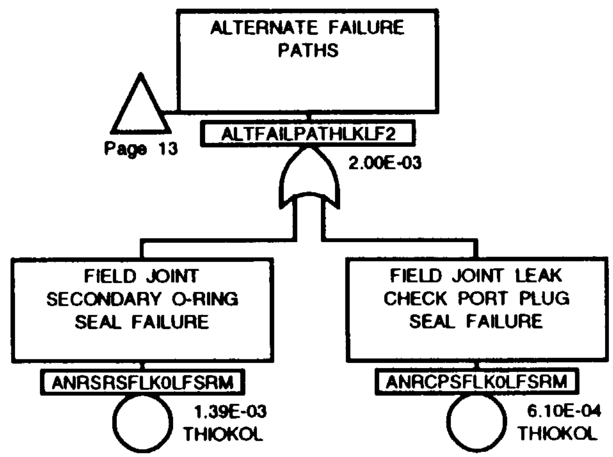
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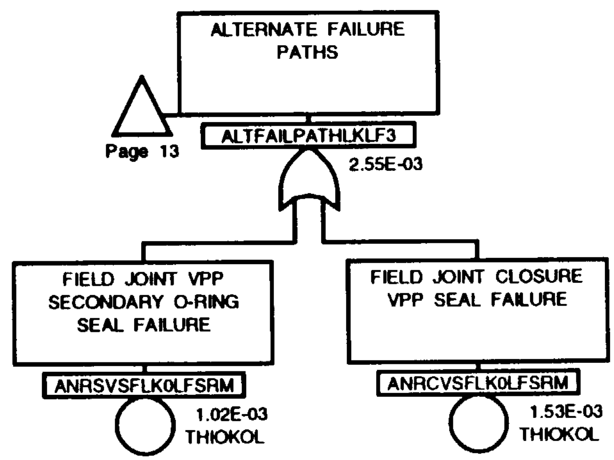

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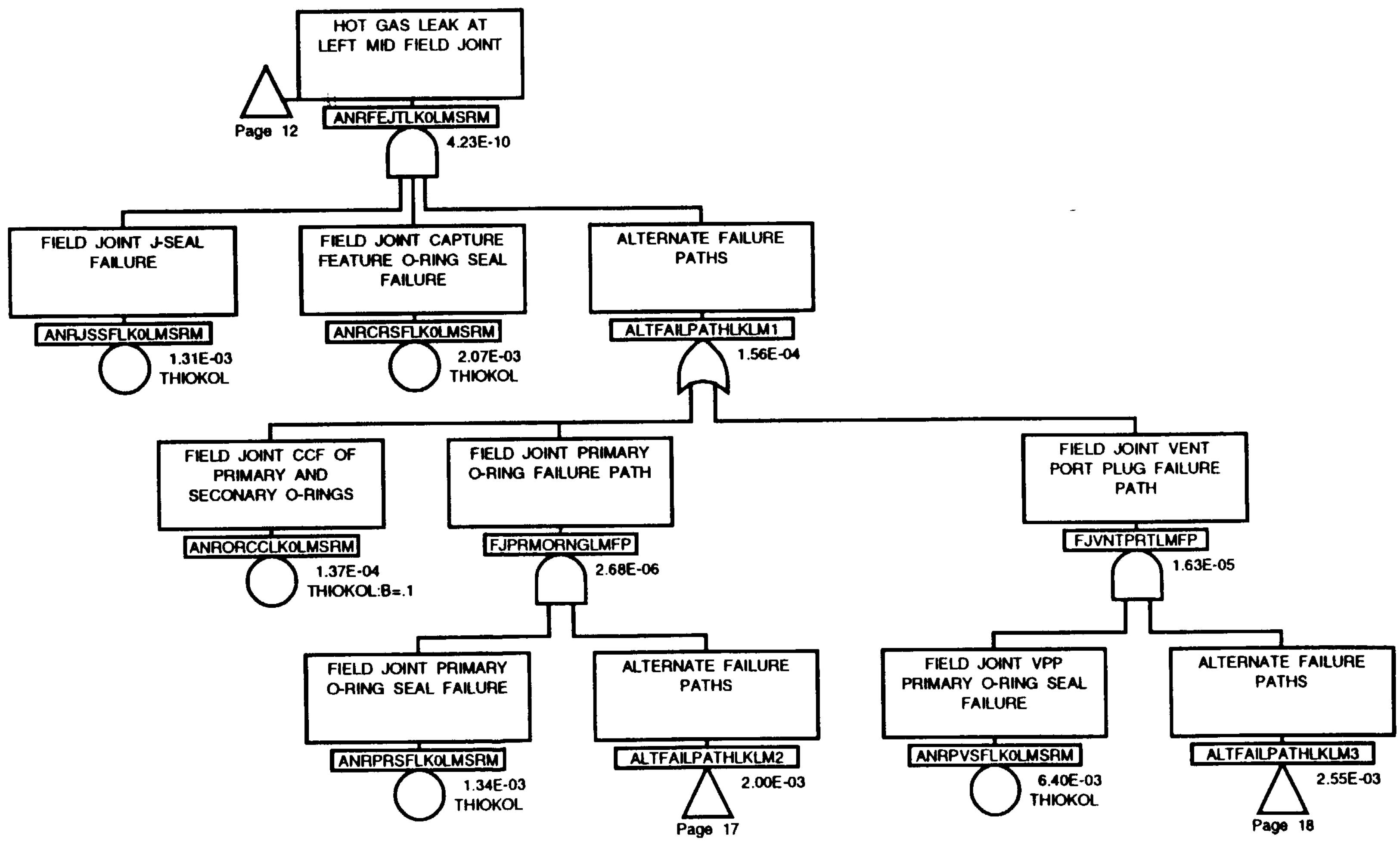
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ALTERNATE FAILURE PATHS
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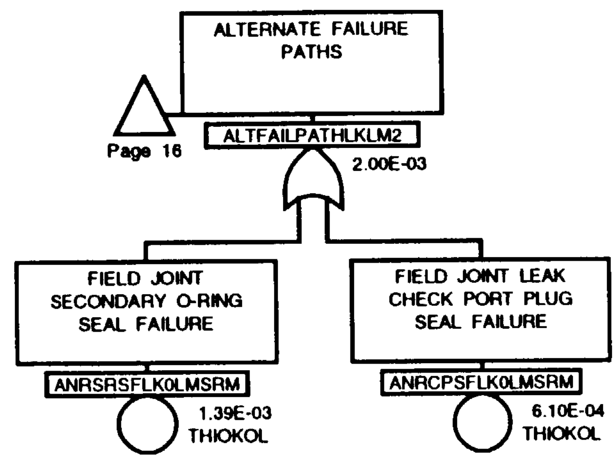
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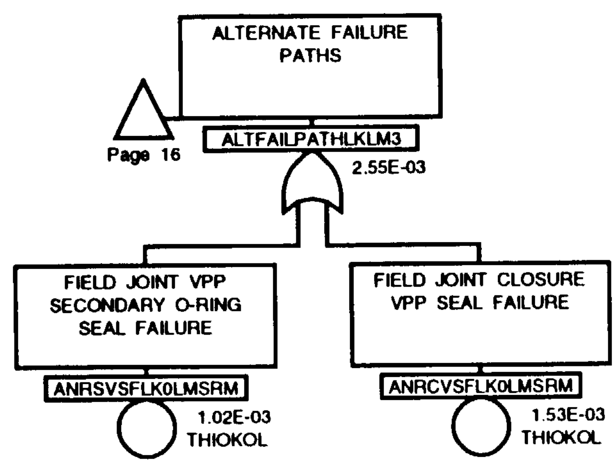
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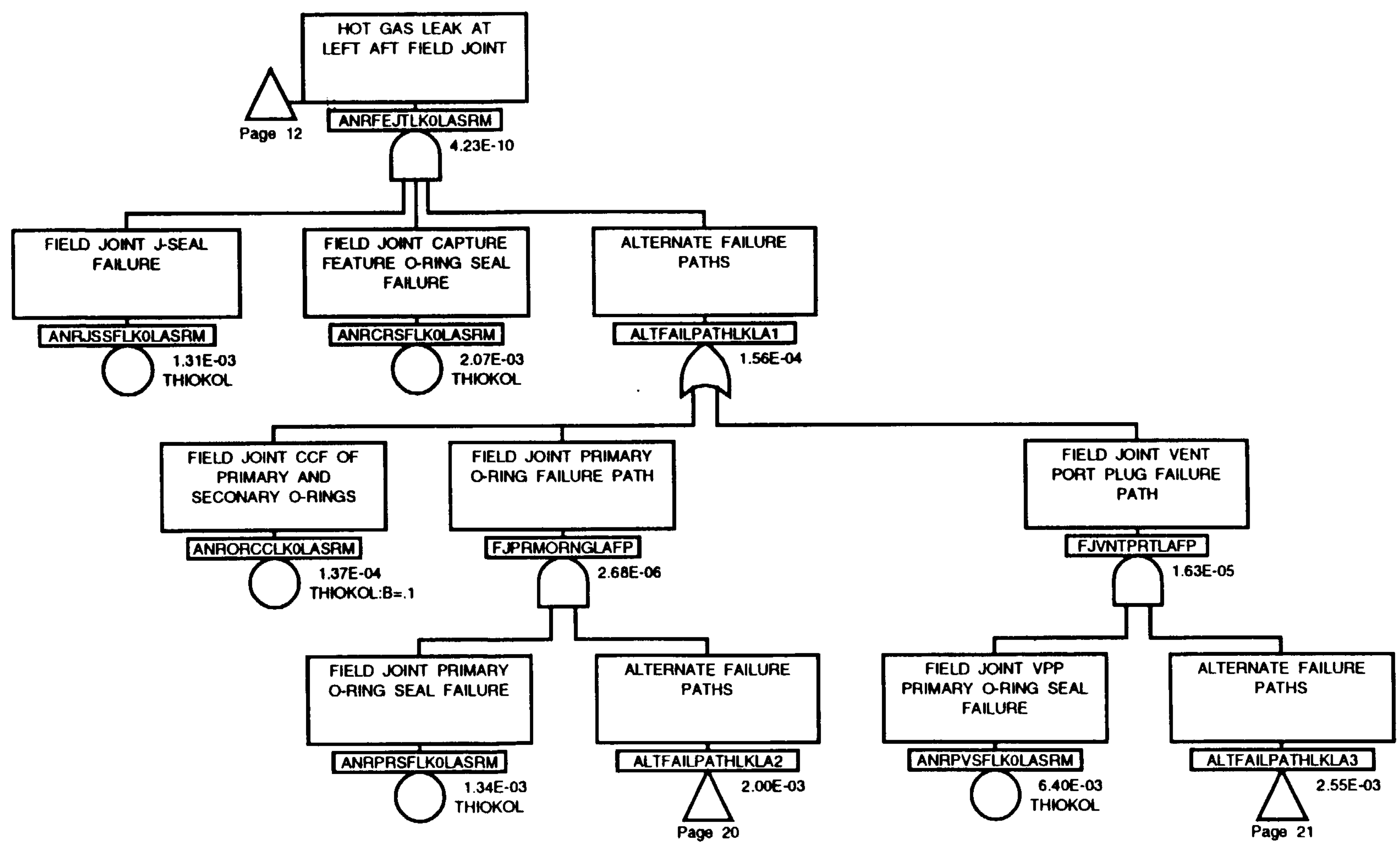
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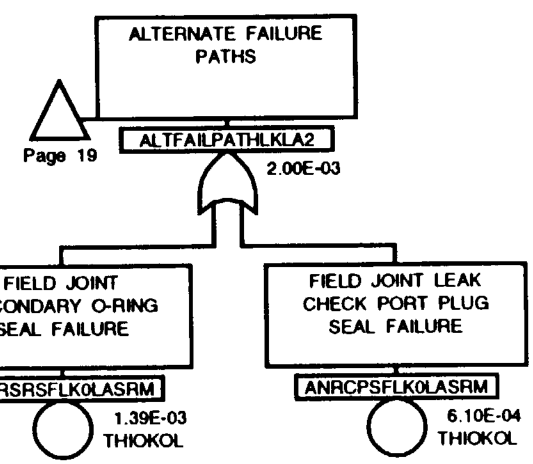
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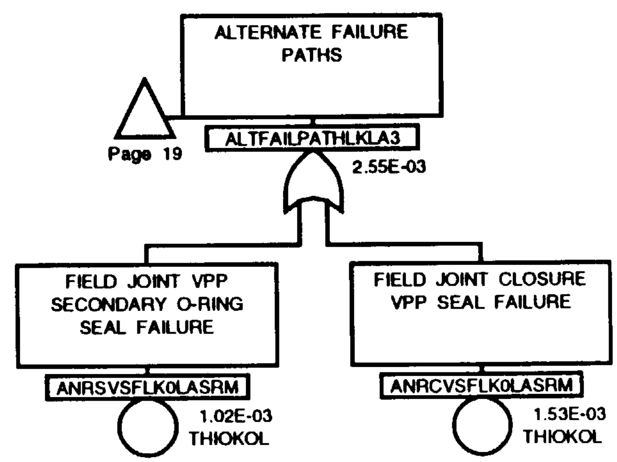
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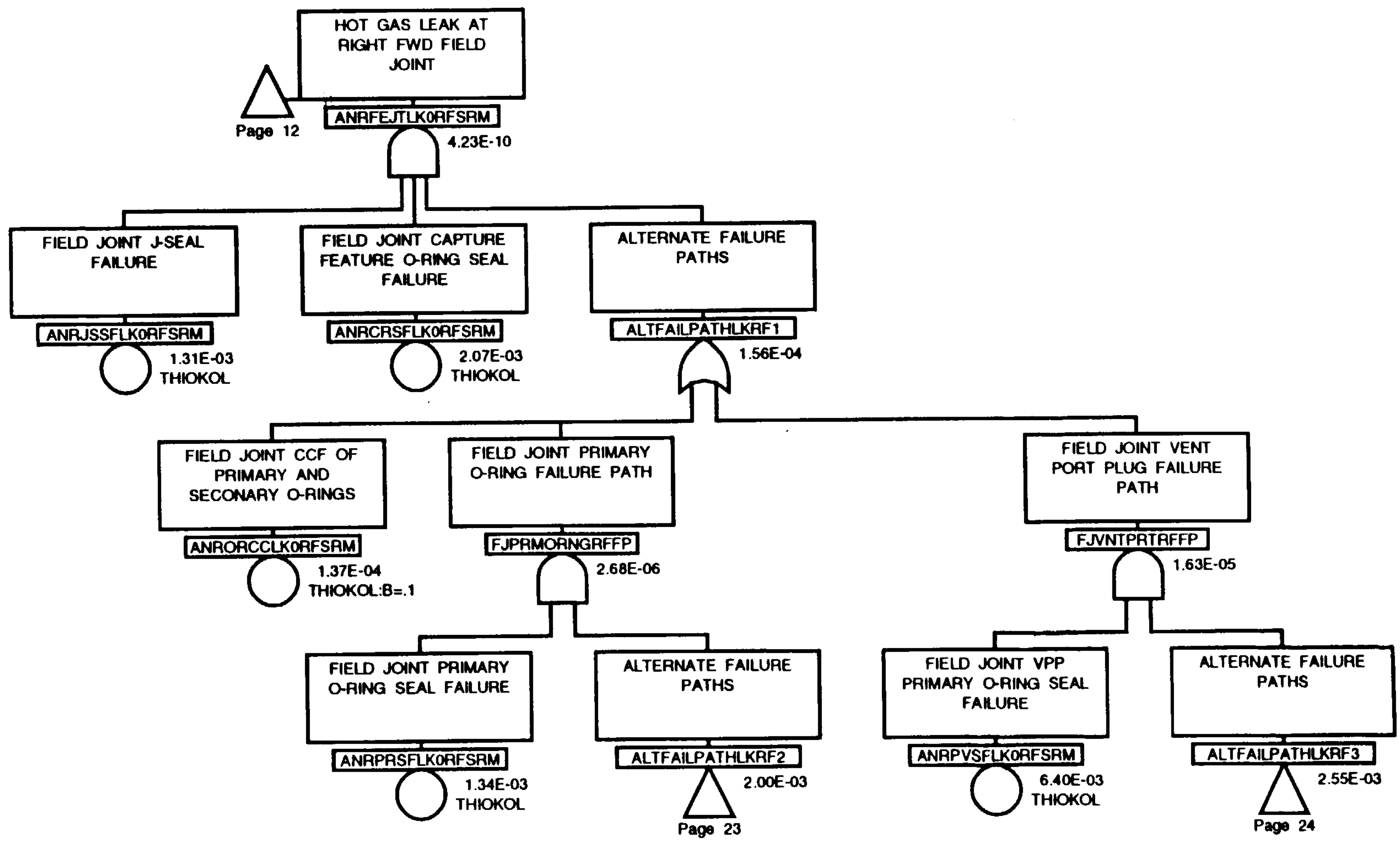
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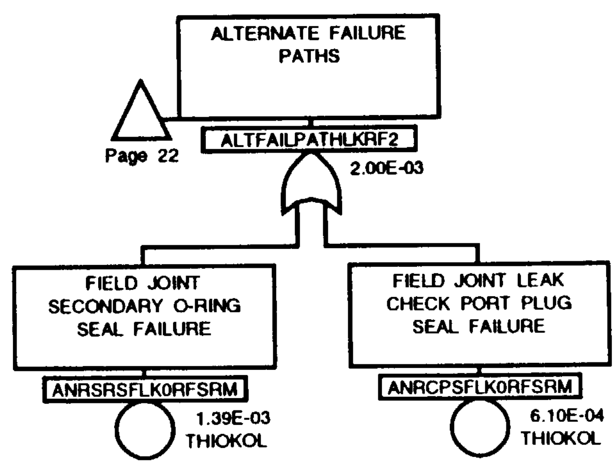
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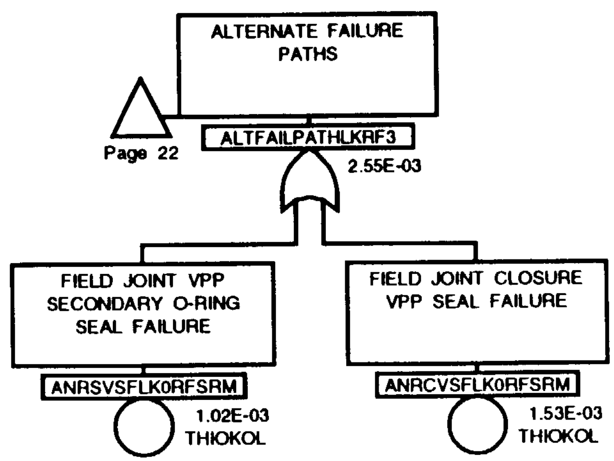
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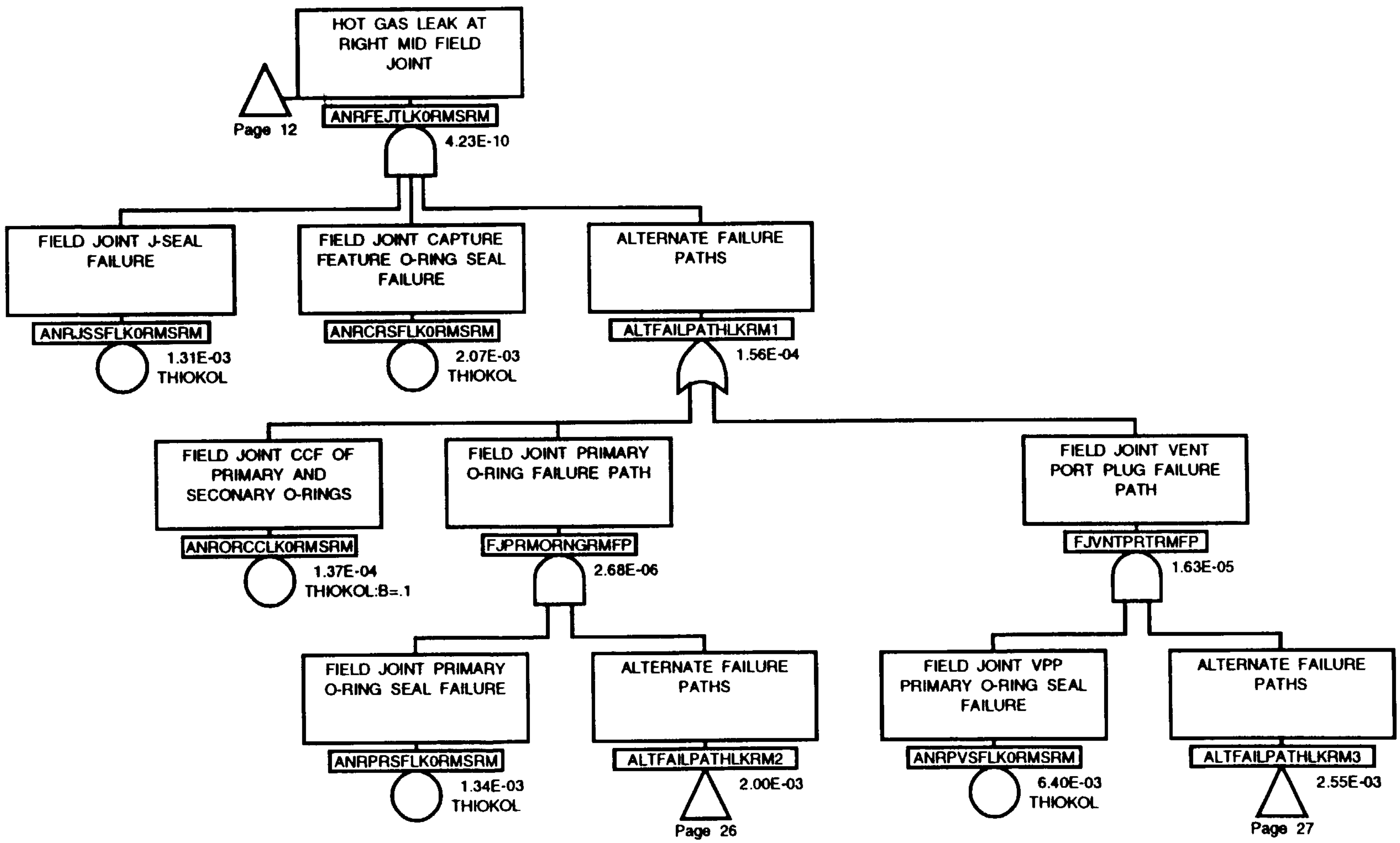

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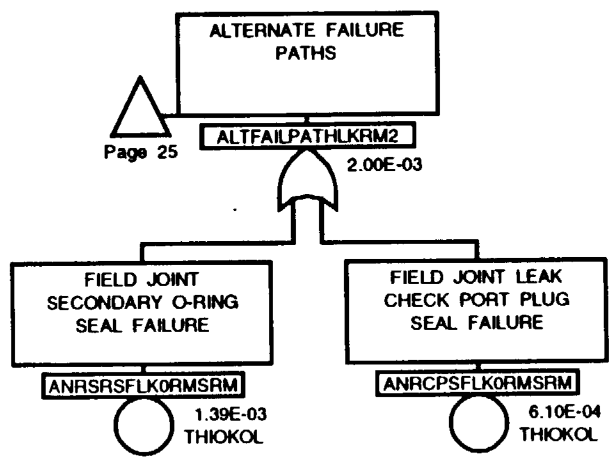
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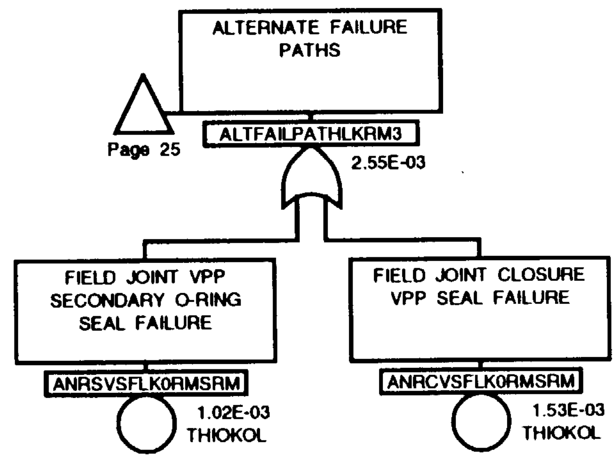
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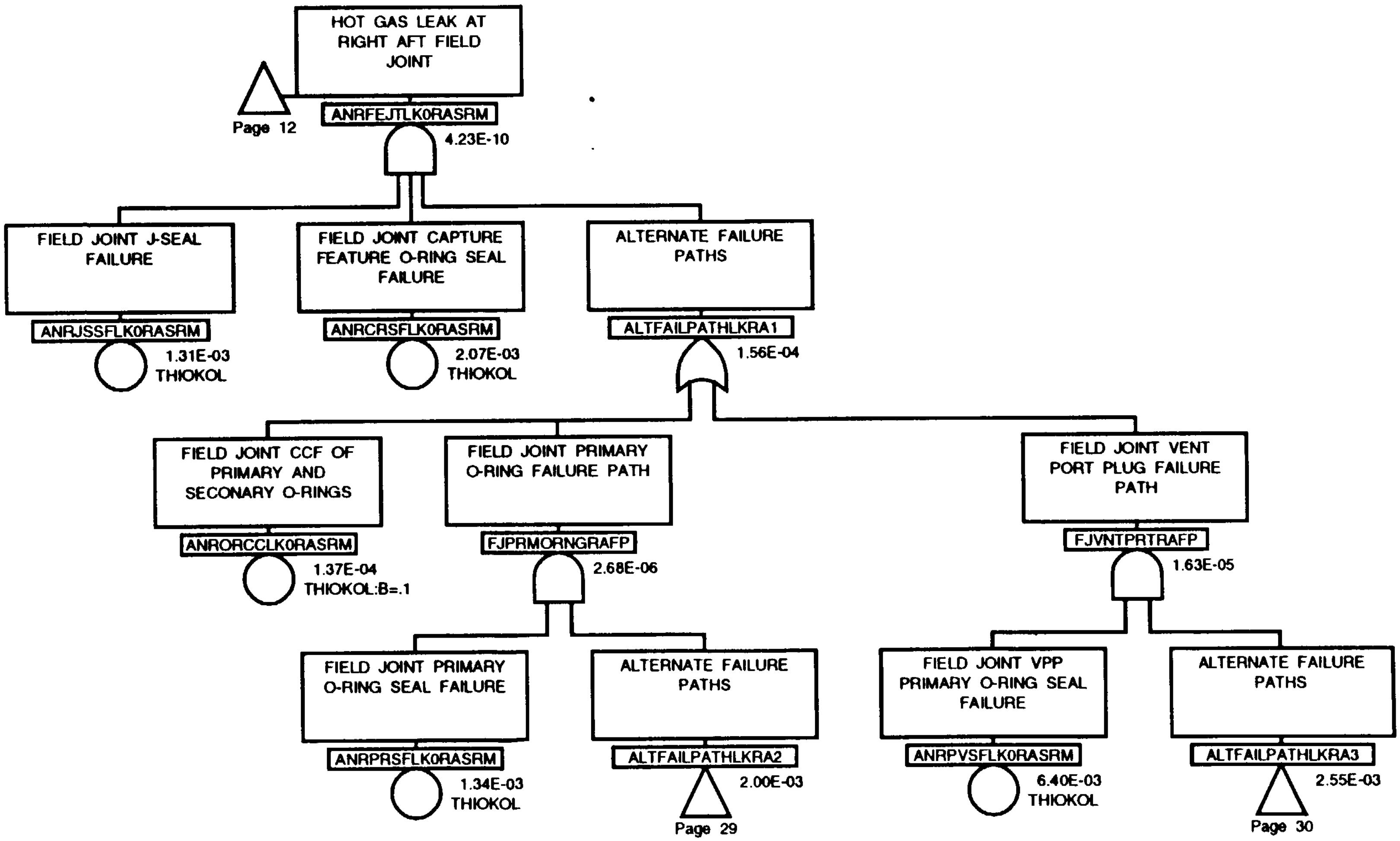
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1.31E-03
THIOKOL
FIELD JOINT CAPTURE FEATURE O-RING SEAL FAILURE
ANRCRSFLK0RASRM
2.07E-03
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ALTERNATE FAILURE PATHS
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1.37E-04
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FJPRMORNGRAFP
2.68E-06
FIELD JOINT VENT PORT PLUG FAILURE PATH
FJVNTPRTRAFP
1.63E-05
FIELD JOINT PRIMARY O-RING SEAL FAILURE
ANRPRSFLK0RASRM
1.34E-03
THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPATHLKRA2
2.00E-03
Page 29
FIELD JOINT VPP PRIMARY O-RING SEAL FAILURE
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ALTERNATE FAILURE PATHS
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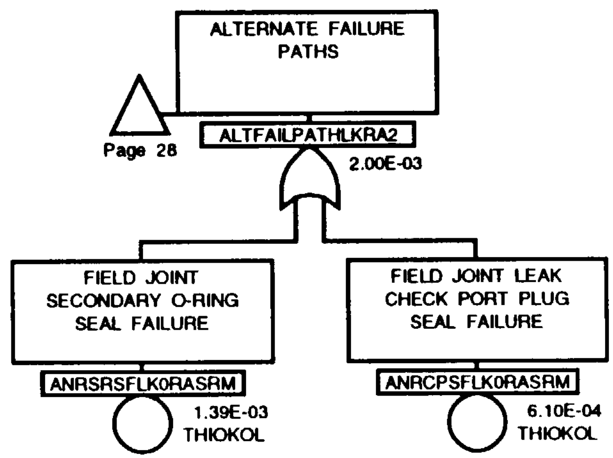
Page 30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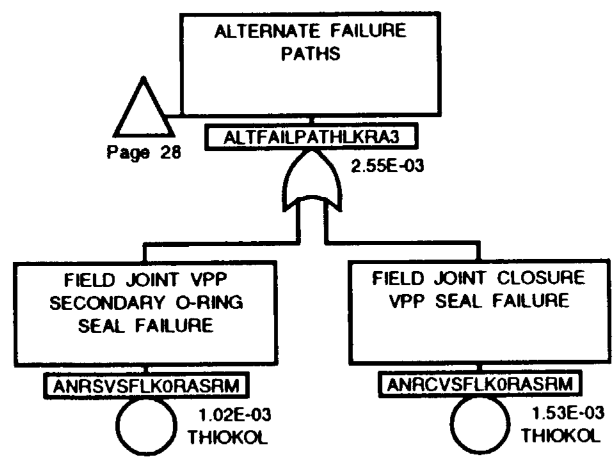
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FIELD JOINT CLOSURE VPP SEAL FAILURE
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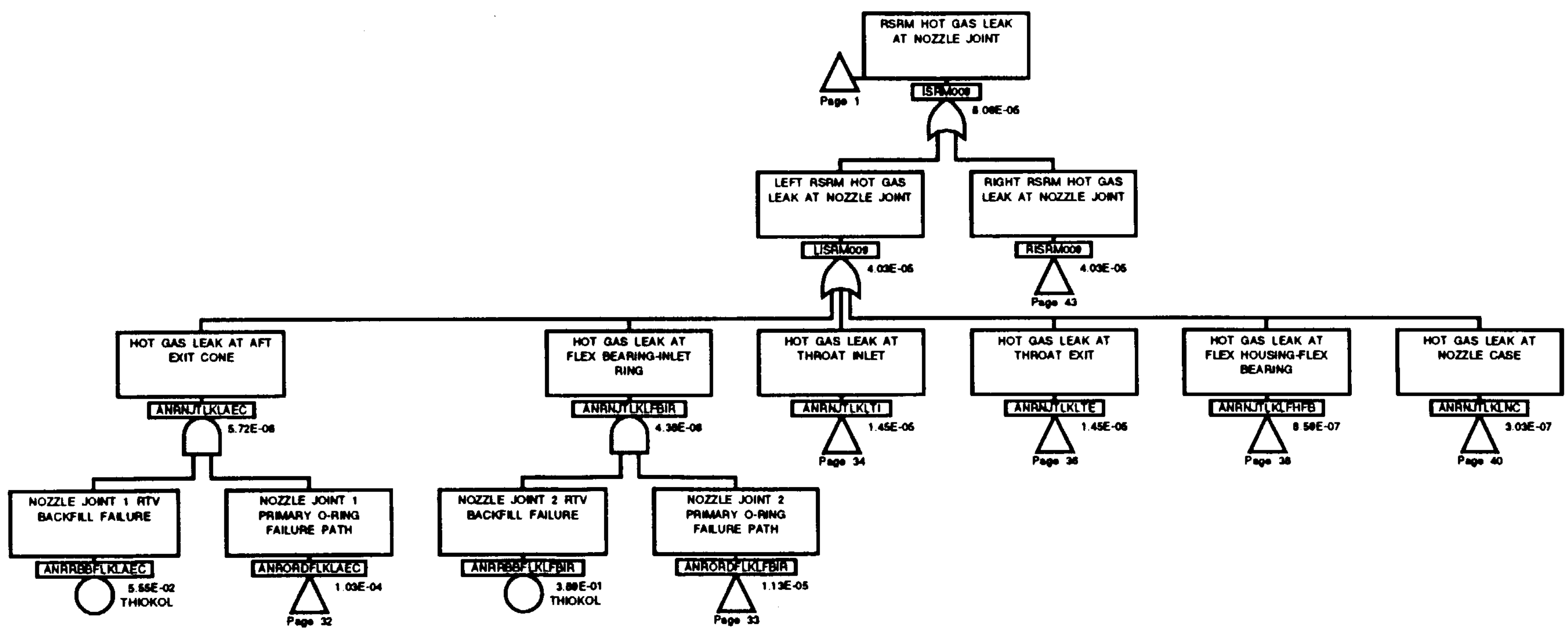
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LISRM009
4.03E-06
RIGHT RSRM HOT GAS LEAK AT NOZZLE JOINT
RISRM009
4.03E-06
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ANRNJTLKLAEC
5.72E-06
HOT GAS LEAK AT FLEX BEARING-INLET RING
ANRNJTLKLFBIR
4.38E-06
HOT GAS LEAK AT THROAT INLET
ANRNJTLKLTI
1.45E-05
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HOT GAS LEAK AT THROAT EXIT
ANRNJTLKLTE
1.45E-06
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HOT GAS LEAK AT FLEX HOUSING-FLEX BEARING
ANRNJTLKLFHFB
8.58E-07
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HOT GAS LEAK AT NOZZLE CASE
ANRNJTLKLNC
3.03E-07
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NOZZLE JOINT 1 RTV BACKFILL FAILURE
ANRRBBFLKLAEC
5.55E-02
THIOKOL
NOZZLE JOINT 1 PRIMARY O-RING FAILURE PATH
ANRORDFLKLAEC
1.03E-04
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NOZZLE JOINT 2 RTV BACKFILL FAILURE
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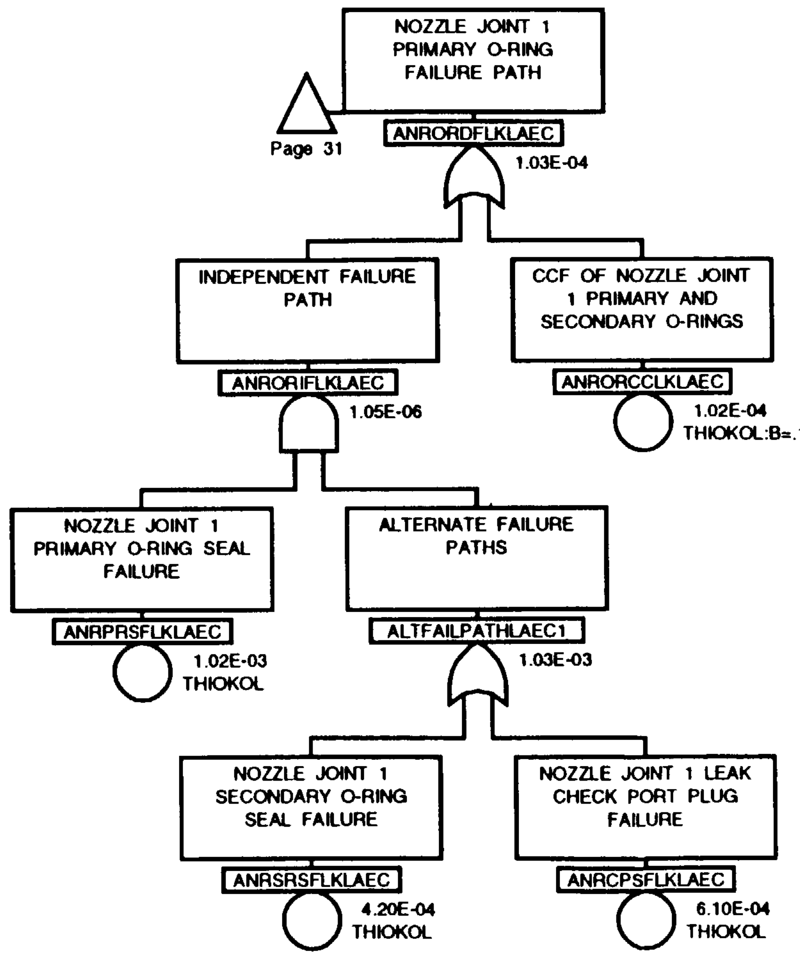
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CCF OF NOZZLE JOINT 1 PRIMARY AND SECONDARY O-RINGS
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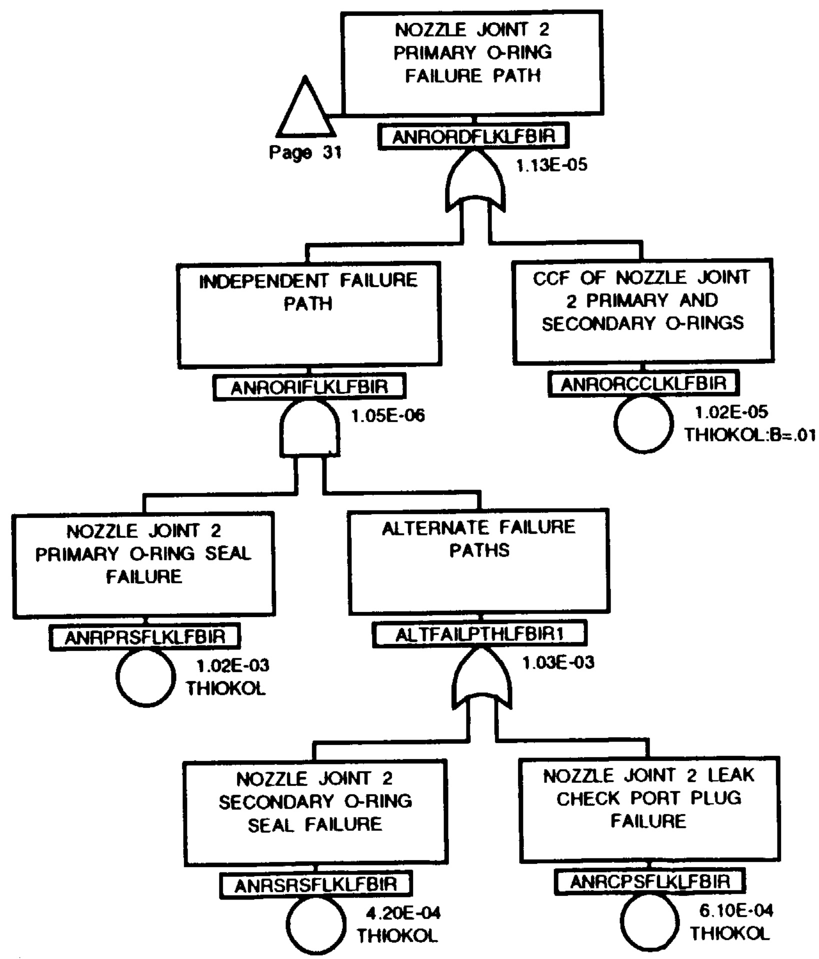
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CCF OF NOZZLE JOINT 2 PRIMARY AND SECONDARY O-RINGS
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ALTERNATE FAILURE PATHS
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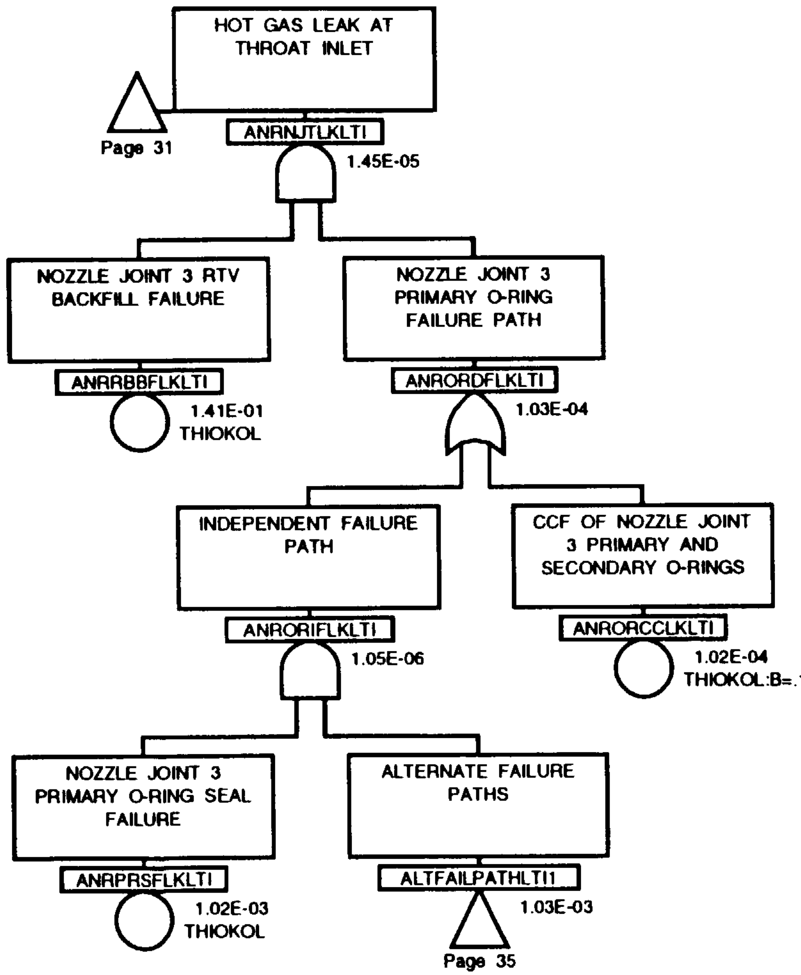
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1.41E-01
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NOZZLE JOINT 3 PRIMARY O-RING FAILURE PATH
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INDEPENDENT FAILURE PATH
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1.05E-06
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NOZZLE JOINT 3 PRIMARY O-RING SEAL FAILURE
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1.02E-03
THIOKOL
ALTERNATE FAILURE PATHS
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1.03E-03
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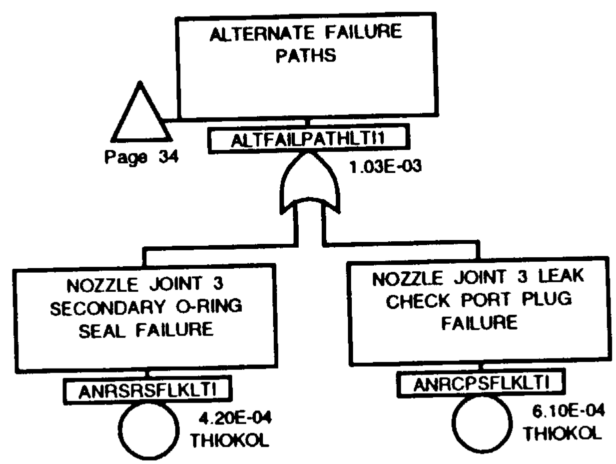
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THIOKOL
NOZZLE JOINT 3 LEAK CHECK PORT PLUG FAILURE
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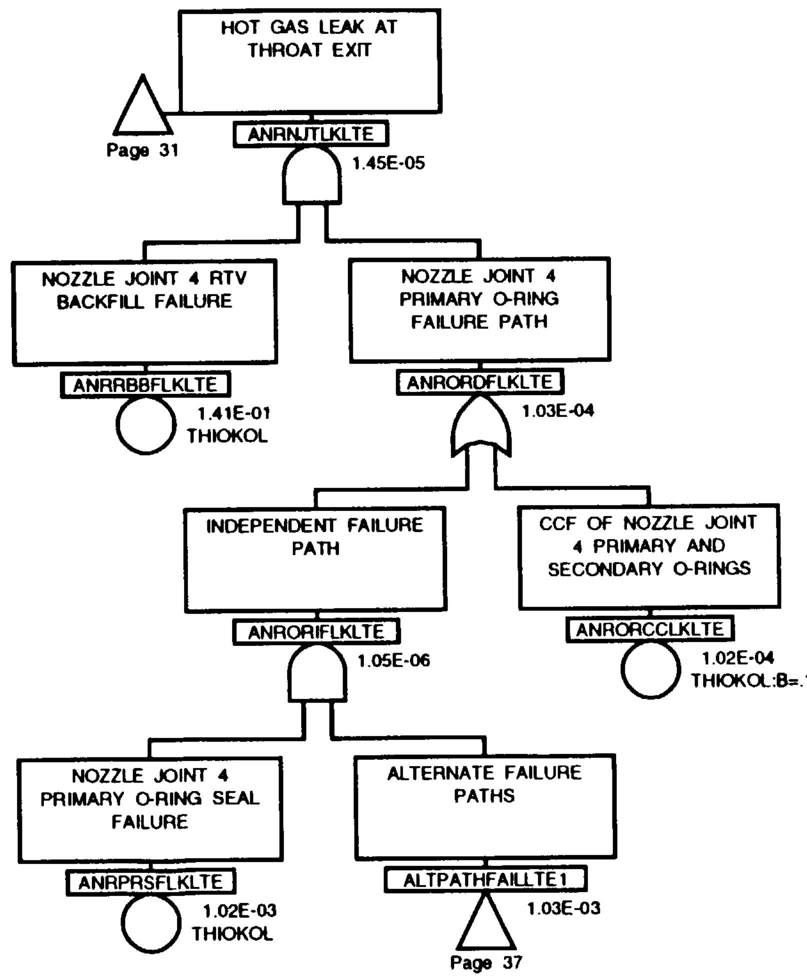
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1.41E-01
THIOKOL
NOZZLE JOINT 4 PRIMARY O-RING FAILURE PATH
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1.03E-04
INDEPENDENT FAILURE PATH
ANRORIFLKLTE
1.05E-06
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NOZZLE JOINT 4 PRIMARY O-RING SEAL FAILURE
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ALTERNATE FAILURE PATHS
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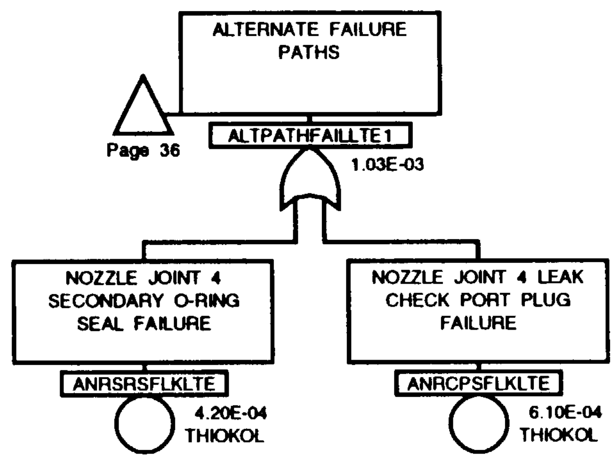
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NOZZLE JOINT 4 SECONDARY O-RING SEAL FAILURE
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NOZZLE JOINT 4 LEAK CHECK PORT PLUG FAILURE
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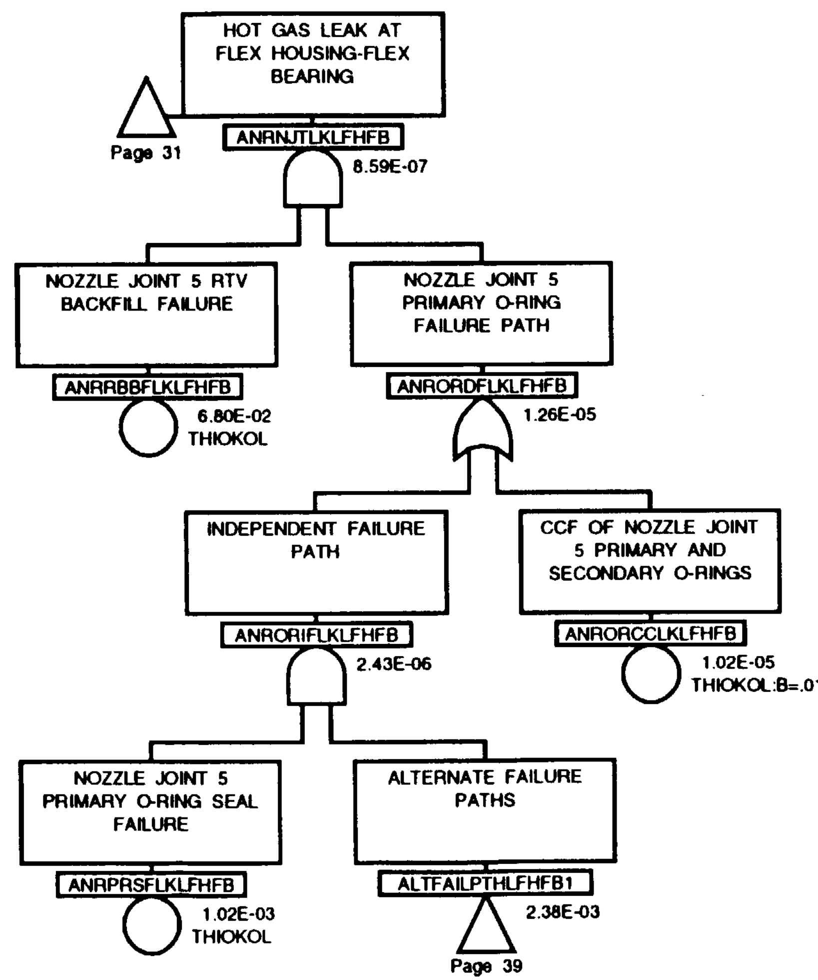
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6.80E-02
THIOKOL
NOZZLE JOINT 5 PRIMARY O-RING FAILURE PATH
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INDEPENDENT FAILURE PATH
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2.43E-06
CCF OF NOZZLE JOINT 5 PRIMARY AND SECONDARY O-RINGS
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1.02E-05
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NOZZLE JOINT 5 PRIMARY O-RING SEAL FAILURE
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1.02E-03
THIOKOL
ALTERNATE FAILURE PATHS
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2.38E-03
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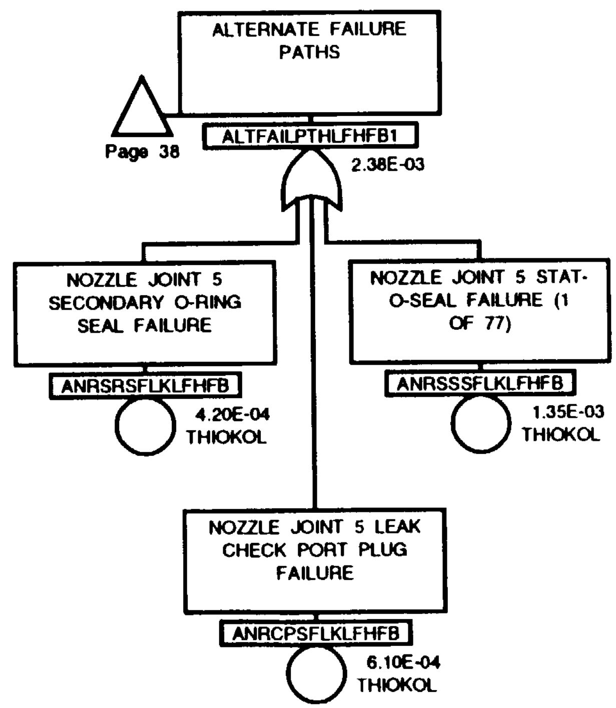
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NOZZLE JOINT 5 SECONDARY O-RING SEAL FAILURE
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4.20E-04
THIOKOL
NOZZLE JOINT 5 STAT-O-SEAL FAILURE (1 OF 77)
ANRSSSFLKLFHFB
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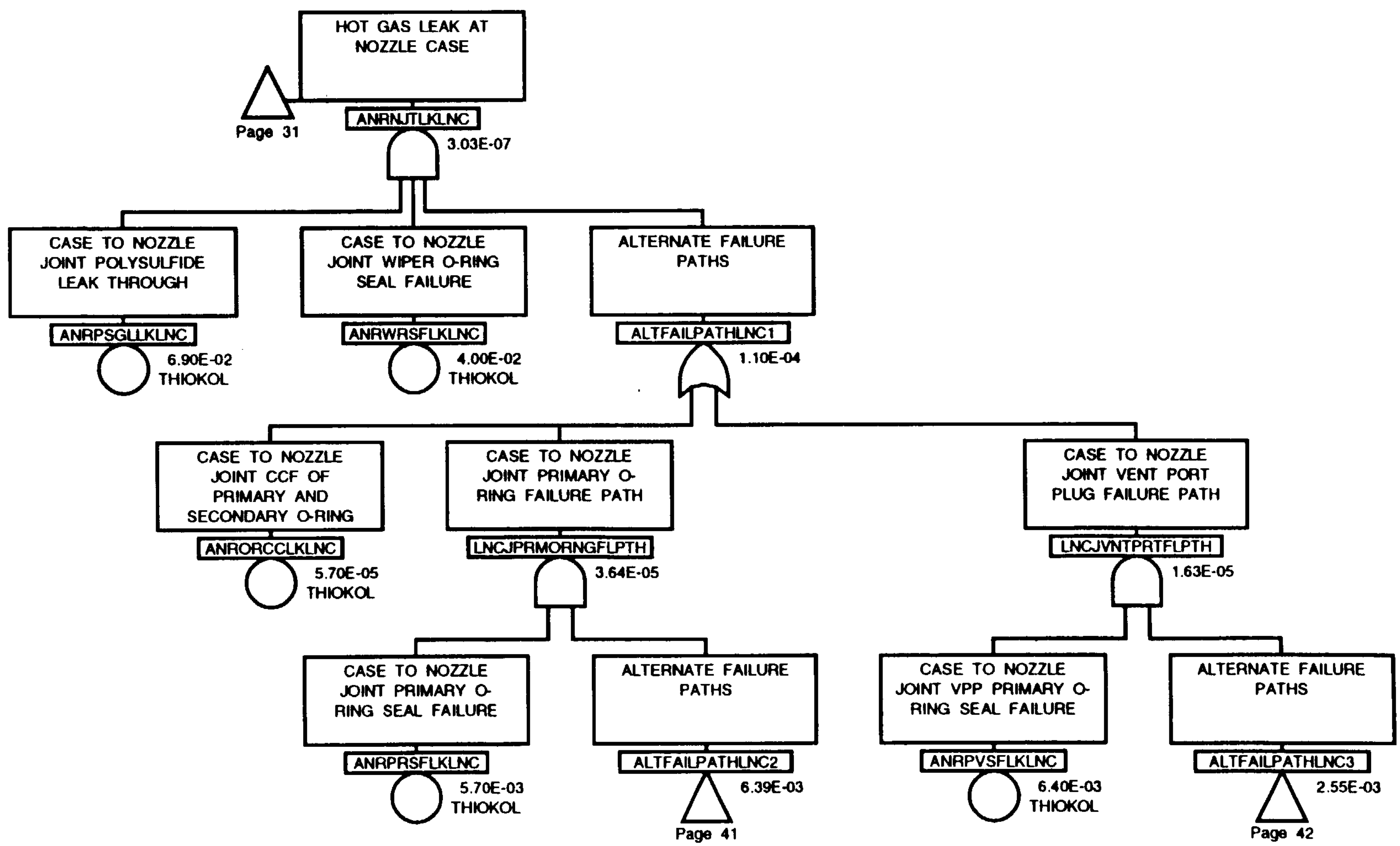
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CASE TO NOZZLE JOINT POLYSULFIDE LEAK THROUGH
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CASE TO NOZZLE JOINT WIPER O-RING SEAL FAILURE
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CASE TO NOZZLE JOINT PRIMARY O-RING SEAL FAILURE
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5.70E-03
THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPATHLNC2
6.39E-03
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CASE TO NOZZLE JOINT VPP PRIMARY O-RING SEAL FAILURE
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ALTERNATE FAILURE PATHS
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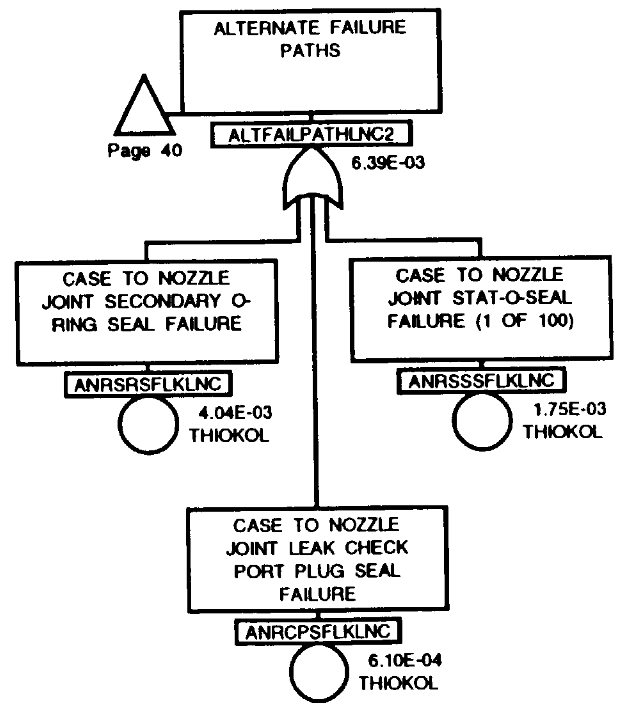
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4.04E-03
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CASE TO NOZZLE JOINT STAT-O-SEAL FAILURE (1 OF 100)
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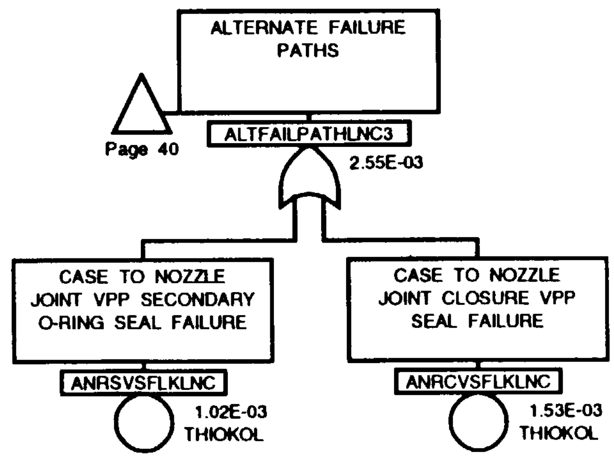
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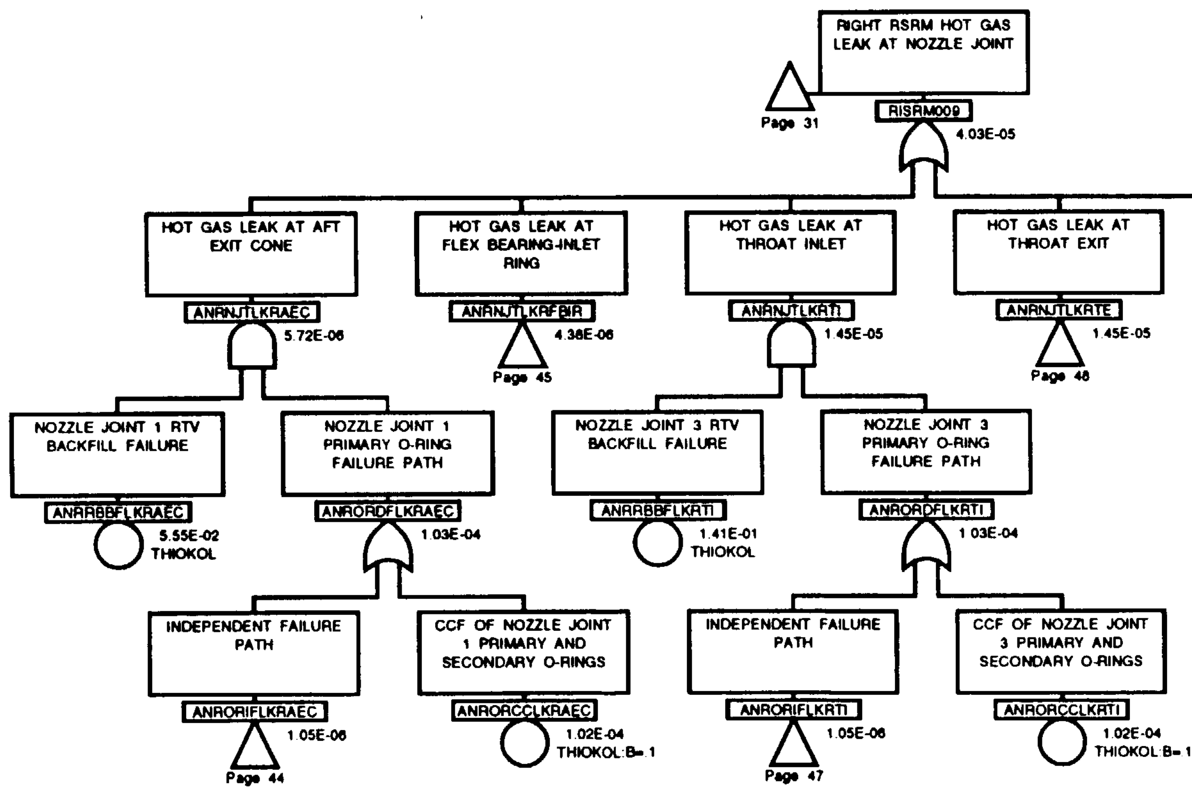
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HOT GAS LEAK AT FLEX BEARING-INLET RING
ANRNJTLKRFBIR
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ANRNJTLKRTI
1.45E-05
HOT GAS LEAK AT THROAT EXIT
ANRNJTLKRTE
1.45E-05
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ANRNJTLKRFHFB
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ANRNJTLKRNC
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5.55E-02
THIOKOL
NOZZLE JOINT 1 PRIMARY O-RING FAILURE PATH
ANRORDFLKRAEC
1.03E-04
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NOZZLE JOINT 3 PRIMARY O-RING FAILURE PATH
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1.03E-04
INDEPENDENT FAILURE PATH
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1.05E-06
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CCF OF NOZZLE JOINT 1 PRIMARY AND SECONDARY O-RINGS
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INDEPENDENT FAILURE PATH
ANRORIFLKRTI
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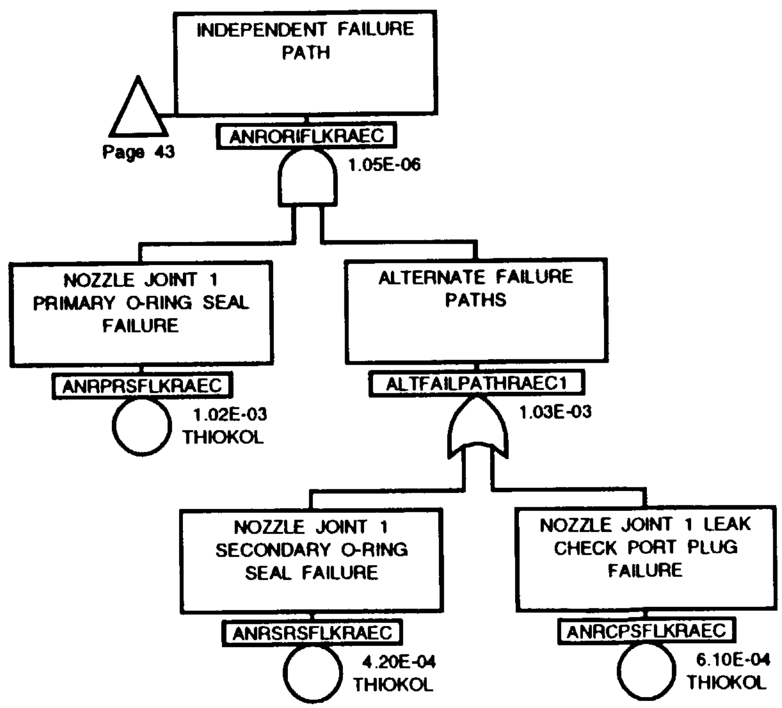
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THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPATHRAEC1
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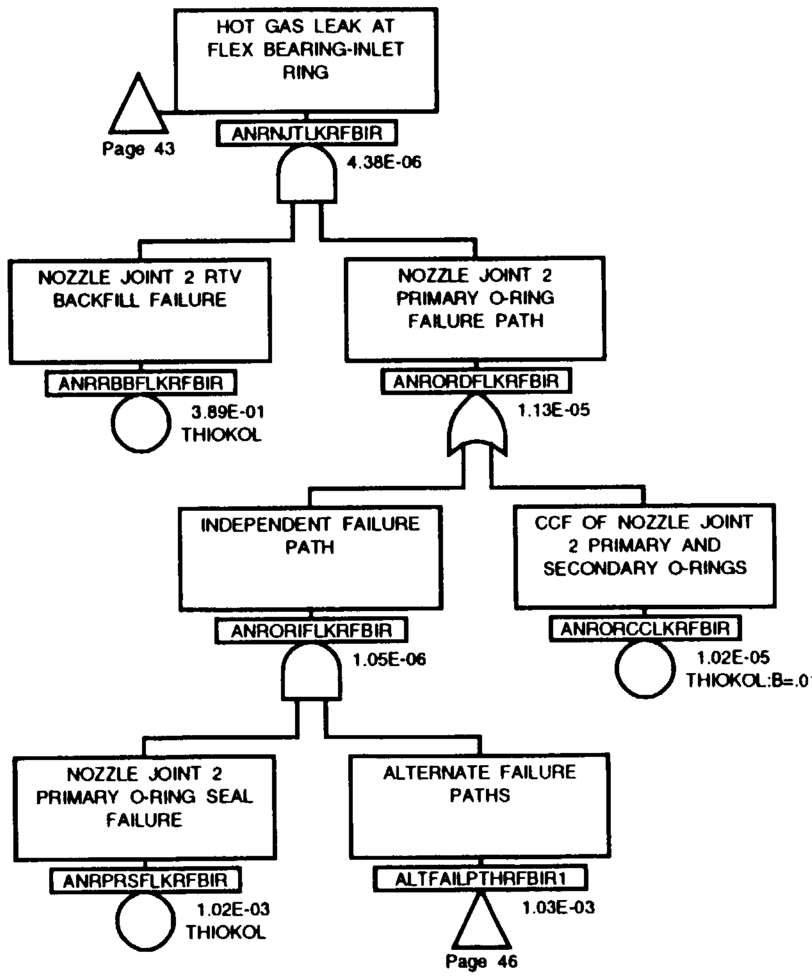
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3.89E-01
THIOKOL
NOZZLE JOINT 2 PRIMARY O-RING FAILURE PATH
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INDEPENDENT FAILURE PATH
ANRORIFLKRFBIR
1.05E-06
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NOZZLE JOINT 2 PRIMARY O-RING SEAL FAILURE
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ALTERNATE FAILURE PATHS
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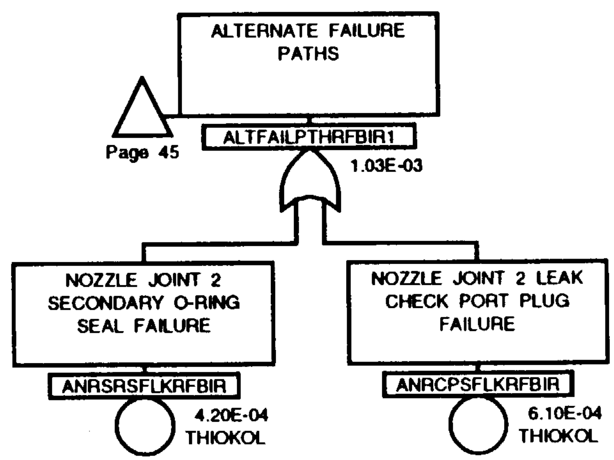
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NOZZLE JOINT 2 LEAK CHECK PORT PLUG FAILURE
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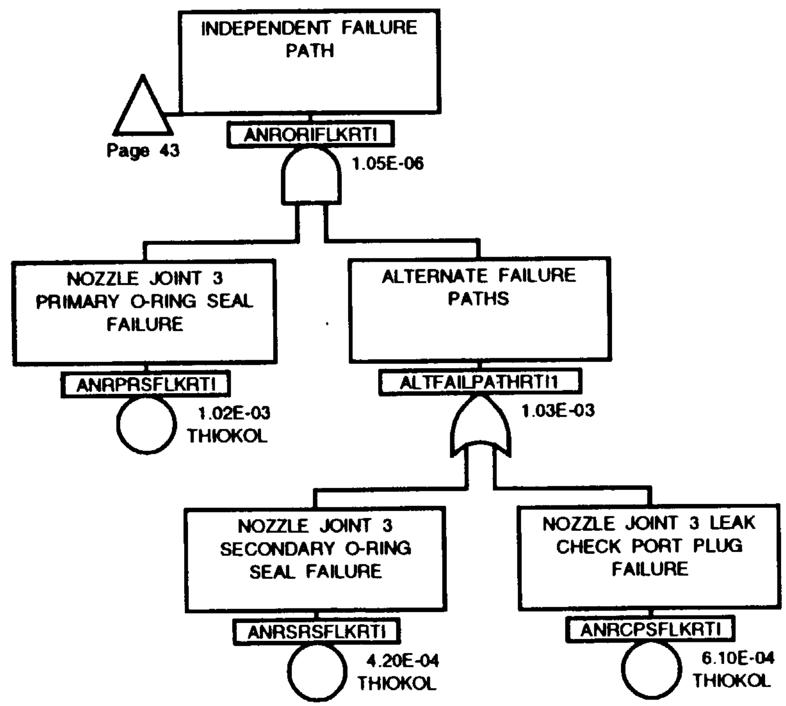

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ALTERNATE FAILURE PATHS
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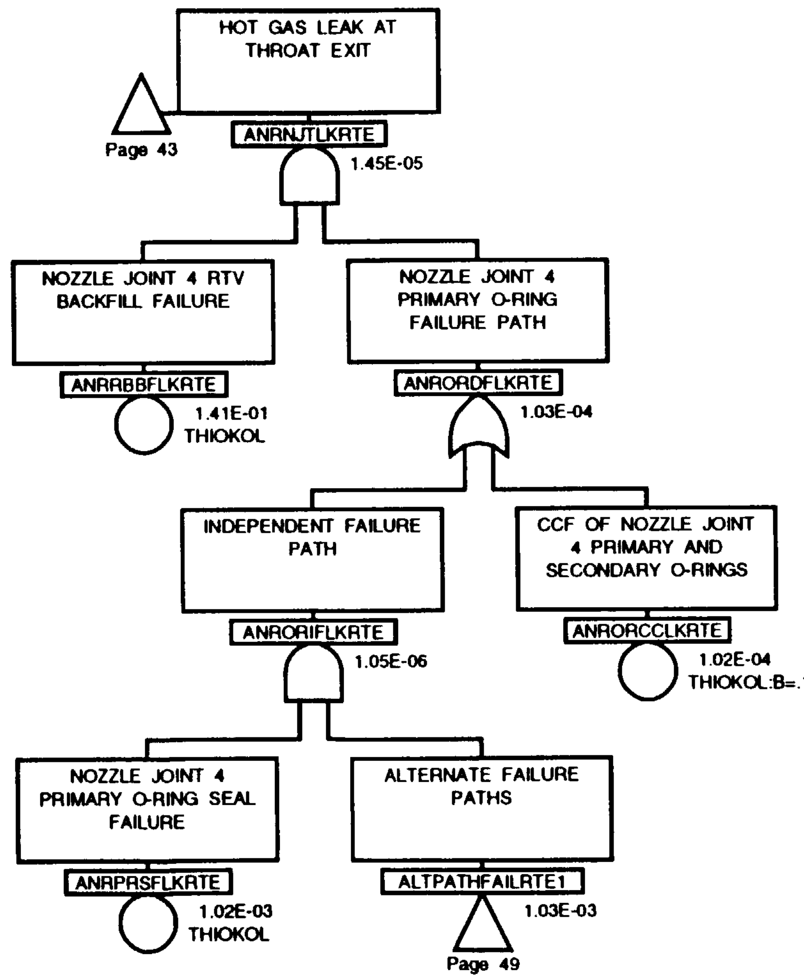
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NOZZLE JOINT 4 RTV BACKFILL FAILURE
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ANRORDFLKRTE
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INDEPENDENT FAILURE PATH
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NOZZLE JOINT 4 PRIMARY O-RING SEAL FAILURE
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1.02E-03
THIOKOL
ALTERNATE FAILURE PATHS
ALTPATHFAILRTE1
1.03E-03
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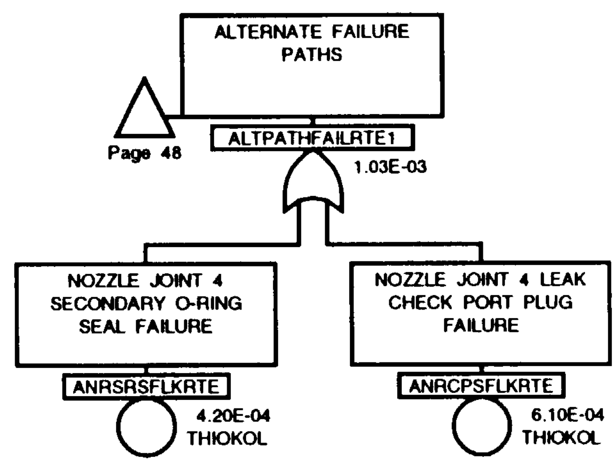
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NOZZLE JOINT 4 LEAK CHECK PORT PLUG FAILURE
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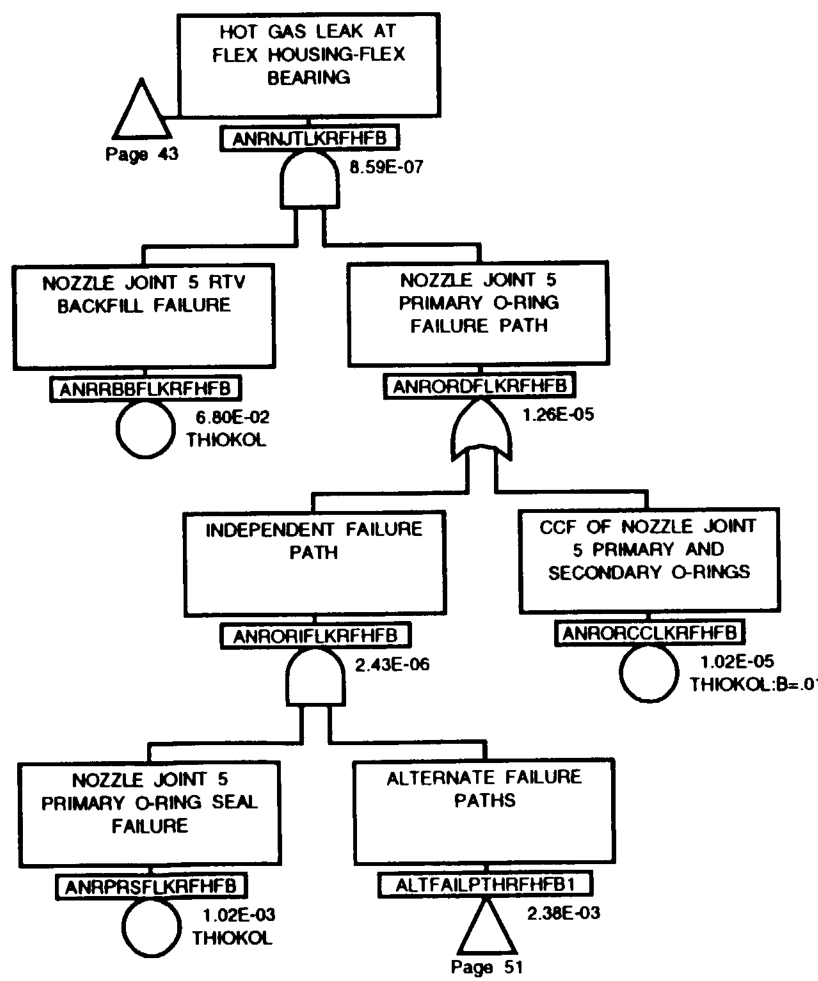
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6.80E-02
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NOZZLE JOINT 5 PRIMARY O-RING FAILURE PATH
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1.26E-05
INDEPENDENT FAILURE PATH
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2.43E-06
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1.02E-05
THIOKOL:B=.01
NOZZLE JOINT 5 PRIMARY O-RING SEAL FAILURE
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ALTERNATE FAILURE PATHS
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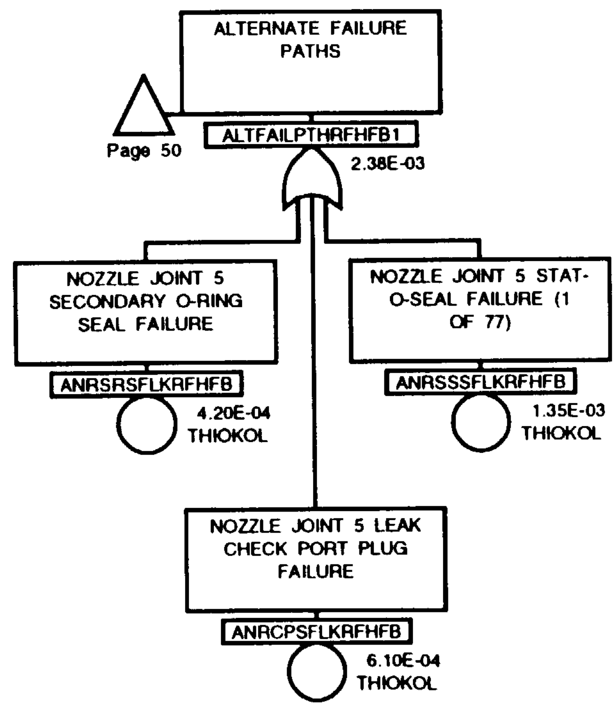
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4.20E-04
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NOZZLE JOINT 5 STAT-O-SEAL FAILURE (1 OF 77)
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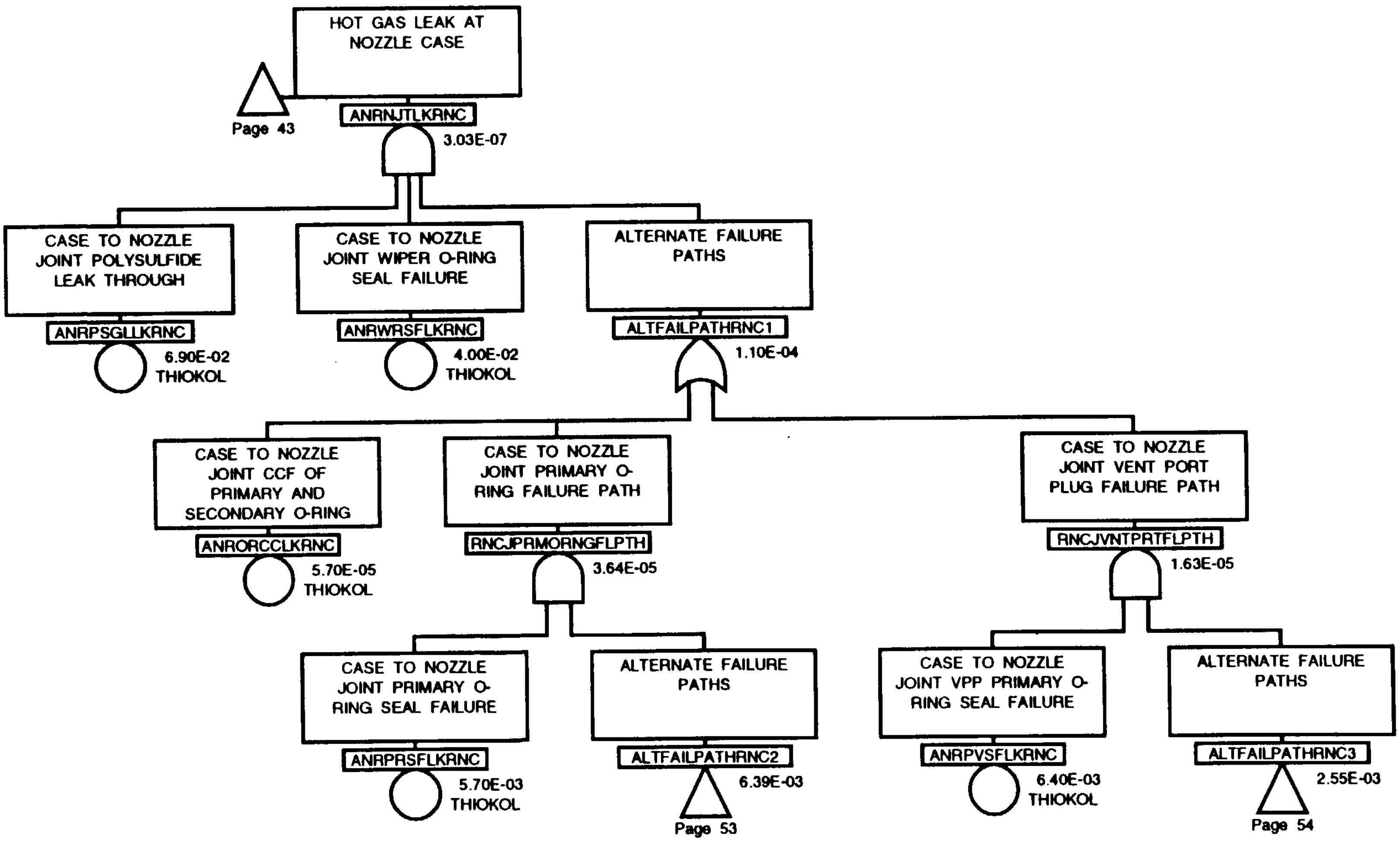
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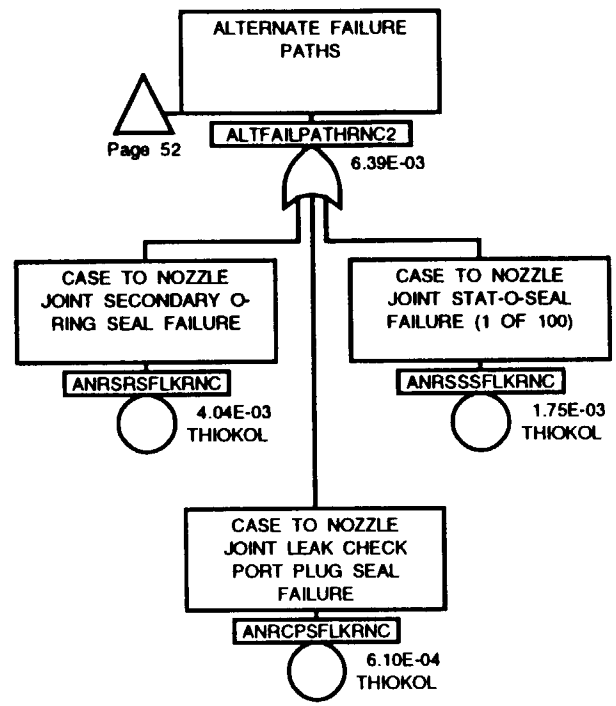
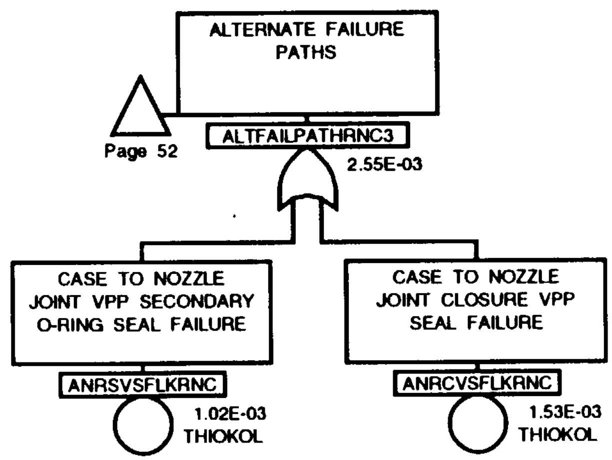
CASE TO NOZZLE JOINT POLYSULFIDE LEAK THROUGH
ANRPSGLLKRNC
6.90E-02
THIOKOL
CASE TO NOZZLE JOINT WIPER O-RING SEAL FAILURE
ANRWRSFLKRNC
4.00E-02
THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPATHRNC1
1.10E-04
CASE TO NOZZLE JOINT CCF OF PRIMARY AND SECONDARY O-RING
ANRORCCLKRNC
5.70E-05
THIOKOL
CASE TO NOZZLE JOINT PRIMARY O-RING FAILURE PATH
RNCJPRMORNGFLPTH
3.64E-05
CASE TO NOZZLE JOINT VENT PORT PLUG FAILURE PATH
RNCJVNTPRTFLPTH
1.63E-05
CASE TO NOZZLE JOINT PRIMARY O-RING SEAL FAILURE
ANRPRSFLKRNC
5.70E-03
THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPATHRNC2
6.39E-03
Page 53
CASE TO NOZZLE JOINT VPP PRIMARY O-RING SEAL FAILURE
ANRPVSFLKRNC
6.40E-03
THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPATHRNC3
2.55E-03
Page 54


ALTERNATE FAILURE PATHS
ALTFAILPATHRNC2
6.39E-03
Page 52
CASE TO NOZZLE JOINT SECONDARY O-RING SEAL FAILURE
ANRSRSFLKRNC
4.04E-03
THIOKOL
CASE TO NOZZLE JOINT STAT-O-SEAL FAILURE (1 OF 100)
ANRSSSFLKRNC
1.75E-03
THIOKOL
CASE TO NOZZLE JOINT LEAK CHECK PORT PLUG SEAL FAILURE
ANRCPSFLKRNC
6.10E-04
THIOKOL


ALTERNATE FAILURE PATHS
ALTFAILPATHRNC3
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Page 52
CASE TO NOZZLE JOINT VPP SECONDARY O-RING SEAL FAILURE
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THIOKOL
CASE TO NOZZLE JOINT CLOSURE VPP SEAL FAILURE
ANRCVSFLKRNC
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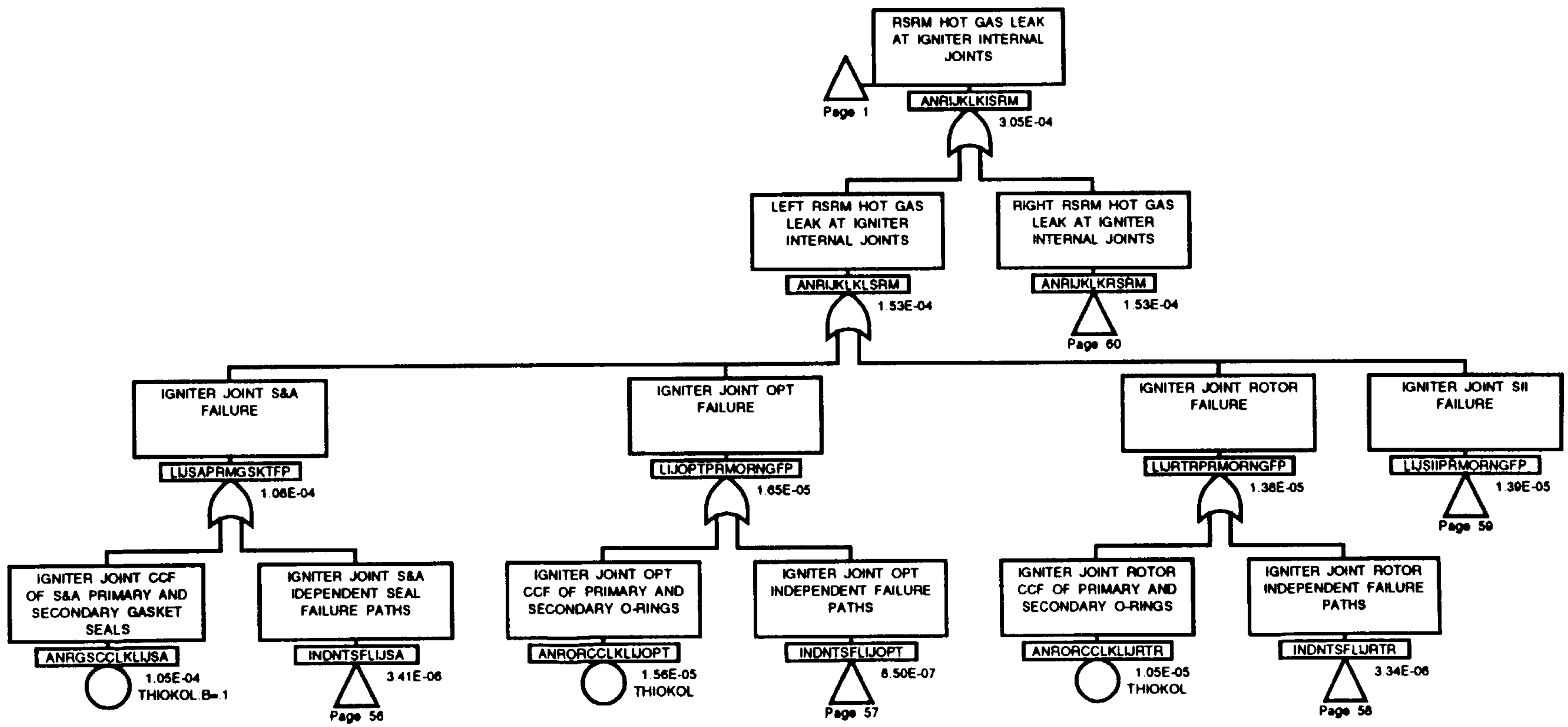
RSRM HOT GAS LEAK AT IGNITER INTERNAL JOINTS
ANRIJKLKISRM
3.05E-04
Page 1
LEFT RSRM HOT GAS LEAK AT IGNITER INTERNAL JOINTS
ANRIJKLKLSRM
1.53E-04
RIGHT RSRM HOT GAS LEAK AT IGNITER INTERNAL JOINTS
ANRIJKLKRSRM
1.53E-04
Page 60
IGNITER JOINT S&A FAILURE
LIJSAPRMGSKTFP
1.08E-04
IGNITER JOINT OPT FAILURE
LIJOPTPRMORNGFP
1.65E-05
IGNITER JOINT ROTOR FAILURE
LIJRTRPRMORNGFP
1.38E-05
IGNITER JOINT SII FAILURE
LIJSIIPRMORNGFP
1.39E-05
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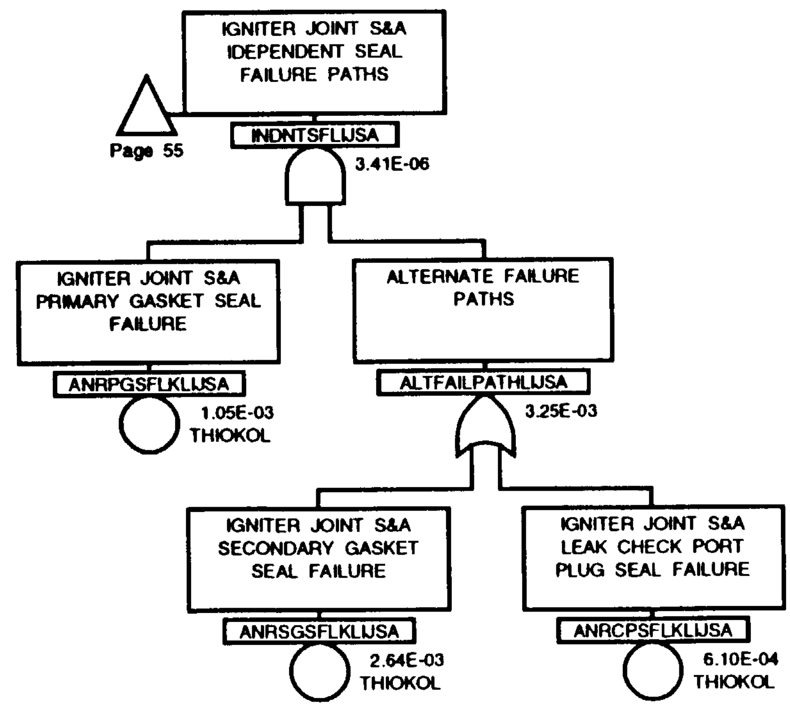
IGNITER JOINT CCF OF S&A PRIMARY AND SECONDARY GASKET SEALS
ANRGSCCLKLIJSA
1.05E-04
THIOKOL B-1
IGNITER JOINT S&A IDEPENDENT SEAL FAILURE PATHS
INDNTSFLIJSA
3.41E-06
Page 56
IGNITER JOINT OPT CCF OF PRIMARY AND SECONDARY O-RINGS
ANRORCCLKLIJOPT
1.56E-05
THIOKOL
IGNITER JOINT OPT INDEPENDENT FAILURE PATHS
INDNTSFLIJOPT
8.50E-07
Page 57
IGNITER JOINT ROTOR CCF OF PRIMARY AND SECONDARY O-RINGS
ANRORCCLKLIJRTR
1.05E-05
THIOKOL
IGNITER JOINT ROTOR INDEPENDENT FAILURE PATHS
INDNTSFLIJRTR
3.34E-06
Page 58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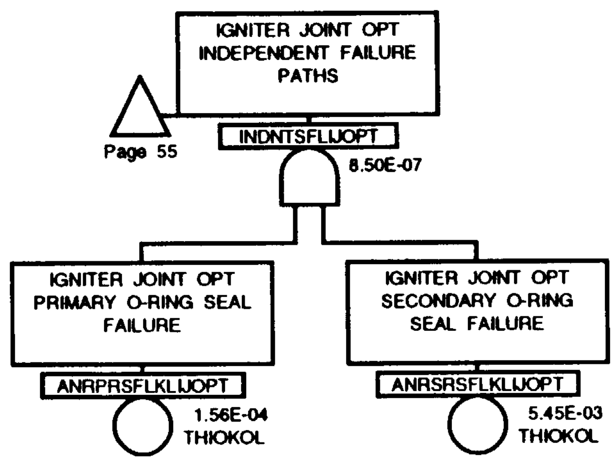
INDNTSFLIJSA
3.41E-06
Page 55
IGNITER JOINT S&A PRIMARY GASKET SEAL FAILURE
ANRPGSFLKLIJSA
1.05E-03
THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPATHLIJSA
3.25E-03
IGNITER JOINT S&A SECONDARY GASKET SEAL FAILURE
ANRSGSFLKLIJSA
2.64E-03
THIOKOL
IGNITER JOINT S&A LEAK CHECK PORT PLUG SEAL FAILURE
ANRCPSFLKLIJSA
6.10E-04
THIOKOL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INDNTSFLIJOPT
8.50E-07
Page 55
IGNITER JOINT OPT PRIMARY O-RING SEAL FAILURE
ANRPRSFLKLIJOPT
1.56E-04
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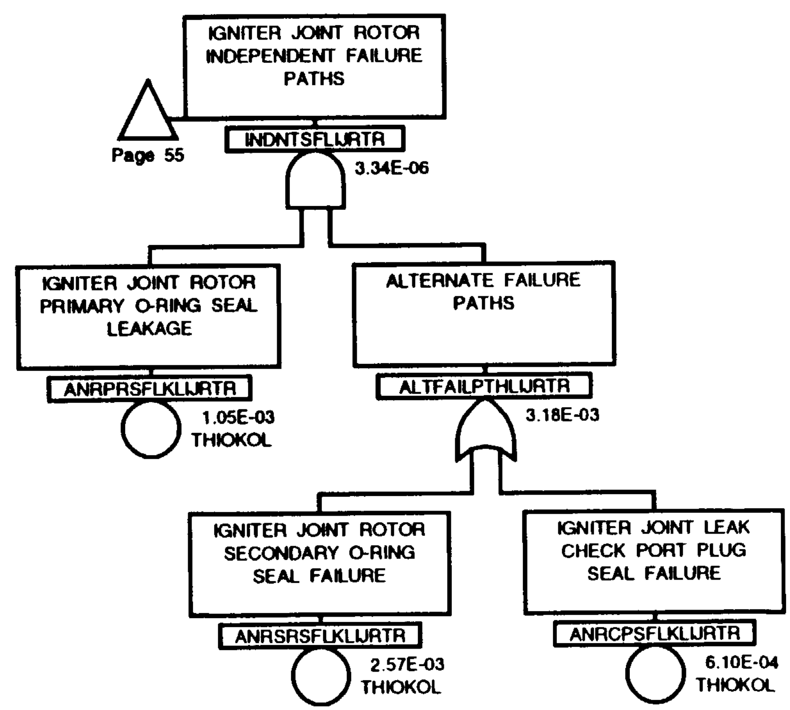
IGNITER JOINT OPT SECONDARY O-RING SEAL FAILURE
ANRSRSFLKLIJOPT
5.45E-03
THIOKOL


IGNITER JOINT ROTOR INDEPENDENT FAILURE PATHS
Page 55
INDNTSFLIJRTR
3.34E-06
IGNITER JOINT ROTOR PRIMARY O-RING SEAL LEAKAGE
ANRPRSFLKLIJRTR
1.05E-03
THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPTHLIJRTR
3.18E-03
IGNITER JOINT ROTOR SECONDARY O-RING SEAL FAILURE
ANRSRSFLKLIJRTR
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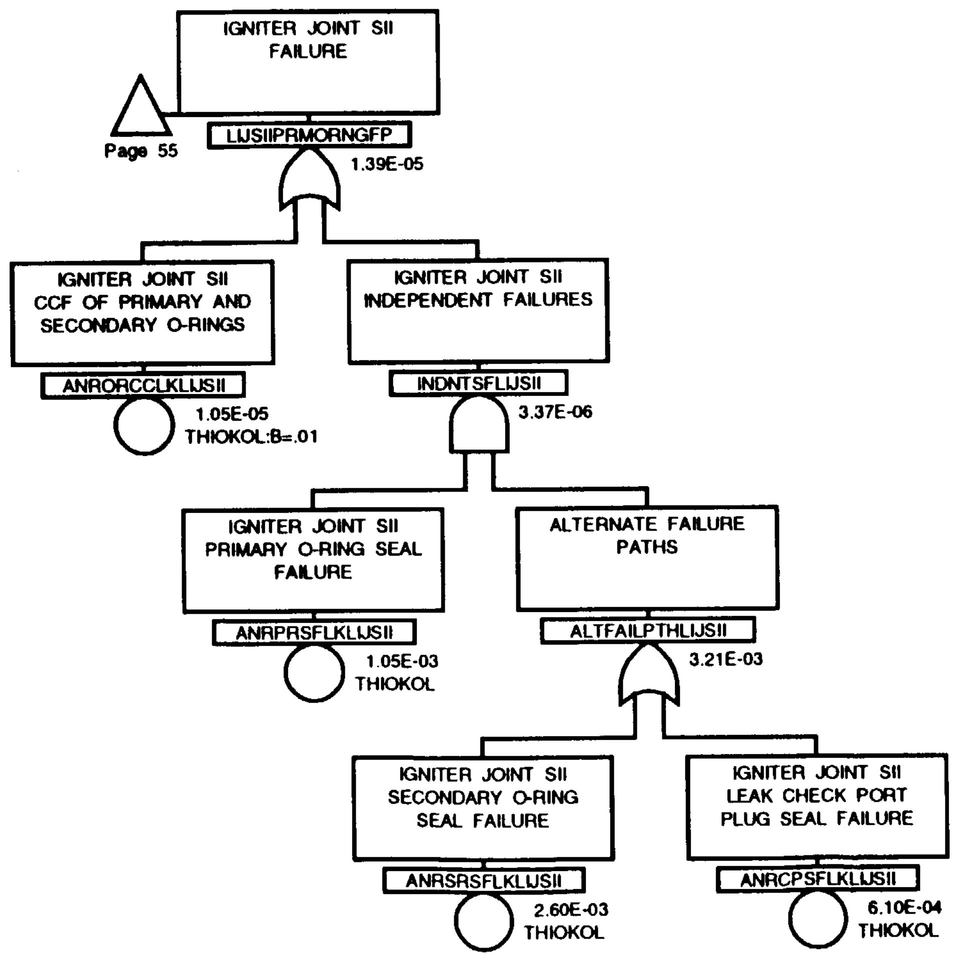
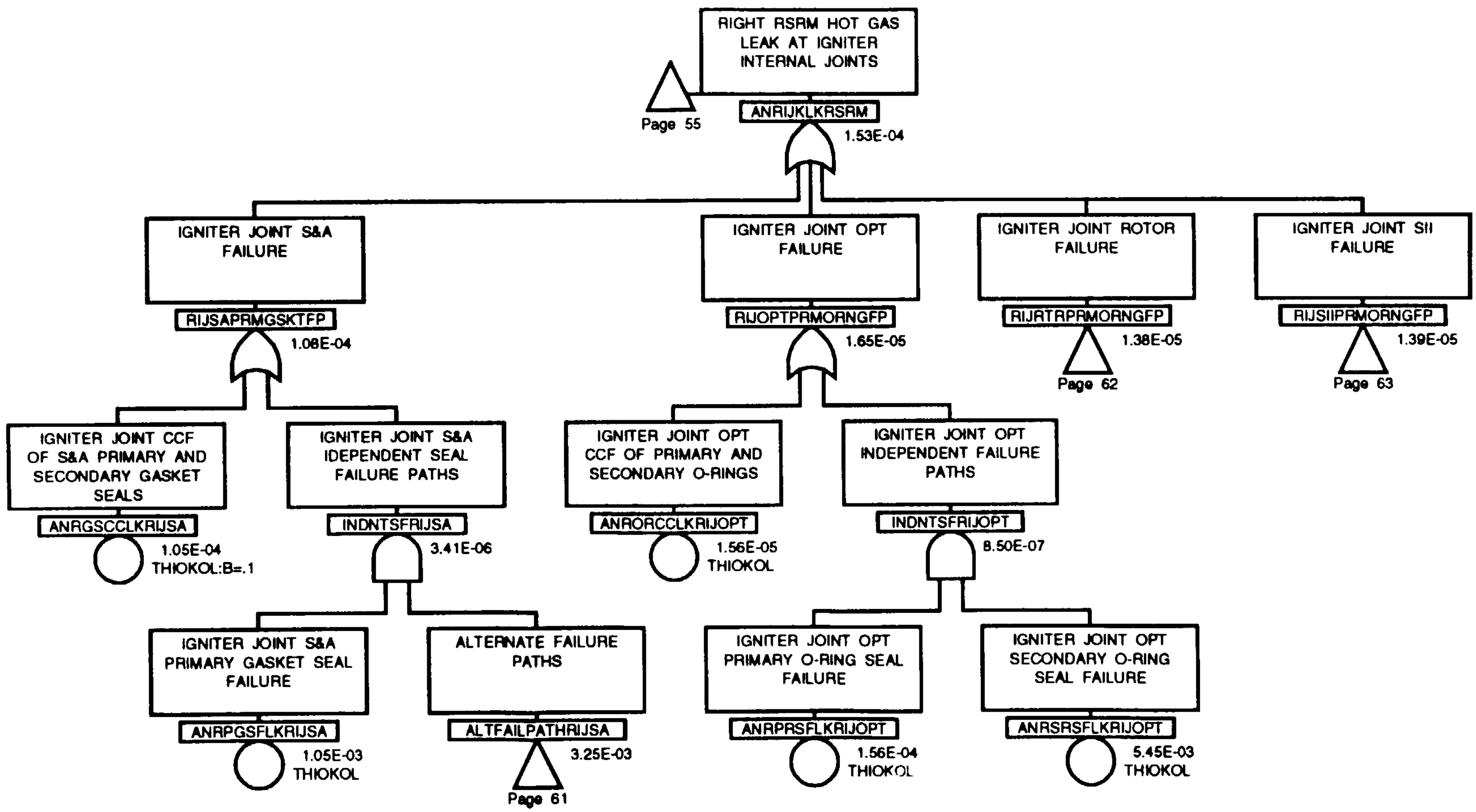
THIOKOL
IGNITER JOINT LEAK CHECK PORT PLUG SEAL FAILURE
ANRCPSFLKLIJRTR
6.10E-04
THIOKOL


IGNITER JOINT SII FAILURE
Page 55
LIJSIIPRMORNGFP
1.39E-05
IGNITER JOINT SII CCF OF PRIMARY AND SECONDARY O-RINGS
ANRORCCLKLIJSII
1.05E-05
THIOKOL:B=.01
IGNITER JOINT SII INDEPENDENT FAILURES
INDNTSFLIJSII
3.37E-06
IGNITER JOINT SII PRIMARY O-RING SEAL FAILURE
ANRPRSFLKLIJSII
1.05E-03
THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPTHLIJSII
3.21E-03
IGNITER JOINT SII SECONDARY O-RING SEAL FAILURE
ANRSRSFLKLIJSII
2.60E-03
THIOKOL
IGNITER JOINT SII LEAK CHECK PORT PLUG SEAL FAILURE
ANRCPSFLKLIJSII
6.10E-04
THIOKOL


RIGHT RSRM HOT GAS LEAK AT IGNITER INTERNAL JOINTS
ANRIJKLKRSRM
1.53E-04
Page 55
IGNITER JOINT S&A FAILURE
RIJSAPRMGSKTFP
1.08E-04
IGNITER JOINT OPT FAILURE
RIJOPTPRMORNGFP
1.65E-05
IGNITER JOINT ROTOR FAILURE
RIJRTRPRMORNGFP
1.38E-05
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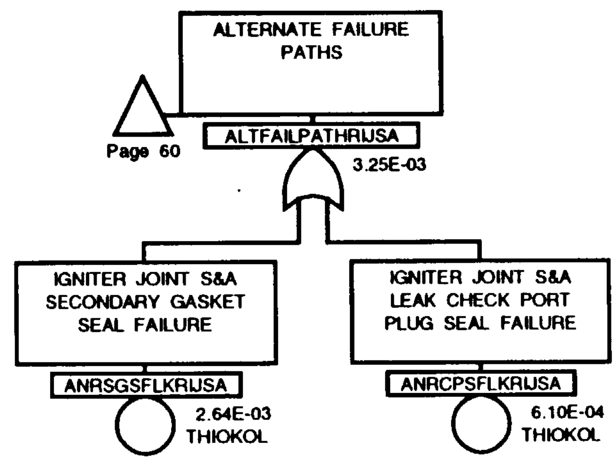
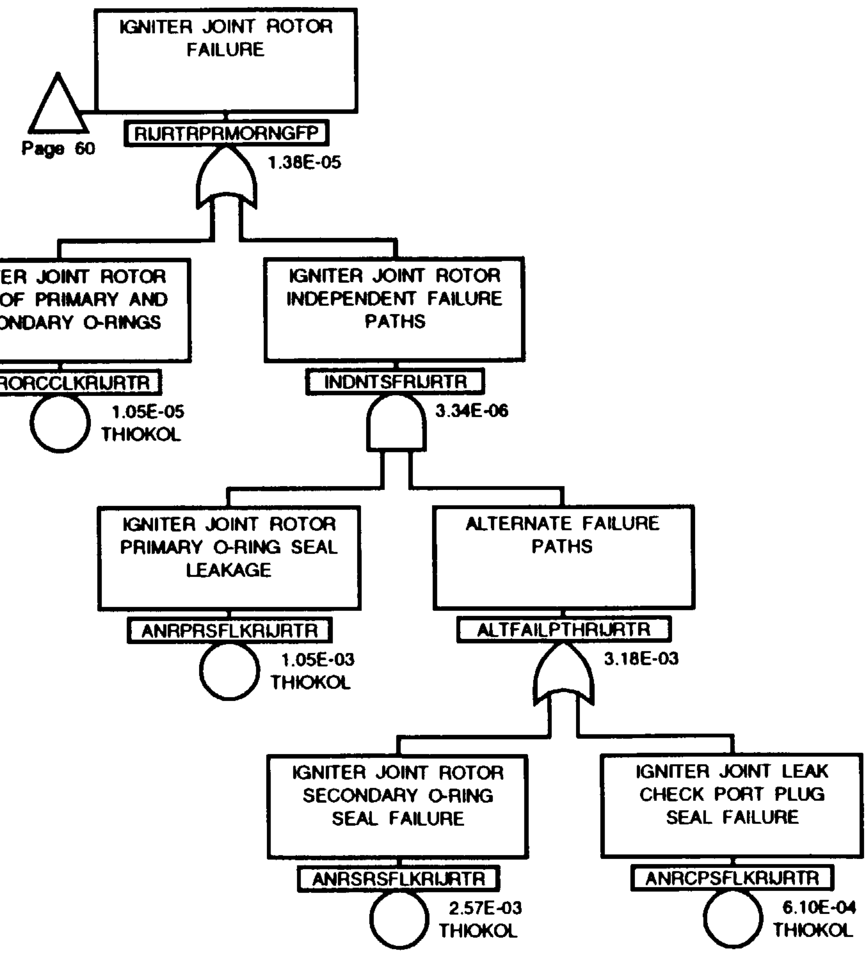
IGNITER JOINT SII FAILURE
RIJSIIPRMORNGFP
1.39E-05
Page 63
IGNITER JOINT CCF OF S&A PRIMARY AND SECONDARY GASKET SEALS
ANRGSCCLKRIJSA
1.05E-04
THIOKOL:B=.1
IGNITER JOINT S&A IDEPENDENT SEAL FAILURE PATHS
INDNTSFRIJSA
3.41E-06
IGNITER JOINT OPT CCF OF PRIMARY AND SECONDARY O-RINGS
ANRORCCLKRIJOPT
1.56E-05
THIOKOL
IGNITER JOINT OPT INDEPENDENT FAILURE PATHS
INDNTSFRIJOPT
8.50E-07
IGNITER JOINT S&A PRIMARY GASKET SEAL FAILURE
ANRPGSFLKRIJSA
1.05E-03
THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPATHRIJSA
3.25E-03
Page 61
IGNITER JOINT OPT PRIMARY O-RING SEAL FAILURE
ANRPRSFLKRIJOPT
1.56E-04
THIOKOL
IGNITER JOINT OPT SECONDARY O-RING SEAL FAILURE
ANRSRSFLKRIJOPT
5.45E-03
THIOKOL


ALTERNATE FAILURE PATHS
ALTFAILPATHRIJSA
3.25E-03
Page 60
IGNITER JOINT S&A SECONDARY GASKET SEAL FAILURE
ANRSGSFLKRIJSA
2.64E-03
THIOKOL
IGNITER JOINT S&A LEAK CHECK PORT PLUG SEAL FAILURE
ANRCPSFLKRIJSA
6.10E-04
THIOKOL


IGNITER JOINT ROTOR FAILURE
Page 60
RIJRTRPRMORNGFP
1.38E-05
IGNITER JOINT ROTOR CCF OF PRIMARY AND SECONDARY O-RINGS
ANRORCCLKRIJRTR
1.05E-05
THIOKOL
IGNITER JOINT ROTOR INDEPENDENT FAILURE PATHS
INDNTSFRIJRTR
3.34E-06
IGNITER JOINT ROTOR PRIMARY O-RING SEAL LEAKAGE
ANRPRSFLKRIJRTR
1.05E-03
THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPTHRIJRTR
3.18E-03
IGNITER JOINT ROTOR SECONDARY O-RING SEAL FAILURE
ANRSRSFLKRIJRTR
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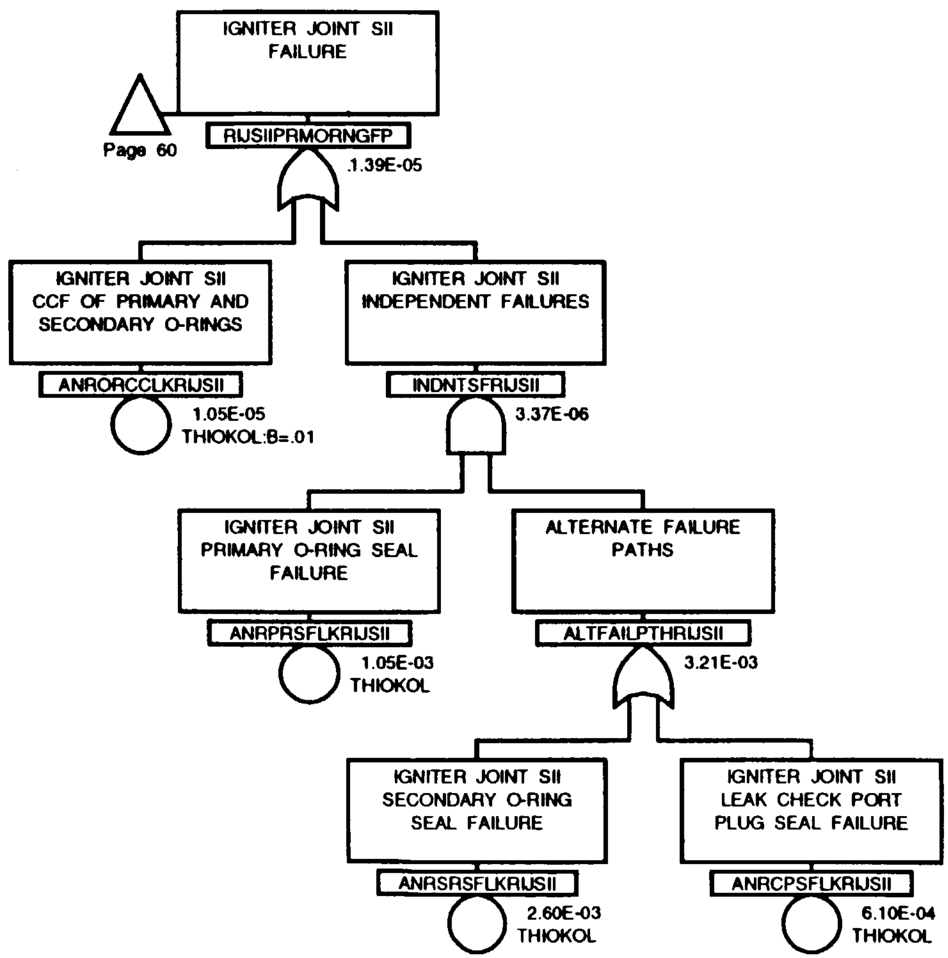
THIOKOL
IGNITER JOINT LEAK CHECK PORT PLUG SEAL FAILURE
ANRCPSFLKRIJRTR
6.10E-04
THIOKOL


IGNITER JOINT SII FAILURE
Page 60
RIJSIIPRMORNGFP
.1.39E-05
IGNITER JOINT SII CCF OF PRIMARY AND SECONDARY O-RINGS
ANRORCCLKRIJSII
1.05E-05
THIOKOL:B=.01
IGNITER JOINT SII INDEPENDENT FAILURES
INDNTSFRIJSII
3.37E-06
IGNITER JOINT SII PRIMARY O-RING SEAL FAILURE
ANRPRSFLKRIJSII
1.05E-03
THIOKOL
ALTERNATE FAILURE PATHS
ALTFAILPTHRIJSII
3.21E-03
IGNITER JOINT SII SECONDARY O-RING SEAL FAILURE
ANRSRSFLKRIJSII
2.60E-03
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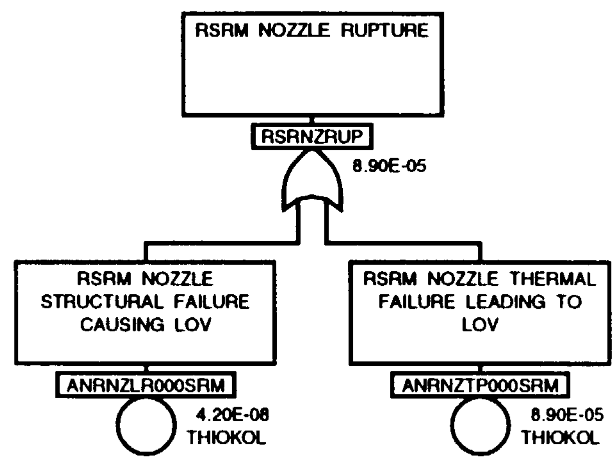
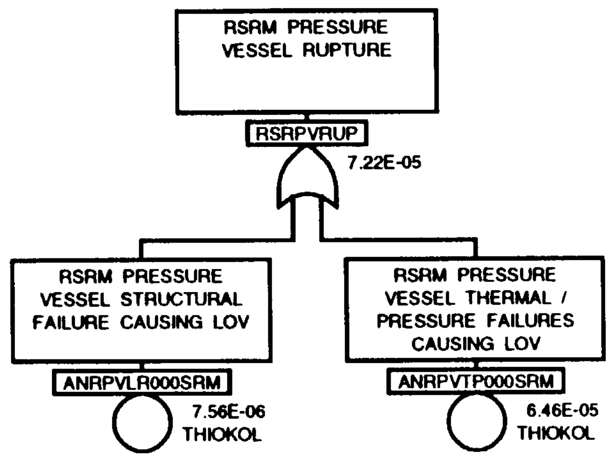
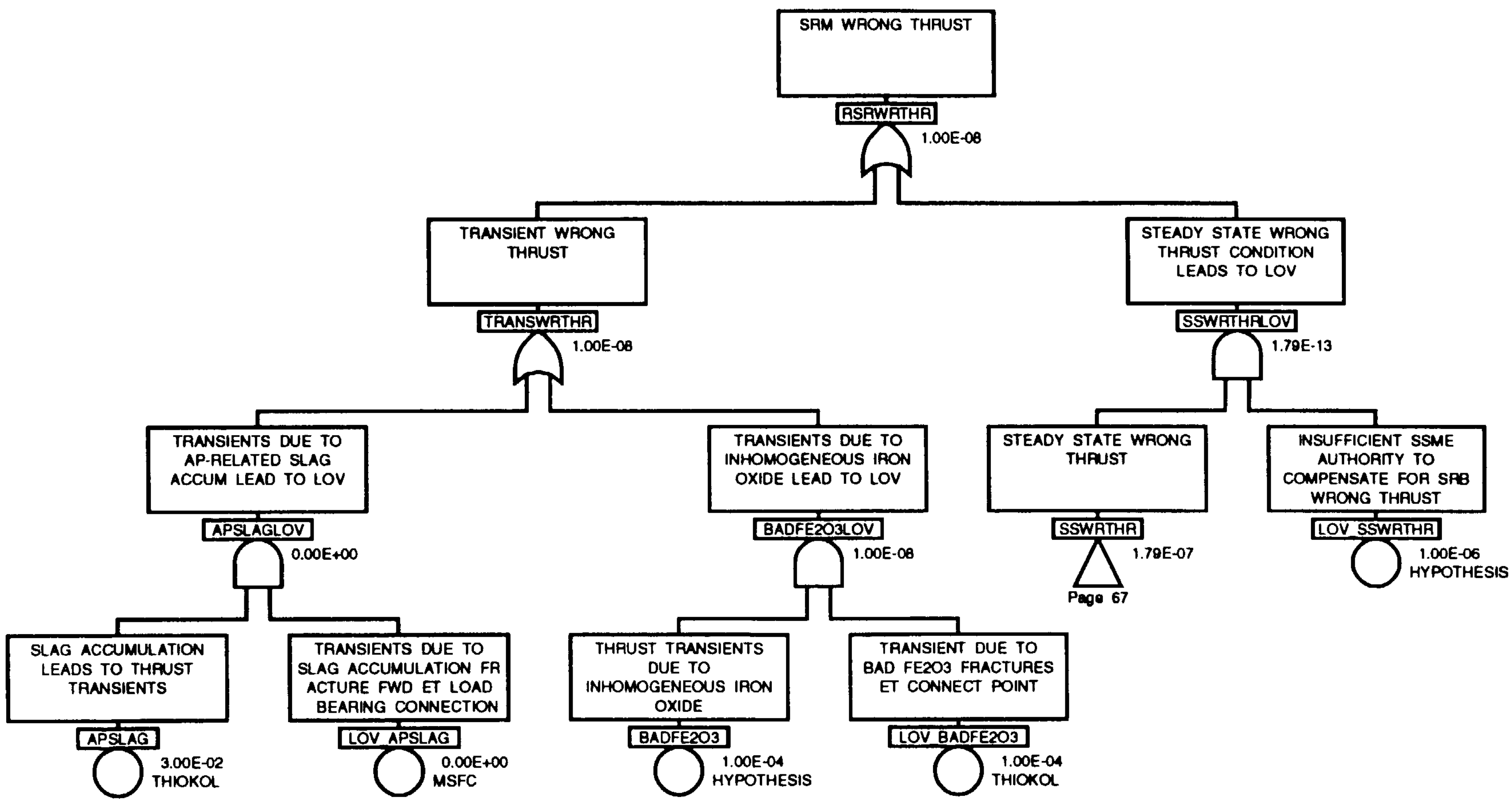
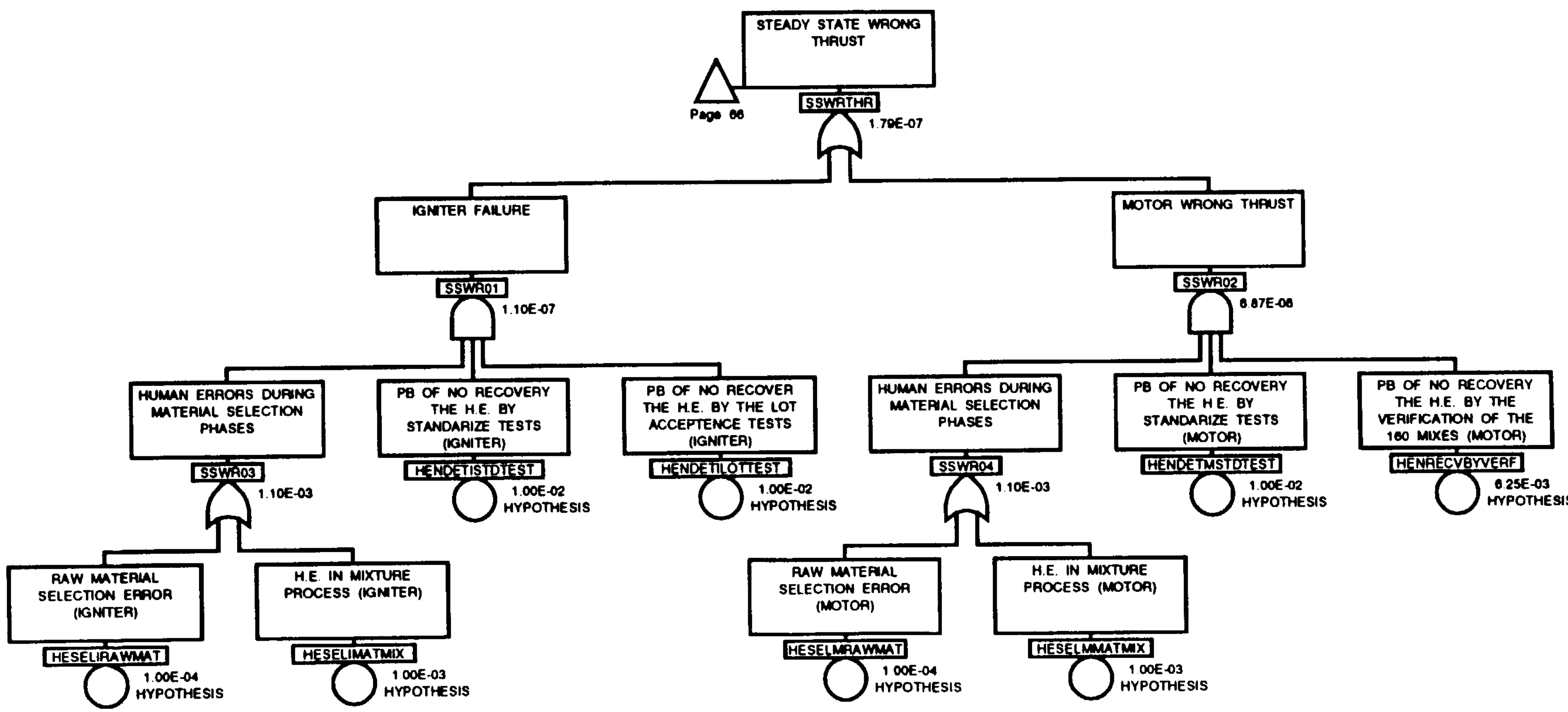
IGNITER JOINT SII LEAK CHECK PORT PLUG SEAL FAILURE
ANRCPSFLKRIJSII
6.10E-04
THIOKOL


RSRM NOZZLE RUPTURE
RSRNZRUP
8.90E-05
RSRM NOZZLE STRUCTURAL FAILURE CAUSING LOV
ANRNZLR000SRM
4.20E-08
THIOKOL
RSRM NOZZLE THERMAL FAILURE LEADING TO LOV
ANRNZTP000SRM
8.90E-05
THIOKOL


RSRM PRESSURE VESSEL RUPTURE
RSRPVRUP
7.22E-05
RSRM PRESSURE VESSEL STRUCTURAL FAILURE CAUSING LOV
ANRPVLR000SRM
7.56E-06
THIOKOL
RSRM PRESSURE VESSEL THERMAL / PRESSURE FAILURES CAUSING LOV
ANRPVTP000SRM
6.46E-05
THIOKOL


SRM WRONG THRUST
RSRWRTHR
1.00E-08
TRANSIENT WRONG THRUST
TRANSWRTHR
1.00E-08
STEADY STATE WRONG THRUST CONDITION LEADS TO LOV
SSWRTHRLOV
1.79E-13
TRANSIENTS DUE TO AP-RELATED SLAG ACCUM LEAD TO LOV
APSLAGLOV
0.00E+00
TRANSIENTS DUE TO INHOMOGENEOUS IRON OXIDE LEAD TO LOV
BADFE2O3LOV
1.00E-08
STEADY STATE WRONG THRUST
SSWRTHR
1.79E-07
Page 67
INSUFFICIENT SSME AUTHORITY TO COMPENSATE FOR SRB WRONG THRUST
LOV SSWRTHR
1.00E-06
HYPOTHESIS
SLAG ACCUMULATION LEADS TO THRUST TRANSIENTS
APSLAG
3.00E-02
THIOKOL
TRANSIENTS DUE TO SLAG ACCUMULATION FR ACTURE FWD ET LOAD BEARING CONNECTION
LOV APSLAG
0.00E+00
MSFC
THRUST TRANSIENTS DUE TO INHOMOGENEOUS IRON OXIDE
BADFE2O3
1.00E-04
HYPOTHESIS
TRANSIENT DUE TO BAD FE2O3 FRACTURES ET CONNECT POINT
LOV BADFE2O3
1.00E-04
THIOKOL



STEADY STATE WRONG THRUST
Page 66
SSWRTHR
1.79E-07
IGNITER FAILURE
SSWR01
1.10E-07
MOTOR WRONG THRUST
SSWR02
6.87E-06
HUMAN ERRORS DURING MATERIAL SELECTION PHASES
SSWR03
1.10E-03
PB OF NO RECOVERY THE H.E. BY STANDARIZE TESTS (IGNITER)
HENDETISTDTEST
1.00E-02
HYPOTHESIS
PB OF NO RECOVER THE H.E. BY THE LOT ACCEPTENCE TESTS (IGNITER)
HENDETILOTTEST
1.00E-02
HYPOTHESIS
HUMAN ERRORS DURING MATERIAL SELECTION PHASES
SSWR04
1.10E-03
PB OF NO RECOVERY THE H.E. BY STANDARIZE TESTS (MOTOR)
HENDETMSTDTEST
1.00E-02
HYPOTHESIS
PB OF NO RECOVERY THE H.E. BY THE VERIFICATION OF THE 160 MIXES (MOTOR)
HENRECVBYVERF
6.25E-03
HYPOTHESIS
RAW MATERIAL SELECTION ERROR (IGNITER)
HESELIRAWMAT
1.00E-04
HYPOTHESIS
H.E. IN MIXTURE PROCESS (IGNITER)
HESELIMATMIX
1.00E-03
HYPOTHESIS
RAW MATERIAL SELECTION ERROR (MOTOR)
HESELMRAWMAT
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H.E. IN MIXTURE PROCESS (MOTOR)
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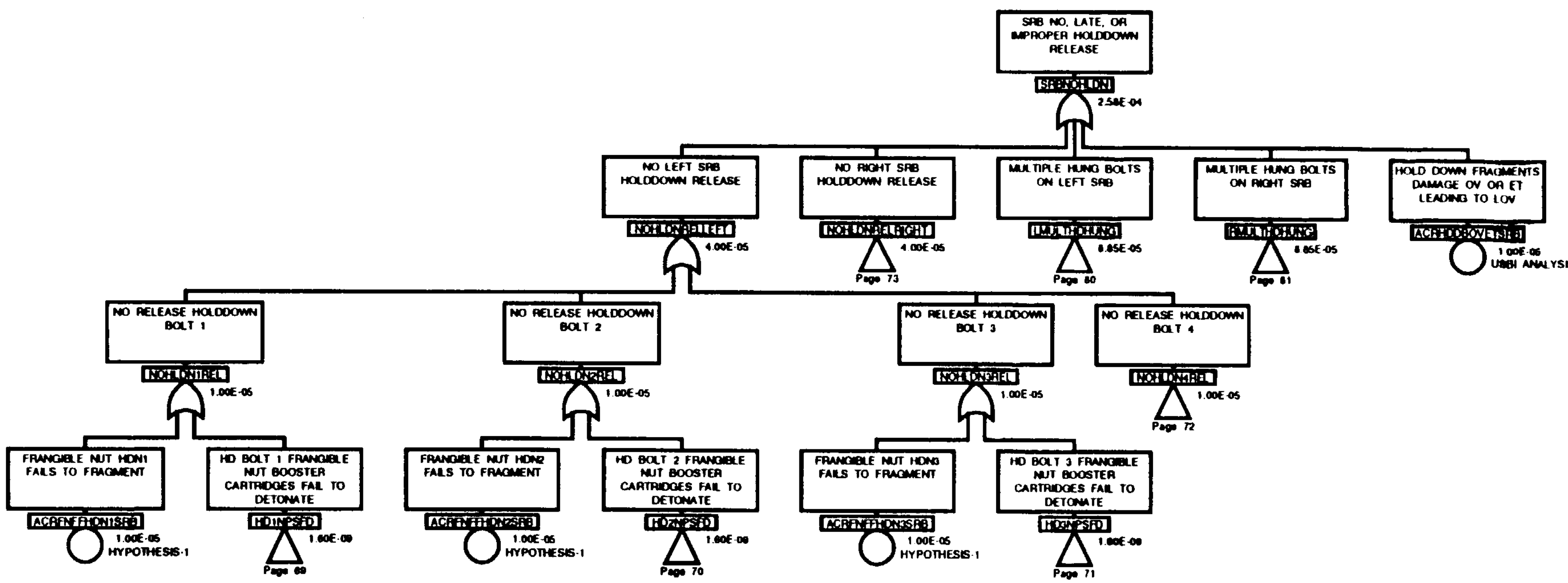
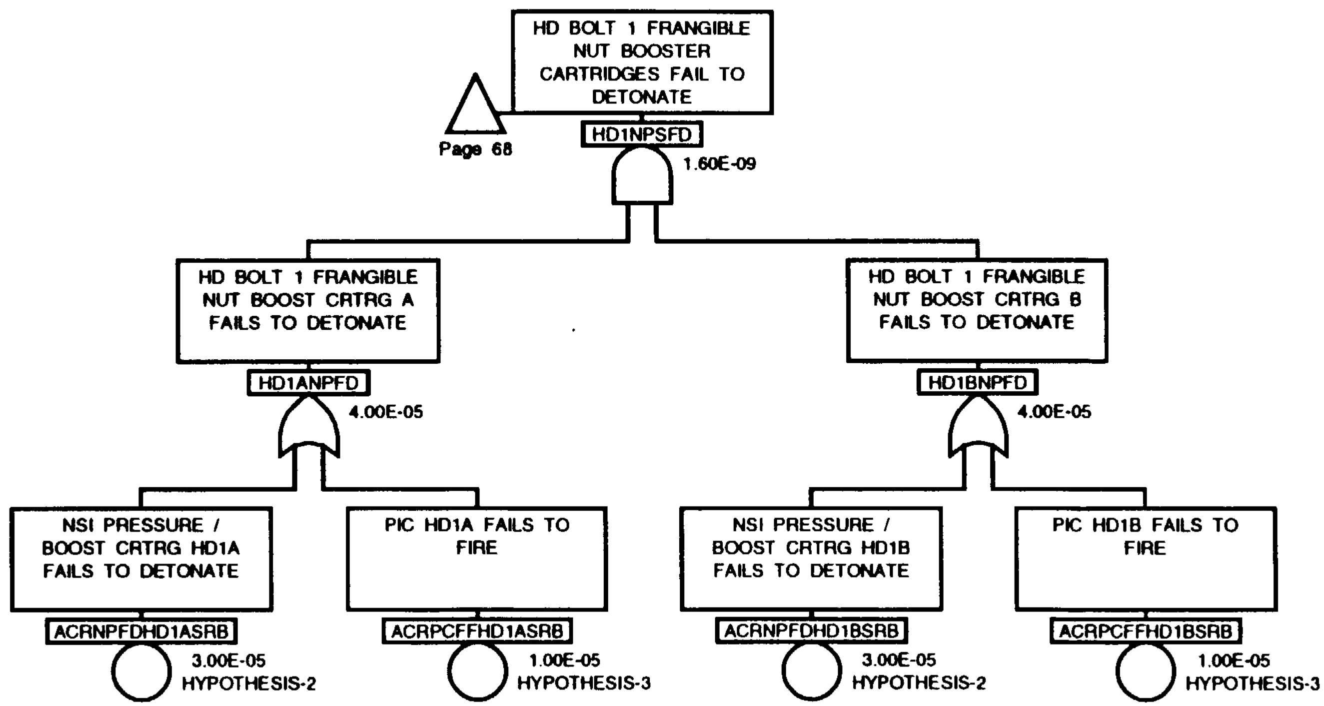
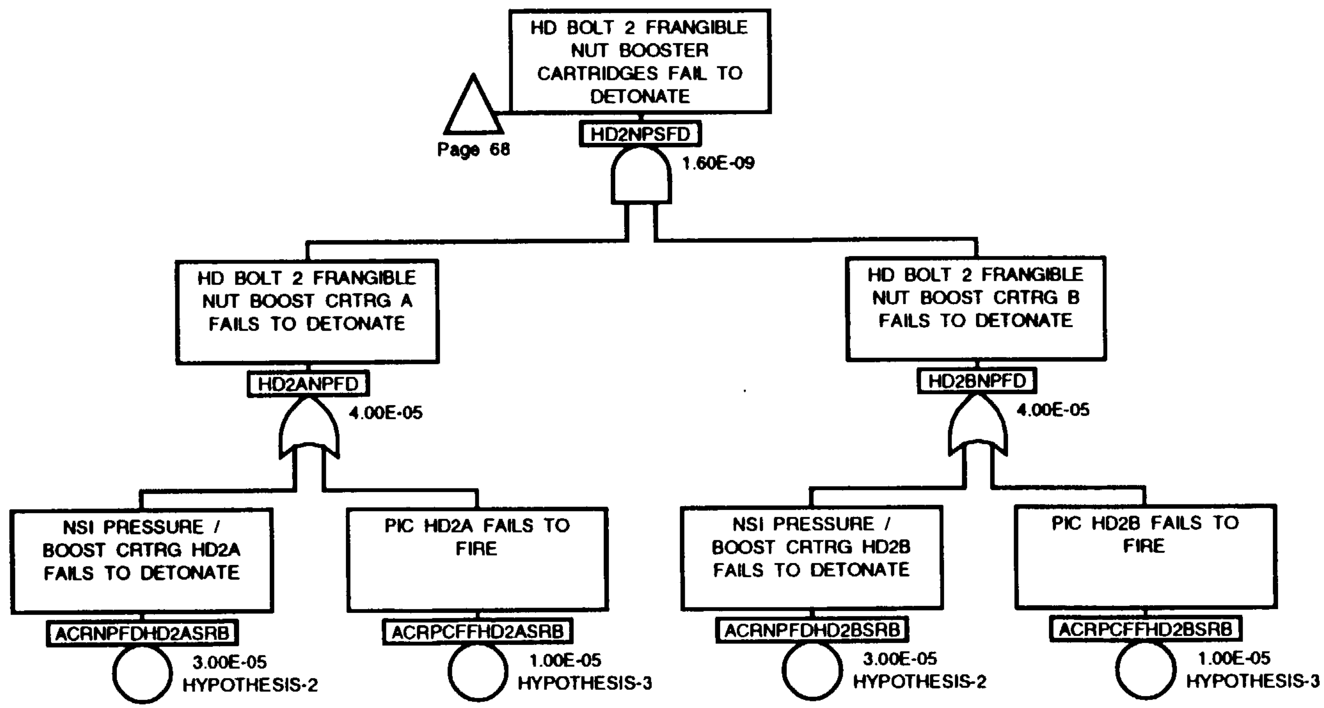
HYPOTHESIS


SRB NO, LATE, OR IMPROPER HOLDDOWN RELEASE
SRBNOHLDN
2.58E-04
NO LEFT SRB HOLDDOWN RELEASE
NOHLDNRELLEFT
4.00E-05
NO RIGHT SRB HOLDDOWN RELEASE
NOHLDNRELRIGHT
4.00E-05
Page 73
MULTIPLE HUNG BOLTS ON LEFT SRB
LMULTHDHUNG
8.85E-05
Page 80
MULTIPLE HUNG BOLTS ON RIGHT SRB
RMULTHDHUNG
8.85E-05
Page 81
HOLD DOWN FRAGMENTS DAMAGE OV OR ET LEADING TO LOV
ACRHDDBOVETSRB
1.00E-06
USBI ANALYSIS
NO RELEASE HOLDDOWN BOLT 1
NOHLDN1REL
1.00E-05
NO RELEASE HOLDDOWN BOLT 2
NOHLDN2REL
1.00E-05
NO RELEASE HOLDDOWN BOLT 3
NOHLDN3REL
1.00E-05
NO RELEASE HOLDDOWN BOLT 4
NOHLDN4REL
1.00E-05
Page 72
FRANGIBLE NUT HDN1 FAILS TO FRAGMENT
ACRFNFFHDN1SRB
1.00E-05
HYPOTHESIS-1
HD BOLT 1 FRANGIBLE NUT BOOSTER CARTRIDGES FAIL TO DETONATE
HD1NPSFD
Page 69
FRANGIBLE NUT HDN2 FAILS TO FRAGMENT
ACRFNFFHDN2SRB
1.00E-05
HYPOTHESIS-1
HD BOLT 2 FRANGIBLE NUT BOOSTER CARTRIDGES FAIL TO DETONATE
HD2NPSFD
Page 70
FRANGIBLE NUT HDN3 FAILS TO FRAGMENT
ACRFNFFHDN3SRB
1.00E-05
HYPOTHESIS-1
HD BOLT 3 FRANGIBLE NUT BOOSTER CARTRIDGES FAIL TO DETONATE
HD3NPSFD
Page 71


HD BOLT 1 FRANGIBLE NUT BOOSTER CARTRIDGES FAIL TO DETONATE
HD1NPSFD
1.60E-09
Page 68
HD BOLT 1 FRANGIBLE NUT BOOST CRTRG A FAILS TO DETONATE
HD1ANPFD
4.00E-05
HD BOLT 1 FRANGIBLE NUT BOOST CRTRG B FAILS TO DETONATE
HD1BNPFD
4.00E-05
NSI PRESSURE / BOOST CRTRG HD1A FAILS TO DETONATE
ACRNPFDHD1ASRB
3.00E-05
HYPOTHESIS-2
PIC HD1A FAILS TO FIRE
ACRPCFFHD1ASRB
1.00E-05
HYPOTHESIS-3
NSI PRESSURE / BOOST CRTRG HD1B FAILS TO DETONATE
ACRNPFDHD1BSRB
3.00E-05
HYPOTHESIS-2
PIC HD1B FAILS TO FIRE
ACRPCFFHD1BSRB
1.00E-05
HYPOTHESIS-3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HD2NPSFD
1.60E-09
Page 68
HD BOLT 2 FRANGIBLE NUT BOOST CRTRG A FAILS TO DETONATE
HD2ANPFD
4.00E-05
HD BOLT 2 FRANGIBLE NUT BOOST CRTRG B FAILS TO DETONATE
HD2BNPFD
4.00E-05
NSI PRESSURE / BOOST CRTRG HD2A FAILS TO DETONATE
ACRNPFDHD2ASRB
3.00E-05
HYPOTHESIS-2
PIC HD2A FAILS TO FIRE
ACRPCFFHD2ASRB
1.00E-05
HYPOTHESIS-3
NSI PRESSURE / BOOST CRTRG HD2B FAILS TO DETONATE
ACRNPFDHD2BSRB
3.00E-05
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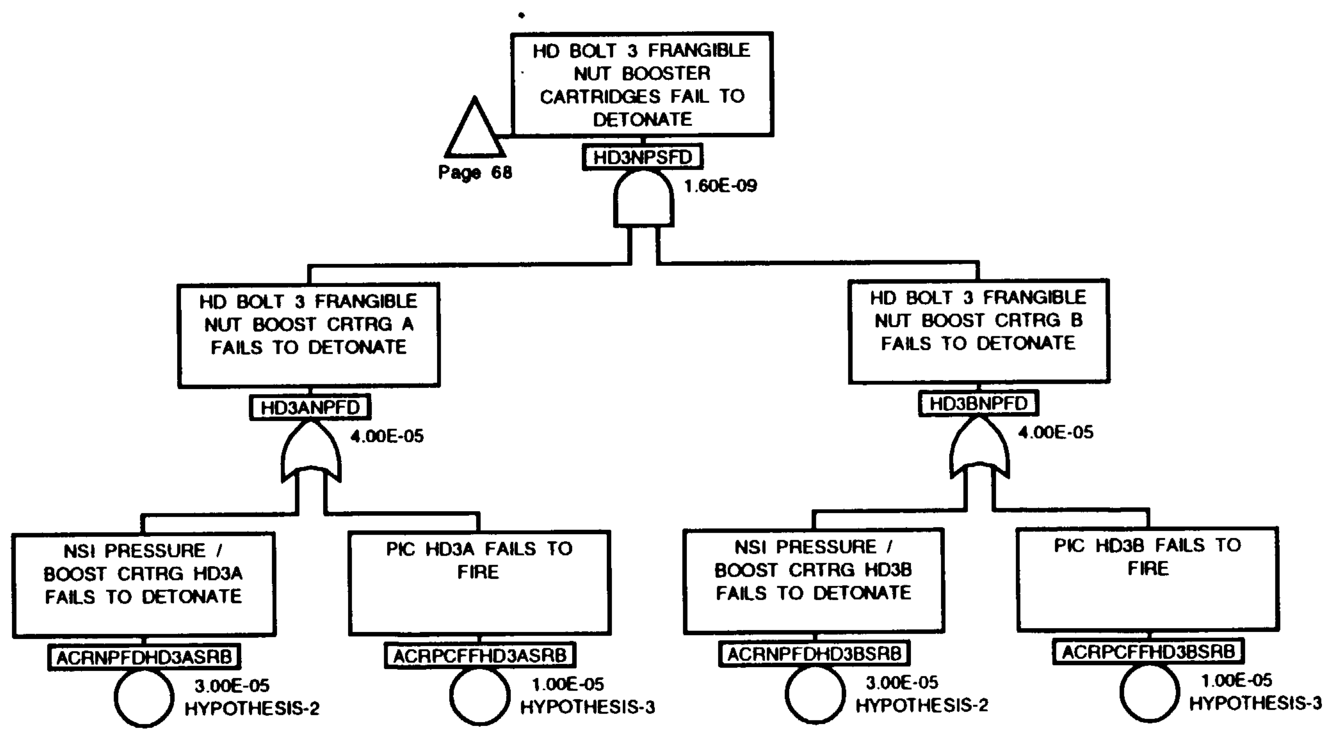
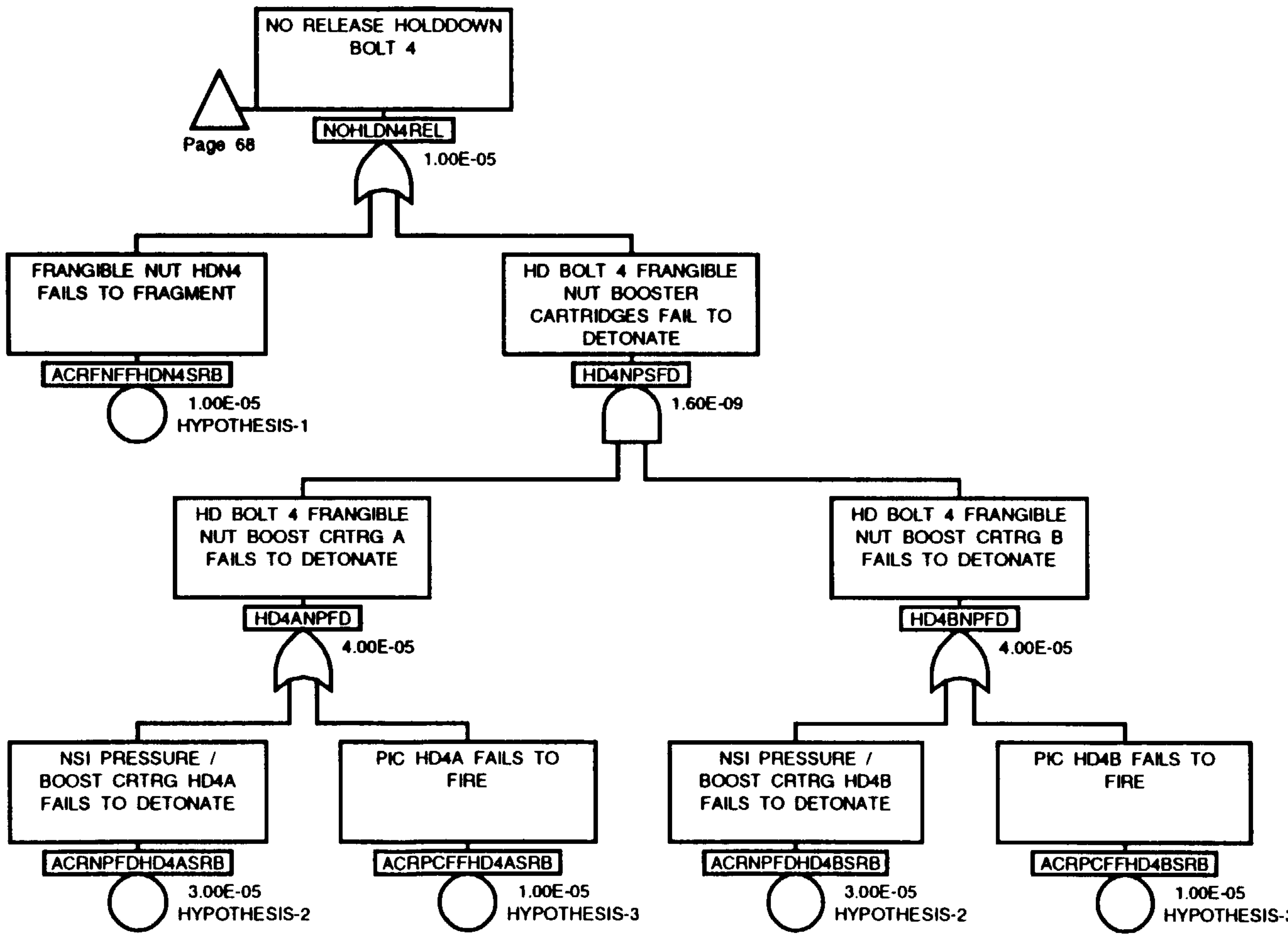
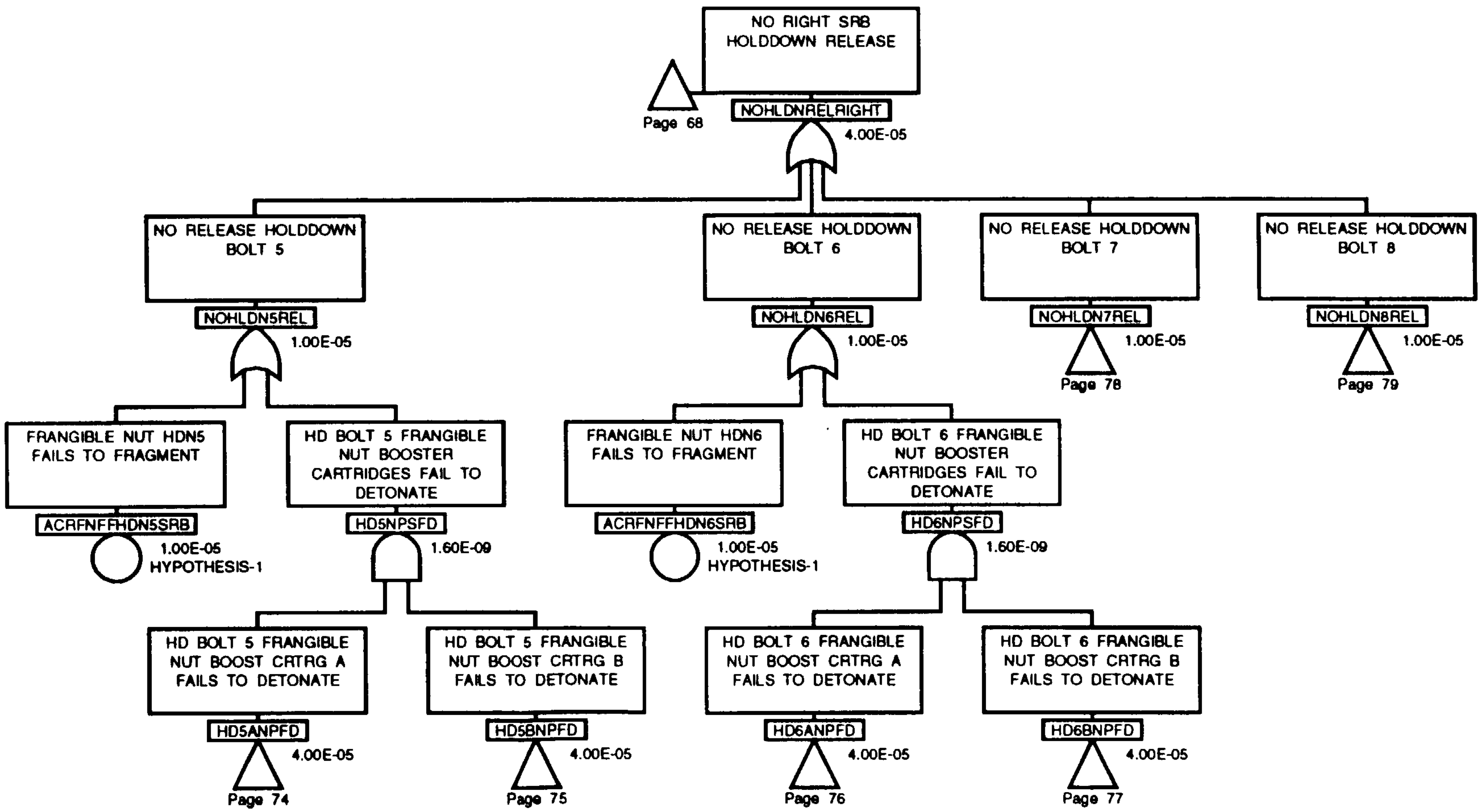
PIC HD2B FAILS TO FIRE
ACRPCFFHD2BSRB
1.00E-05
HYPOTHESIS-3


HD BOLT 3 FRANGIBLE NUT BOOSTER CARTRIDGES FAIL TO DETONATE
HD3NPSFD
1.60E-09
Page 68
HD BOLT 3 FRANGIBLE NUT BOOST CRTRG A FAILS TO DETONATE
HD3ANPFD
4.00E-05
HD BOLT 3 FRANGIBLE NUT BOOST CRTRG B FAILS TO DETONATE
HD3BNPFD
4.00E-05
NSI PRESSURE / BOOST CRTRG HD3A FAILS TO DETONATE
ACRNPFDHD3ASRB
3.00E-05
HYPOTHESIS-2
PIC HD3A FAILS TO FIRE
ACRPCFFHD3ASRB
1.00E-05
HYPOTHESIS-3
NSI PRESSURE / BOOST CRTRG HD3B FAILS TO DETONATE
ACRNPFDHD3BSRB
3.00E-05
HYPOTHESIS-2
PIC HD3B FAILS TO FIRE
ACRPCFFHD3BSRB
1.00E-05
HYPOTHESIS-3



NO RELEASE HOLDDOWN BOLT 4
Page 68
NOHLDN4REL
1.00E-05
FRANGIBLE NUT HDN4 FAILS TO FRAGMENT
ACRFNFFHDN4SRB
1.00E-05
HYPOTHESIS-1
HD BOLT 4 FRANGIBLE NUT BOOSTER CARTRIDGES FAIL TO DETONATE
HD4NPSFD
1.60E-09
HD BOLT 4 FRANGIBLE NUT BOOST CRTRG A FAILS TO DETONATE
HD4ANPFD
4.00E-05
HD BOLT 4 FRANGIBLE NUT BOOST CRTRG B FAILS TO DETONATE
HD4BNPFD
4.00E-05
NSI PRESSURE / BOOST CRTRG HD4A FAILS TO DETONATE
ACRNPFDHD4ASRB
3.00E-05
HYPOTHESIS-2
PIC HD4A FAILS TO FIRE
ACRPCFFHD4ASRB
1.00E-05
HYPOTHESIS-3
NSI PRESSURE / BOOST CRTRG HD4B FAILS TO DETONATE
ACRNPFDHD4BSRB
3.00E-05
HYPOTHESIS-2
PIC HD4B FAILS TO FIRE
ACRPCFFHD4BSRB
1.00E-05
HYPOTHESIS-3


NO RIGHT SRB HOLDDOWN RELEASE
NOHLDNRELRIGHT
4.00E-05
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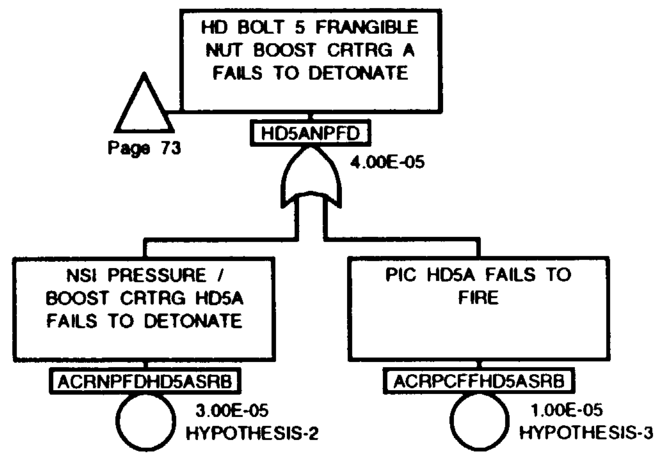
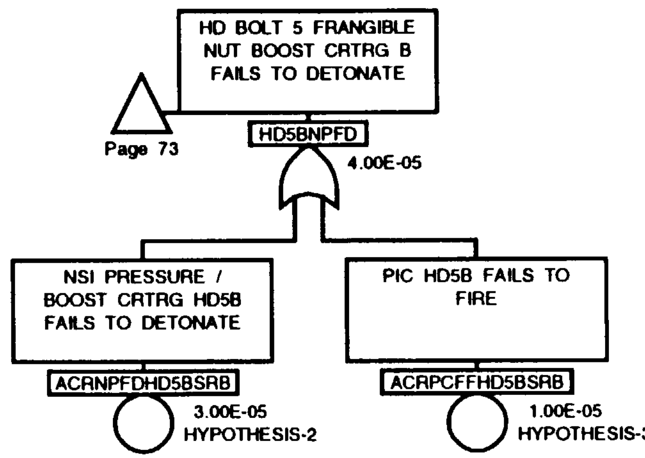
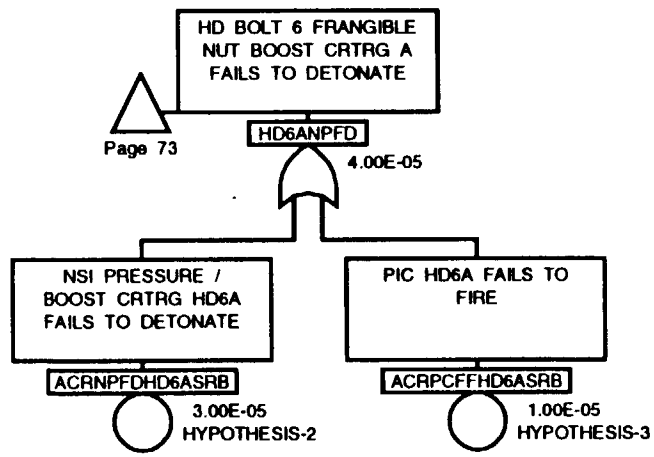
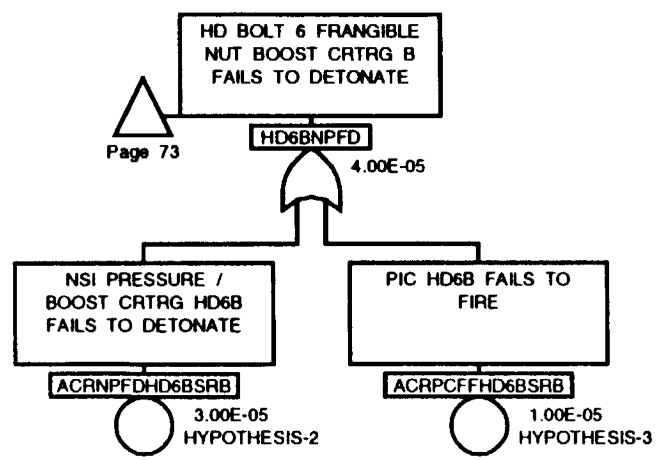
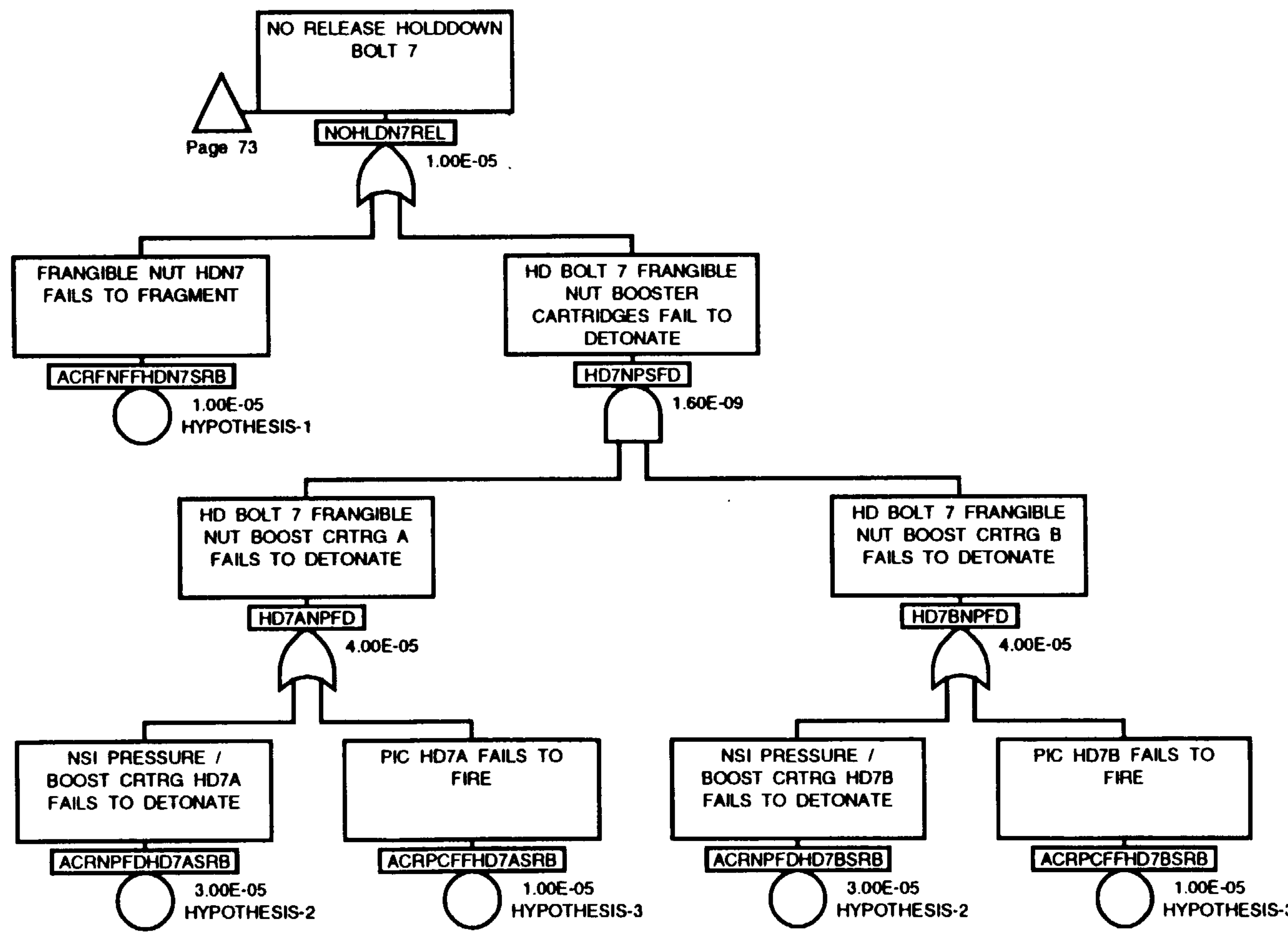
NO RELEASE HOLDDOWN BOLT 5
NOHLDN5REL
1.00E-05
NO RELEASE HOLDDOWN BOLT 6
NOHLDN6REL
1.00E-05
NO RELEASE HOLDDOWN BOLT 7
NOHLDN7REL
1.00E-05
Page 78
NO RELEASE HOLDDOWN BOLT 8
NOHLDN8REL
1.00E-05
Page 79
FRANGIBLE NUT HDN5 FAILS TO FRAGMENT
ACRFNFFHDN5SRB
1.00E-05
HYPOTHESIS-1
HD BOLT 5 FRANGIBLE NUT BOOSTER CARTRIDGES FAIL TO DETONATE
HD5NPSFD
1.60E-09
FRANGIBLE NUT HDN6 FAILS TO FRAGMENT
ACRFNFFHDN6SRB
1.00E-05
HYPOTHESIS-1
HD BOLT 6 FRANGIBLE NUT BOOSTER CARTRIDGES FAIL TO DETONATE
HD6NPSFD
1.60E-09
HD BOLT 5 FRANGIBLE NUT BOOST CRTRG A FAILS TO DETONATE
HD5ANPFD
4.00E-05
Page 74
HD BOLT 5 FRANGIBLE NUT BOOST CRTRG B FAILS TO DETONATE
HD5BNPFD
4.00E-05
Page 75
HD BOLT 6 FRANGIBLE NUT BOOST CRTRG A FAILS TO DETONATE
HD6ANPFD
4.00E-05
Page 76
HD BOLT 6 FRANGIBLE NUT BOOST CRTRG B FAILS TO DETONATE
HD6BNPFD
4.00E-05
Page 77

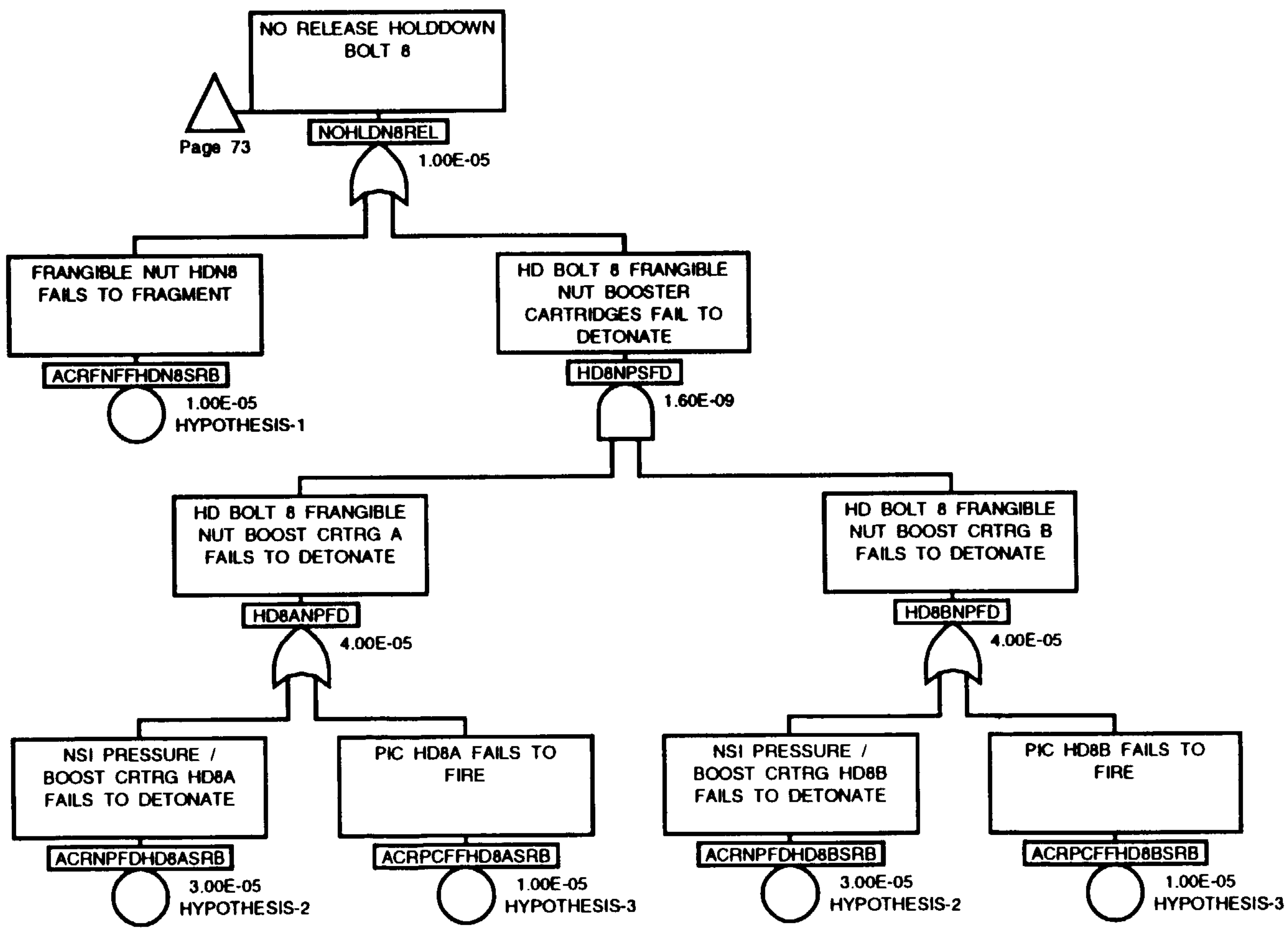

HD BOLT 5 FRANGIBLE NUT BOOST CRTRG A FAILS TO DETONATE
HD5ANPFD
4.00E-05
Page 73
NSI PRESSURE / BOOST CRTRG HD5A FAILS TO DETONATE
ACRNPFDHD5ASRB
3.00E-05
HYPOTHESIS-2
PIC HD5A FAILS TO FIRE
ACRPCFFHD5ASRB
1.00E-05
HYPOTHESIS-3

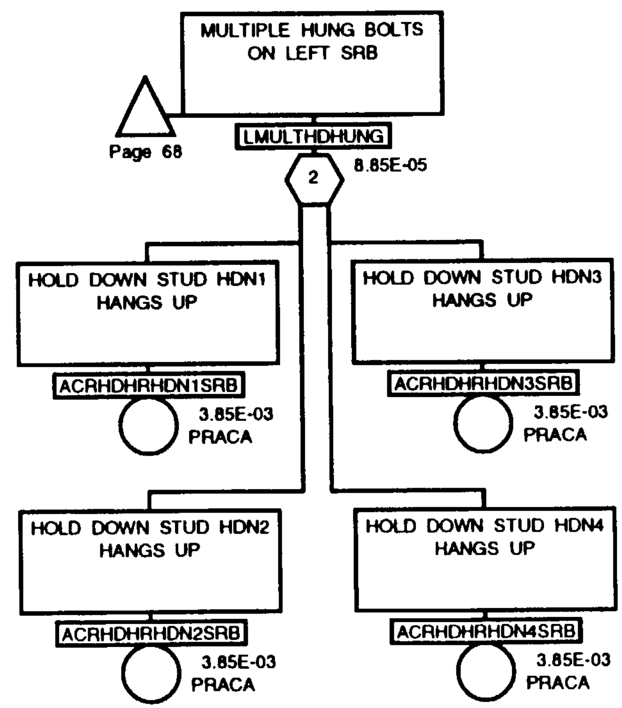

HD BOLT 5 FRANGIBLE NUT BOOST CRTRG B FAILS TO DETONATE
HD5BNPFD
4.00E-05
Page 73
NSI PRESSURE / BOOST CRTRG HD5B FAILS TO DETONATE
ACRNPFDHD5BSRB
3.00E-05
HYPOTHESIS-2
PIC HD5B FAILS TO FIRE
ACRPCFFHD5BSRB
1.00E-05
HYPOTHESIS-3

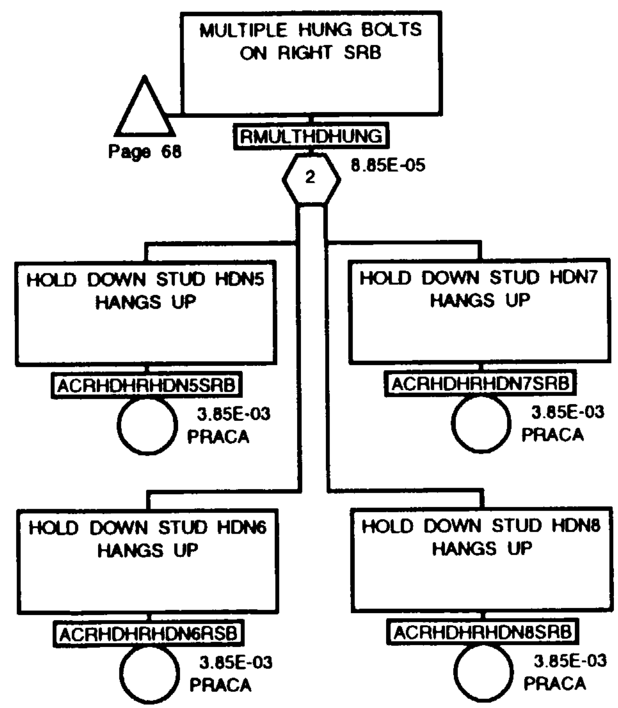

HD BOLT 6 FRANGIBLE NUT BOOST CRTRG A FAILS TO DETONATE
HD6ANPFD
4.00E-05
Page 73
NSI PRESSURE / BOOST CRTRG HD6A FAILS TO DETONATE
ACRNPFDHD6ASRB
3.00E-05
HYPOTHESIS-2
PIC HD6A FAILS TO FIRE
ACRPCFFHD6ASRB
1.00E-05
HYPOTHESIS-3

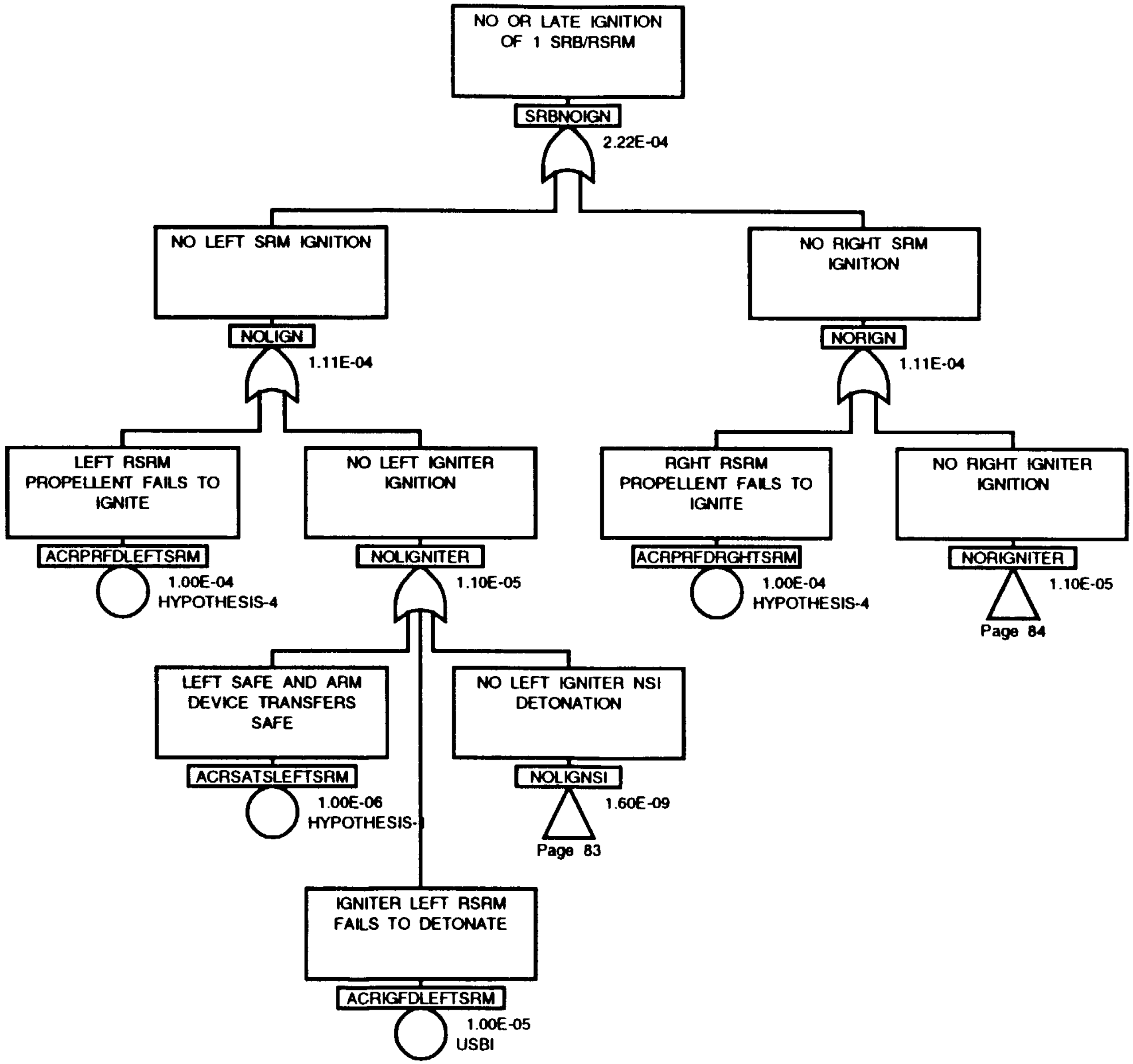

HD BOLT 6 FRANGIBLE NUT BOOST CRTRG B FAILS TO DETONATE
Page 73
HD6BNPFD
4.00E-05
NSI PRESSURE / BOOST CRTRG HD6B FAILS TO DETONATE
ACRNPFDHD6BSRB
3.00E-05
HYPOTHESIS-2
PIC HD6B FAILS TO FIRE
ACRPCFFHD6BSRB
1.00E-05
HYPOTHESIS-3


NO RELEASE HOLDDOWN BOLT 7
Page 73
NOHLDN7REL
1.00E-05
FRANGIBLE NUT HDN7 FAILS TO FRAGMENT
ACRFNFFHDN7SRB
1.00E-05
HYPOTHESIS-1
HD BOLT 7 FRANGIBLE NUT BOOSTER CARTRIDGES FAIL TO DETONATE
HD7NPSFD
1.60E-09
HD BOLT 7 FRANGIBLE NUT BOOST CRTRG A FAILS TO DETONATE
HD7ANPFD
4.00E-05
HD BOLT 7 FRANGIBLE NUT BOOST CRTRG B FAILS TO DETONATE
HD7BNPFD
4.00E-05
NSI PRESSURE / BOOST CRTRG HD7A FAILS TO DETONATE
ACRNPFDHD7ASRB
3.00E-05
HYPOTHESIS-2
PIC HD7A FAILS TO FIRE
ACRPCFFHD7ASRB
1.00E-05
HYPOTHESIS-3
NSI PRESSURE / BOOST CRTRG HD7B FAILS TO DETONATE
ACRNPFDHD7BSRB
3.00E-05
HYPOTHESIS-2
PIC HD7B FAILS TO FIRE
ACRPCFFHD7BSRB
1.00E-05
HYPOTHESIS-3

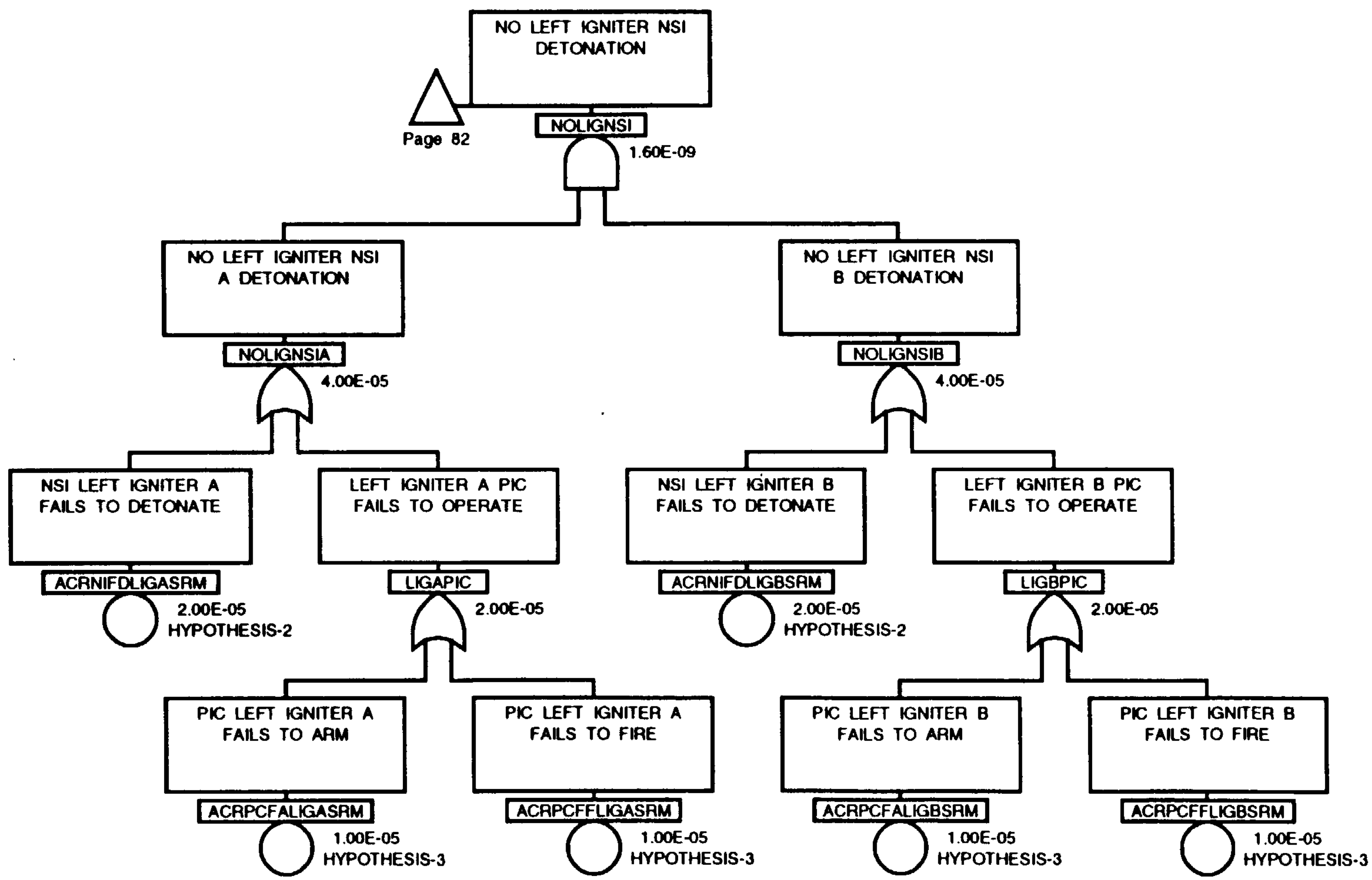

NO RELEASE HOLDDOWN BOLT 8
NOHLDN8REL
1.00E-05
Page 73
FRANGIBLE NUT HDN8 FAILS TO FRAGMENT
ACRFNFFHDN8SRB
1.00E-05
HYPOTHESIS-1
HD BOLT 8 FRANGIBLE NUT BOOSTER CARTRIDGES FAIL TO DETONATE
HD8NPSFD
1.60E-09
HD BOLT 8 FRANGIBLE NUT BOOST CRTRG A FAILS TO DETONATE
HD8ANPFD
4.00E-05
HD BOLT 8 FRANGIBLE NUT BOOST CRTRG B FAILS TO DETONATE
HD8BNPFD
4.00E-05
NSI PRESSURE / BOOST CRTRG HD8A FAILS TO DETONATE
ACRNPFDHD8ASRB
3.00E-05
HYPOTHESIS-2
PIC HD8A FAILS TO FIRE
ACRPCFFHD8ASRB
1.00E-05
HYPOTHESIS-3
NSI PRESSURE / BOOST CRTRG HD8B FAILS TO DETONATE
ACRNPFDHD8BSRB
3.00E-05
HYPOTHESIS-2
PIC HD8B FAILS TO FIRE
ACRPCFFHD8BSRB
1.00E-05
HYPOTHESIS-3

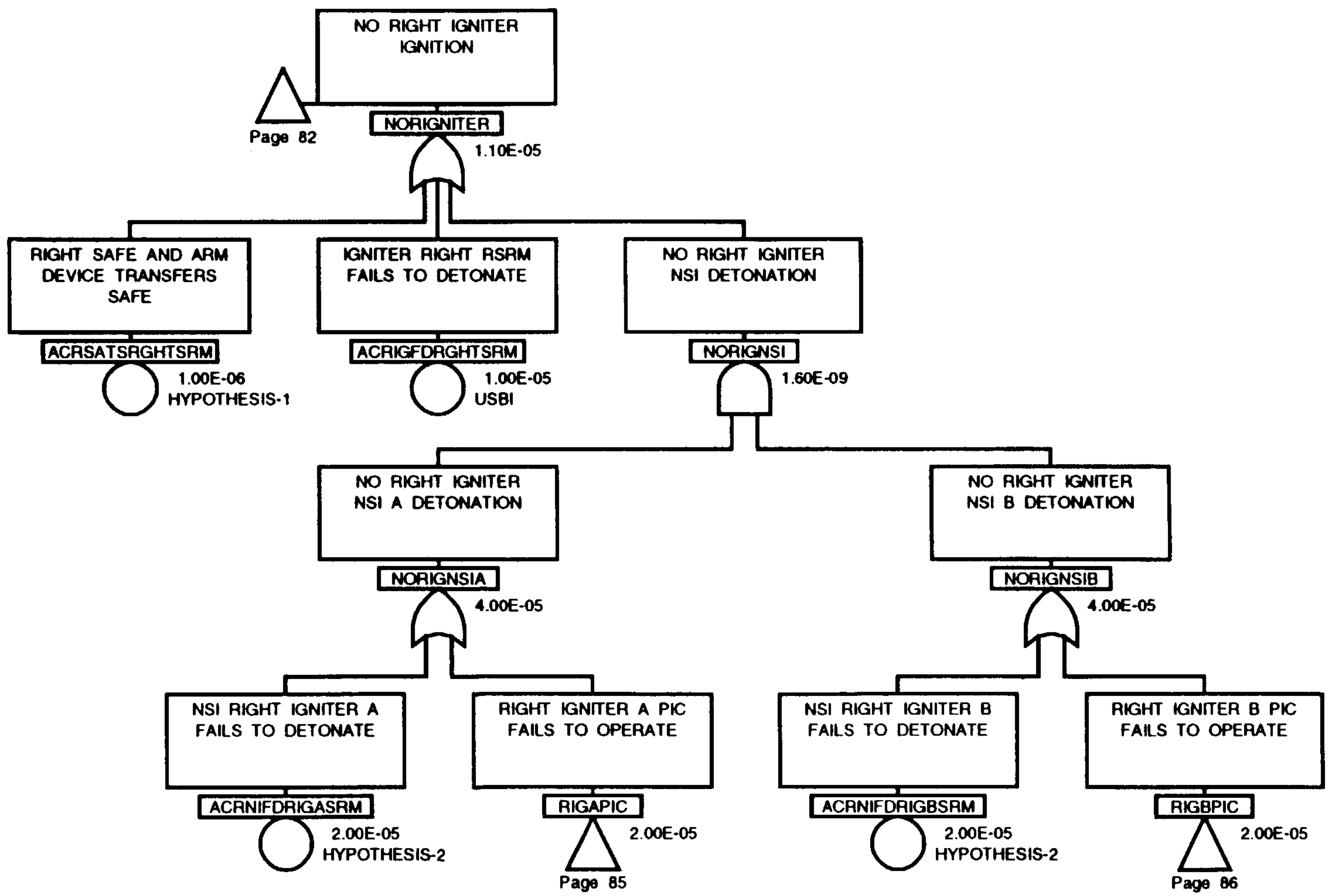

MULTIPLE HUNG BOLTS ON LEFT SRB
Page 68
LMULTHDHUNG
2
8.85E-05
HOLD DOWN STUD HDN1 HANGS UP
ACRHDHRHDN1SRB
3.85E-03
PRACA
HOLD DOWN STUD HDN3 HANGS UP
ACRHDHRHDN3SRB
3.85E-03
PRACA
HOLD DOWN STUD HDN2 HANGS UP
ACRHDHRHDN2SRB
3.85E-03
PRACA
HOLD DOWN STUD HDN4 HANGS UP
ACRHDHRHDN4SRB
3.85E-03
PRACA

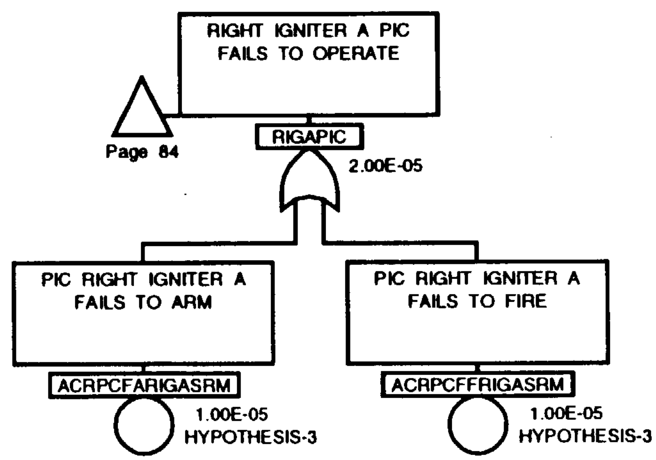

MULTIPLE HUNG BOLTS ON RIGHT SRB
Page 68
RMULTHDHUNG
2
8.85E-05
HOLD DOWN STUD HDN5 HANGS UP
ACRHDHRHDN5SRB
3.85E-03
PRACA
HOLD DOWN STUD HDN7 HANGS UP
ACRHDHRHDN7SRB
3.85E-03
PRACA
HOLD DOWN STUD HDN6 HANGS UP
ACRHDHRHDN6RSB
3.85E-03
PRACA
HOLD DOWN STUD HDN8 HANGS UP
ACRHDHRHDN8SRB
3.85E-03
PRACA

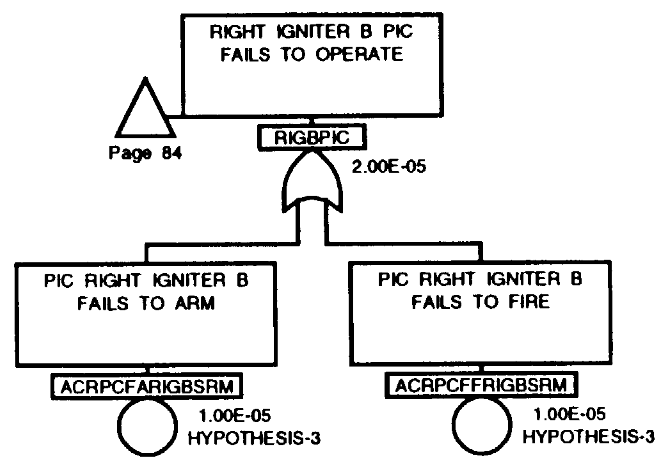


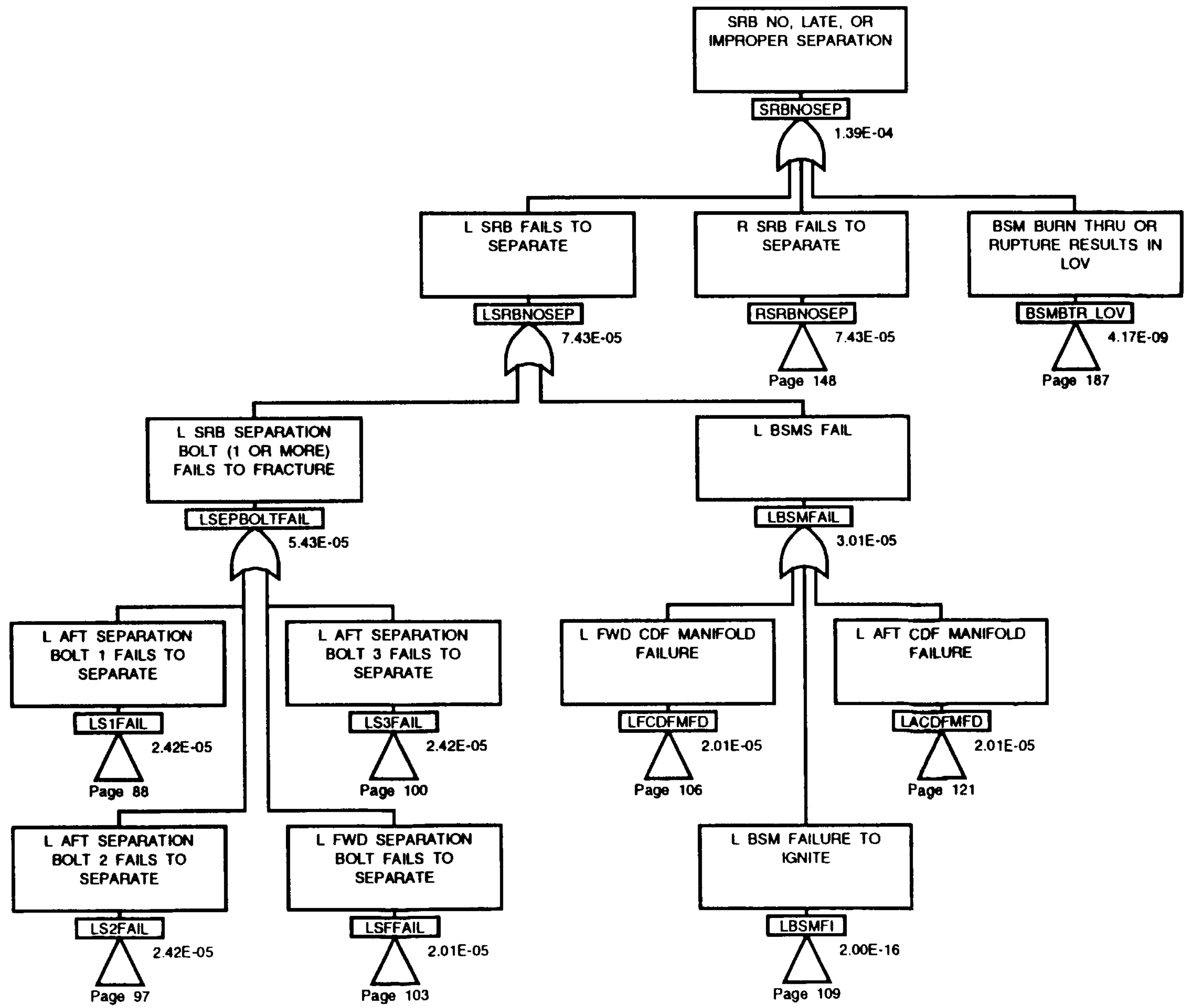
NO OR LATE IGNITION OF 1 SRB/RSRM
SRBNOIGN
2.22E-04
NO LEFT SRM IGNITION
NOLIGN
1.11E-04
NO RIGHT SRM IGNITION
NORIGN
1.11E-04
LEFT RSRM PROPELLENT FAILS TO IGNITE
ACRPRFDLEFTSRM
1.00E-04
HYPOTHESIS-4
NO LEFT IGNITER IGNITION
NOLIGNITER
1.10E-05
RGHT RSRM PROPELLENT FAILS TO IGNITE
ACRPRFDRGHTSRM
1.00E-04
HYPOTHESIS-4
NO RIGHT IGNITER IGNITION
NORIGNITER
1.10E-05
Page 84
LEFT SAFE AND ARM DEVICE TRANSFERS SAFE
ACRSATSLEFTSRM
1.00E-06
HYPOTHESIS-
NO LEFT IGNITER NSI DETONATION
NOLIGNSI
1.60E-09
Page 83
IGNITER LEFT RSRM FAILS TO DETONATE
ACRIGFDLEFTSRM
1.00E-05
USBI

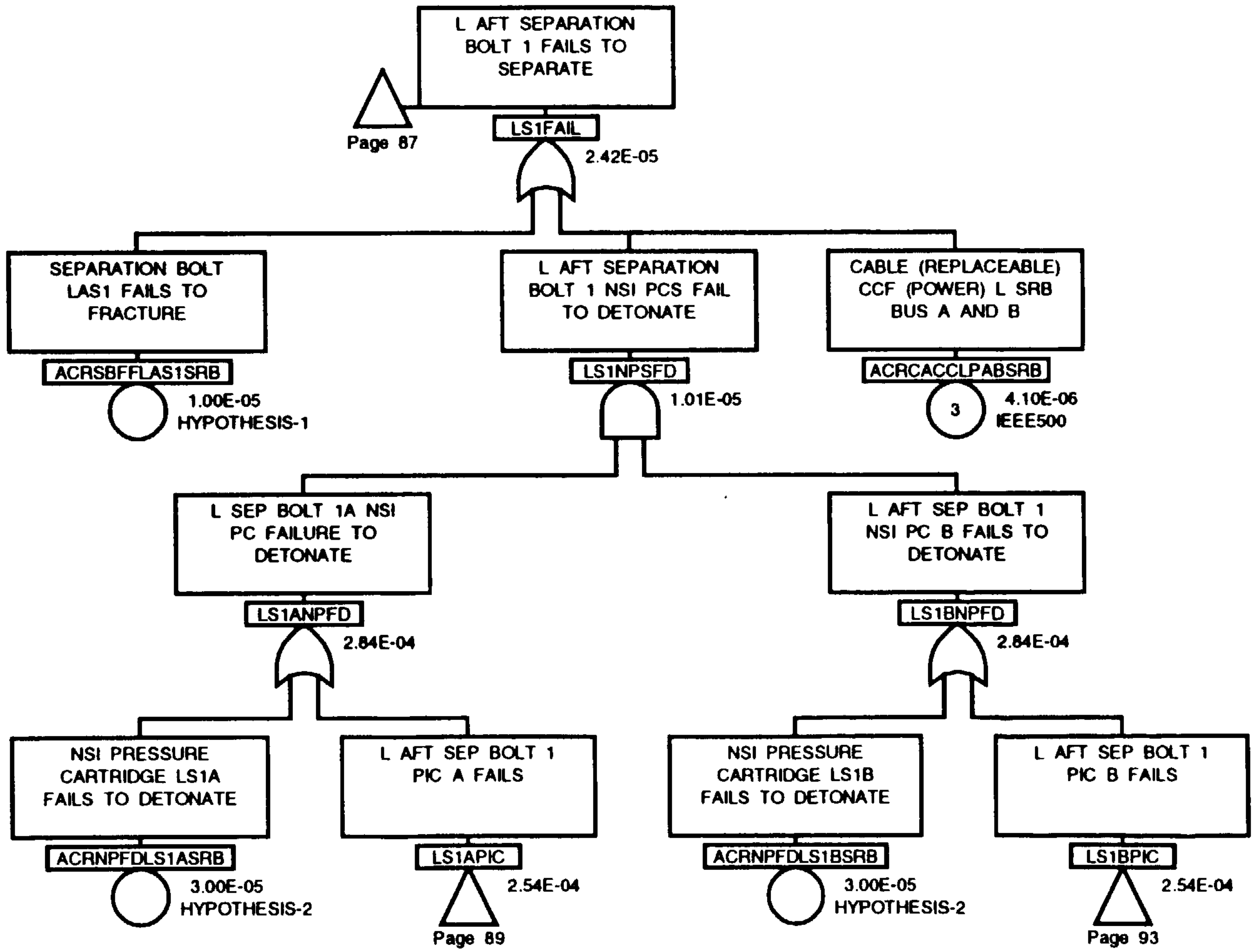

NO LEFT IGNITER NSI DETONATION
NOLIGNSI
1.60E-09
Page 82
NO LEFT IGNITER NSI A DETONATION
NOLIGNSIA
4.00E-05
NO LEFT IGNITER NSI B DETONATION
NOLIGNSIB
4.00E-05
NSI LEFT IGNITER A FAILS TO DETONATE
ACRNIFDLIGASRM
2.00E-05
HYPOTHESIS-2
LEFT IGNITER A PIC FAILS TO OPERATE
LIGAPIC
2.00E-05
NSI LEFT IGNITER B FAILS TO DETONATE
ACRNIFDLIGBSRM
2.00E-05
HYPOTHESIS-2
LEFT IGNITER B PIC FAILS TO OPERATE
LIGBPIC
2.00E-05
PIC LEFT IGNITER A FAILS TO ARM
ACRPCFALIGASRM
1.00E-05
HYPOTHESIS-3
PIC LEFT IGNITER A FAILS TO FIRE
ACRPCFFLIGASRM
1.00E-05
HYPOTHESIS-3
PIC LEFT IGNITER B FAILS TO ARM
ACRPCFALIGBSRM
1.00E-05
HYPOTHESIS-3
PIC LEFT IGNITER B FAILS TO FIRE
ACRPCFFLIGBSRM
1.00E-05
HYPOTHESIS-3

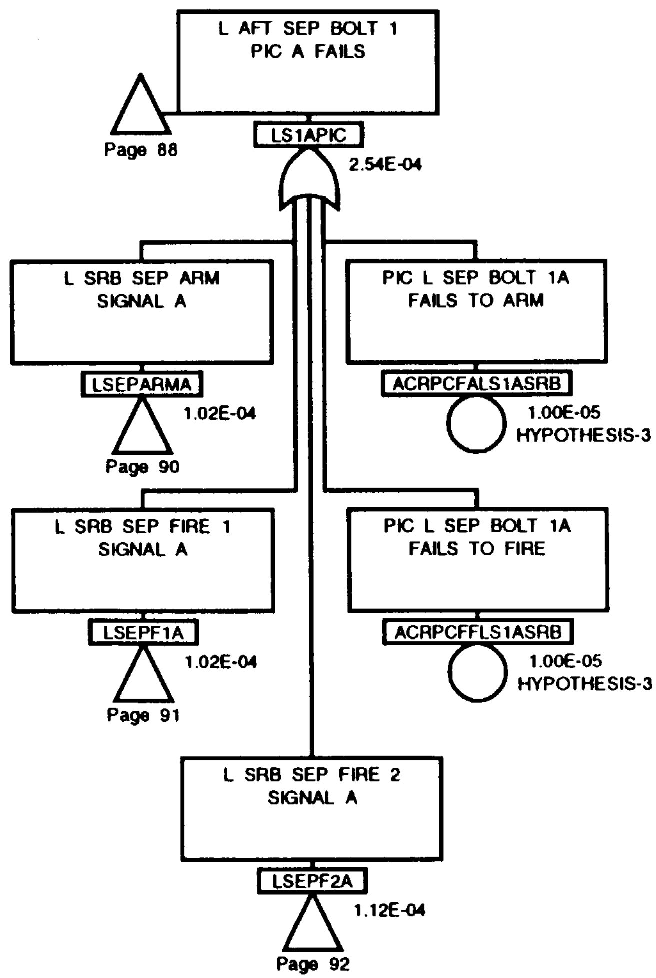

NO RIGHT IGNITER IGNITION
Page 82
NORIGNITER
1.10E-05
RIGHT SAFE AND ARM DEVICE TRANSFERS SAFE
ACRSATSRGHTSRM
1.00E-06
HYPOTHESIS-1
IGNITER RIGHT RSRM FAILS TO DETONATE
ACRIGFDRGHTSRM
1.00E-05
USBI
NO RIGHT IGNITER NSI DETONATION
NORIGNSI
1.60E-09
NO RIGHT IGNITER NSI A DETONATION
NORIGNSIA
4.00E-05
NO RIGHT IGNITER NSI B DETONATION
NORIGNSIB
4.00E-05
NSI RIGHT IGNITER A FAILS TO DETONATE
ACRNIFDRIGASRM
2.00E-05
HYPOTHESIS-2
RIGHT IGNITER A PIC FAILS TO OPERATE
RIGAPIC
2.00E-05
Page 85
NSI RIGHT IGNITER B FAILS TO DETONATE
ACRNIFDRIGBSRM
2.00E-05
HYPOTHESIS-2
RIGHT IGNITER B PIC FAILS TO OPERATE
RIGBPIC
2.00E-05
Page 86


RIGHT IGNITER A PIC FAILS TO OPERATE
Page 84
RIGAPIC
2.00E-05
PIC RIGHT IGNITER A FAILS TO ARM
ACRPCFARIGASRM
1.00E-05
HYPOTHESIS-3
PIC RIGHT IGNITER A FAILS TO FIRE
ACRPCFFRIGASRM
1.00E-05
HYPOTHESIS-3

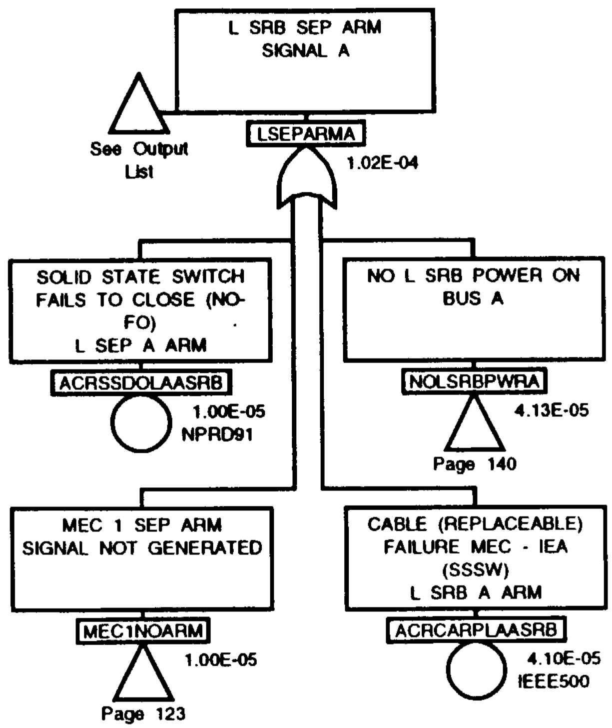

RIGHT IGNITER B PIC
FAILS TO OPERATE
Page 84
RIGBPIC
2.00E-05
PIC RIGHT IGNITER B
FAILS TO ARM
ACRPCFARIGBSRM
1.00E-05
HYPOTHESIS-3
PIC RIGHT IGNITER B
FAILS TO FIRE
ACRPCFFRIGBSRM
1.00E-05
HYPOTHESIS-3


SRB NO, LATE, OR IMPROPER SEPARATION
SRBNOSEP
1.39E-04
L SRB FAILS TO SEPARATE
LSRBNOSEP
7.43E-05
R SRB FAILS TO SEPARATE
RSRBNOSEP
7.43E-05
Page 148
BSM BURN THRU OR RUPTURE RESULTS IN LOV
BSMBTR_LOV
4.17E-09
Page 187
L SRB SEPARATION BOLT (1 OR MORE) FAILS TO FRACTURE
LSEPBOLTFAIL
5.43E-05
L BSMS FAIL
LBSMFAIL
3.01E-05
L AFT SEPARATION BOLT 1 FAILS TO SEPARATE
LS1FAIL
2.42E-05
Page 88
L AFT SEPARATION BOLT 3 FAILS TO SEPARATE
LS3FAIL
2.42E-05
Page 100
L FWD CDF MANIFOLD FAILURE
LFCDFMFD
2.01E-05
Page 106
L AFT CDF MANIFOLD FAILURE
LACDFMFD
2.01E-05
Page 121
L AFT SEPARATION BOLT 2 FAILS TO SEPARATE
LS2FAIL
2.42E-05
Page 97
L FWD SEPARATION BOLT FAILS TO SEPARATE
LSFFAIL
2.01E-05
Page 103
L BSM FAILURE TO IGNITE
LBSMFI
2.00E-16
Page 109

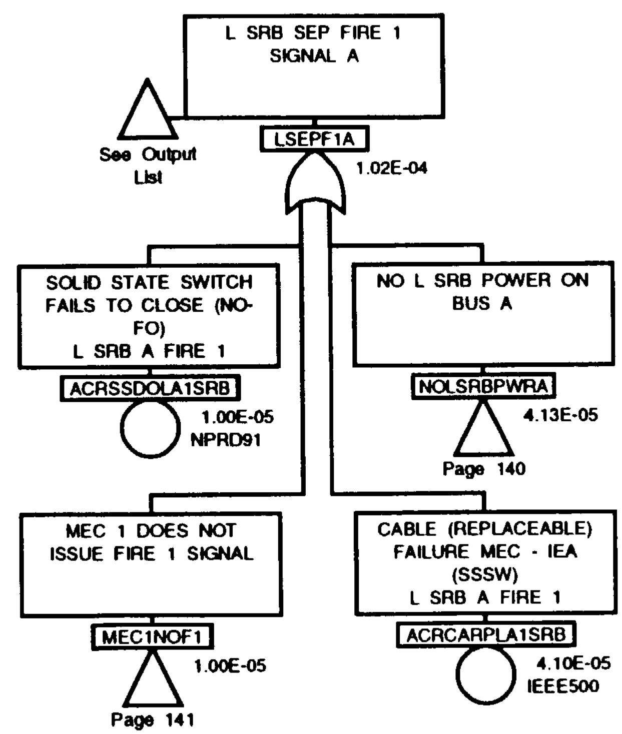

L AFT SEPARATION BOLT 1 FAILS TO SEPARATE
Page 87
LS1FAIL
2.42E-05
SEPARATION BOLT LAS1 FAILS TO FRACTURE
ACRSBFFLAS1SRB
1.00E-05
HYPOTHESIS-1
L AFT SEPARATION BOLT 1 NSI PCS FAIL TO DETONATE
LS1NPSFD
1.01E-05
CABLE (REPLACEABLE) CCF (POWER) L SRB BUS A AND B
ACRCACCLPABSRB
3
4.10E-06
IEEE500
L SEP BOLT 1A NSI PC FAILURE TO DETONATE
LS1ANPFD
2.84E-04
L AFT SEP BOLT 1 NSI PC B FAILS TO DETONATE
LS1BNPFD
2.84E-04
NSI PRESSURE CARTRIDGE LS1A FAILS TO DETONATE
ACRNPFDLS1ASRB
3.00E-05
HYPOTHESIS-2
L AFT SEP BOLT 1 PIC A FAILS
LS1APIC
2.54E-04
Page 89
NSI PRESSURE CARTRIDGE LS1B FAILS TO DETONATE
ACRNPFDLS1BSRB
3.00E-05
HYPOTHESIS-2
L AFT SEP BOLT 1 PIC B FAILS
LS1BPIC
2.54E-04
Page 93


L AFT SEP BOLT 1
PIC A FAILS
Page 88
LS1APIC
2.54E-04
L SRB SEP ARM
SIGNAL A
LSEPARMA
1.02E-04
Page 90
PIC L SEP BOLT 1A
FAILS TO ARM
ACRPCFALS1ASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1
SIGNAL A
LSEPF1A
1.02E-04
Page 91
PIC L SEP BOLT 1A
FAILS TO FIRE
ACRPCFFLS1ASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2
SIGNAL A
LSEPF2A
1.12E-04
Page 92

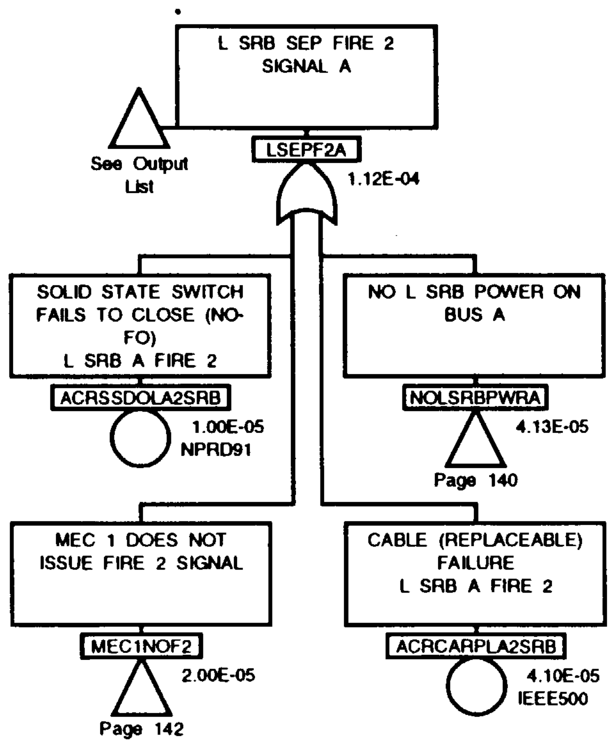
LSEPARMA Outputs:
Page 122, Page 107, Page 89, Page 98, Page 101, Page 104

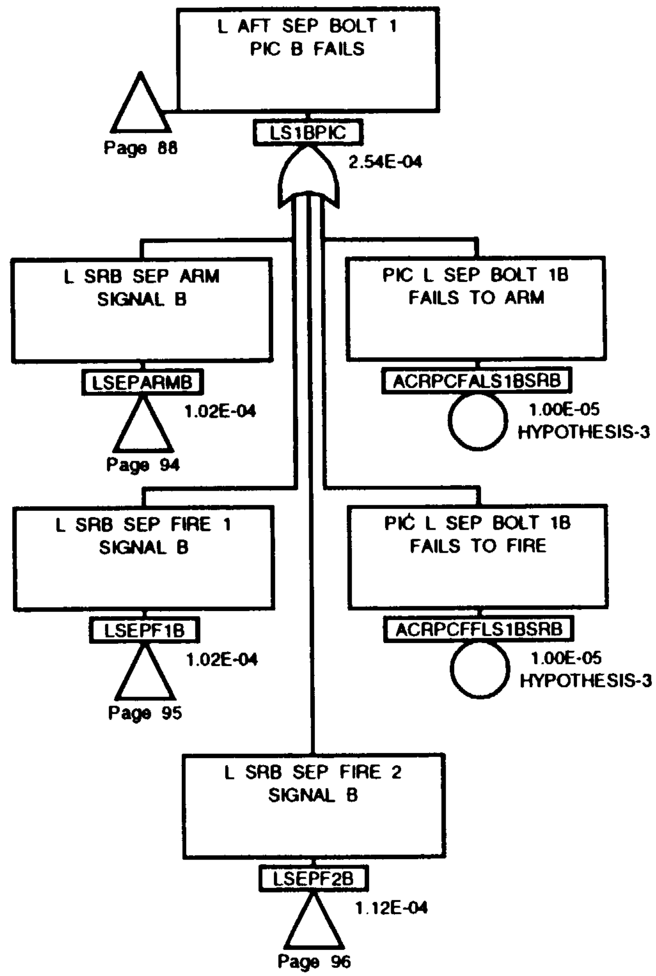


LSEPF1A Outputs:
Page 122, Page 107, Page 89, Page 98, Page 101, Page 104

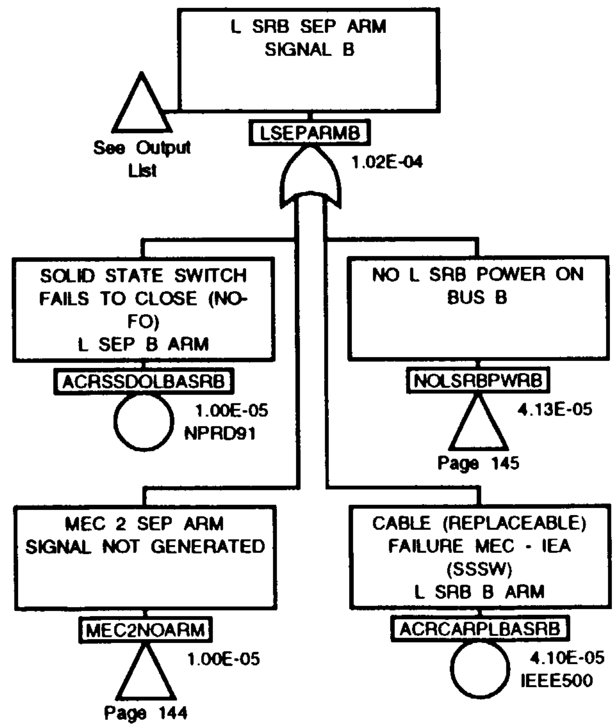


LSEPF2A Outputs:
Page 122, Page 107, Page 89, Page 98, Page 101, Page 104

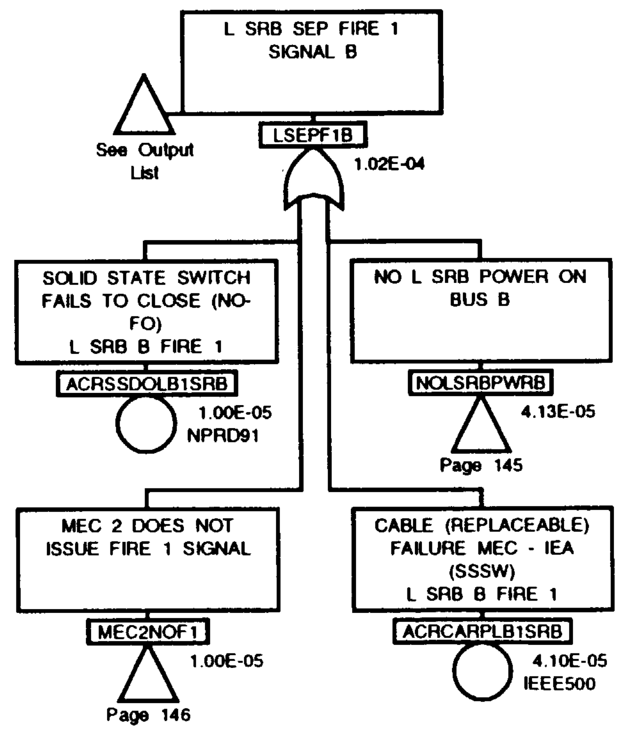



L AFT SEP BOLT 1
PIC B FAILS
LS1BPIC
2.54E-04
Page 88
L SRB SEP ARM
SIGNAL B
LSEPARMB
1.02E-04
Page 94
PIC L SEP BOLT 1B
FAILS TO ARM
ACRPCFALS1BSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1
SIGNAL B
LSEPF1B
1.02E-04
Page 95
PIC L SEP BOLT 1B
FAILS TO FIRE
ACRPCFFLS1BSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2
SIGNAL B
LSEPF2B
1.12E-04
Page 96

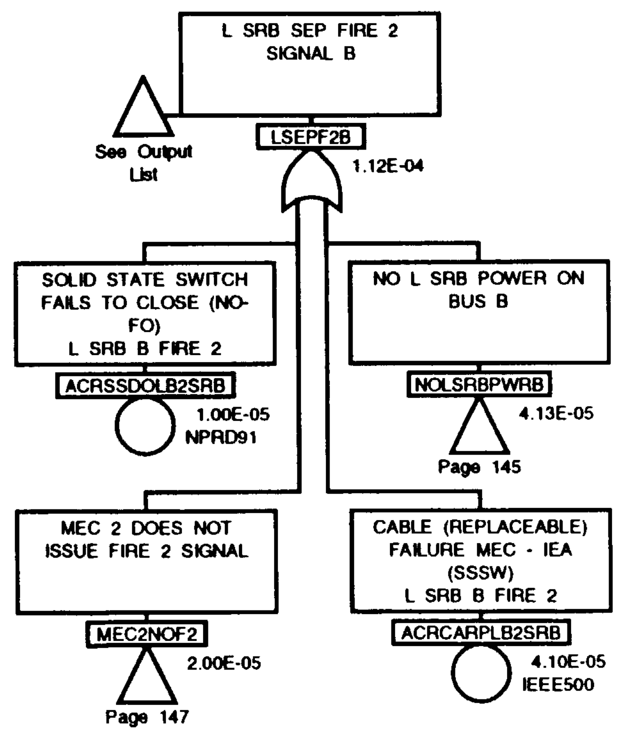
LSEPARMB Outputs:
Page 143, Page 108, Page 93, Page 99, Page 102, Page 105

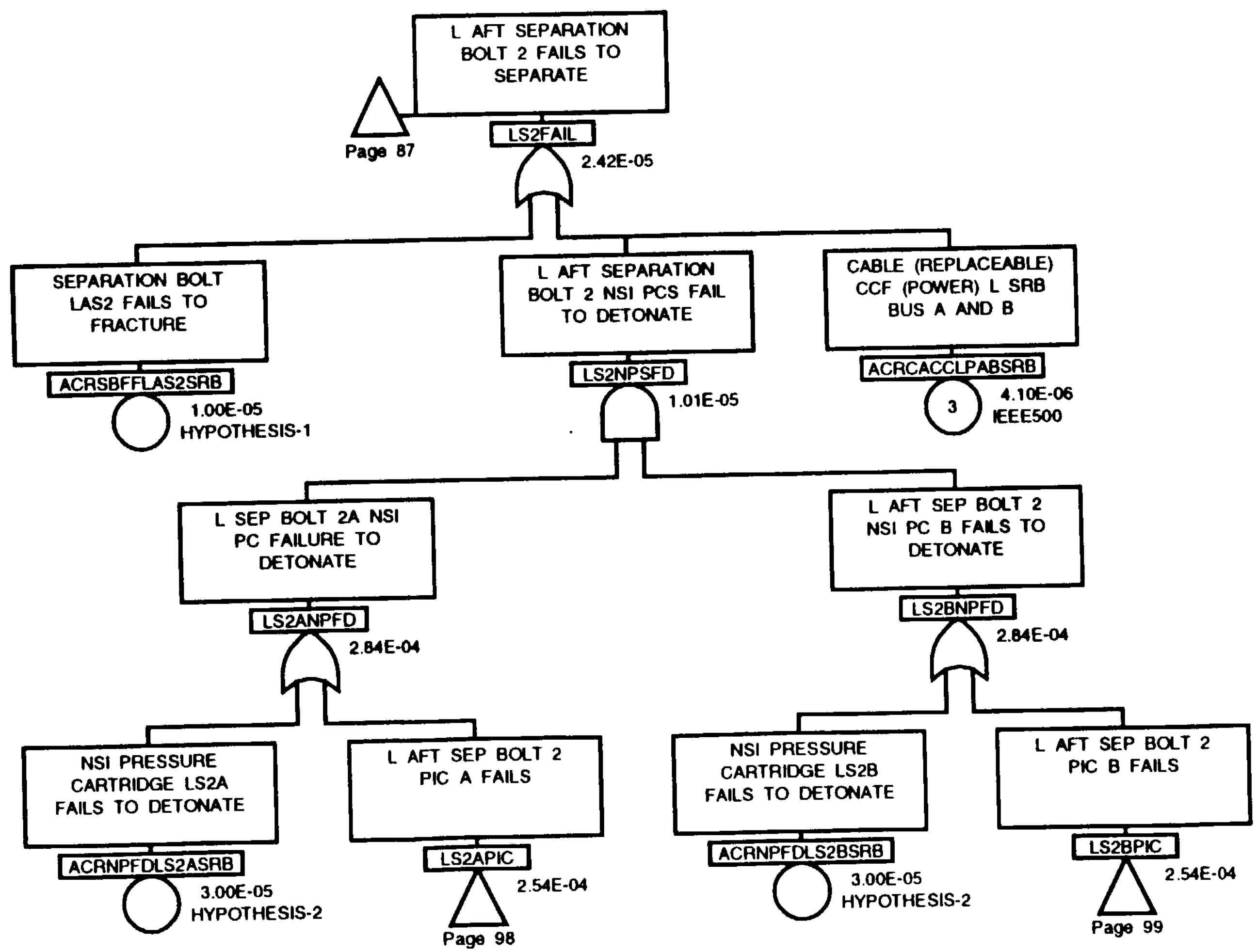


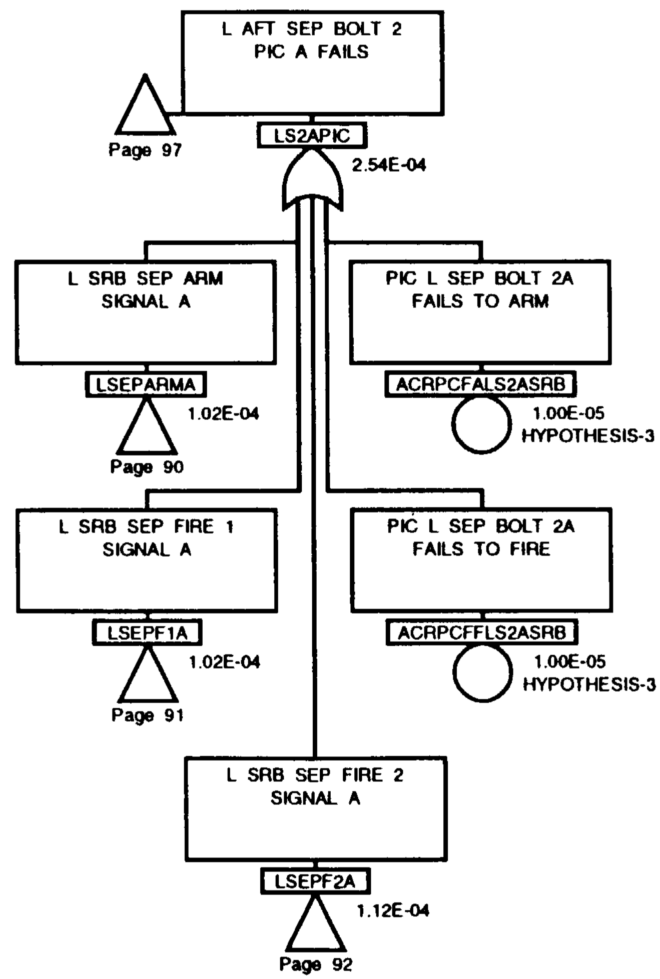
LSEPF1B Outputs:
Page 143, Page 108, Page 93, Page 99, Page 102, Page 105

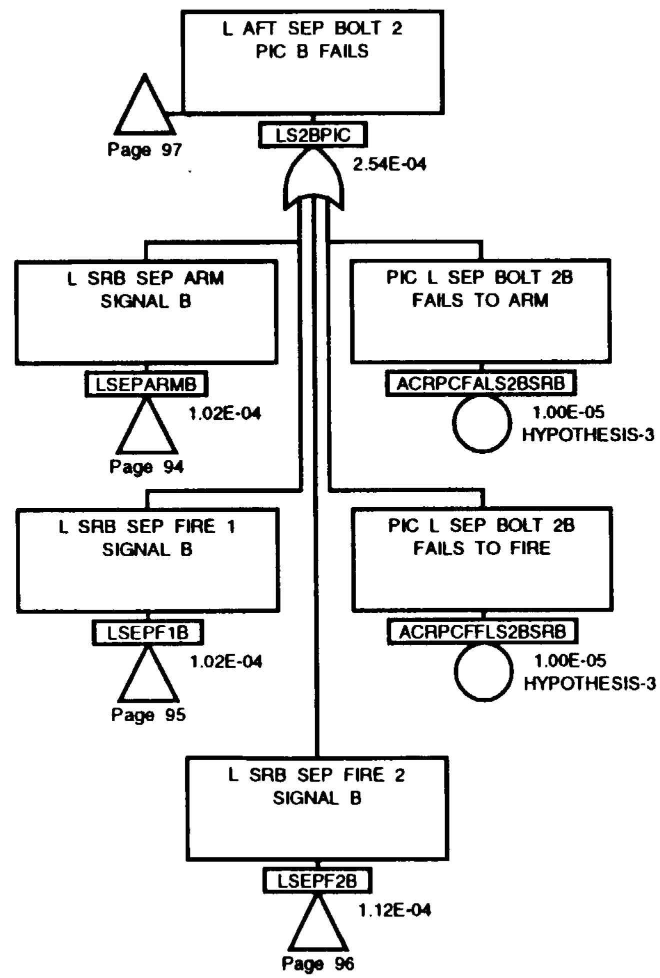


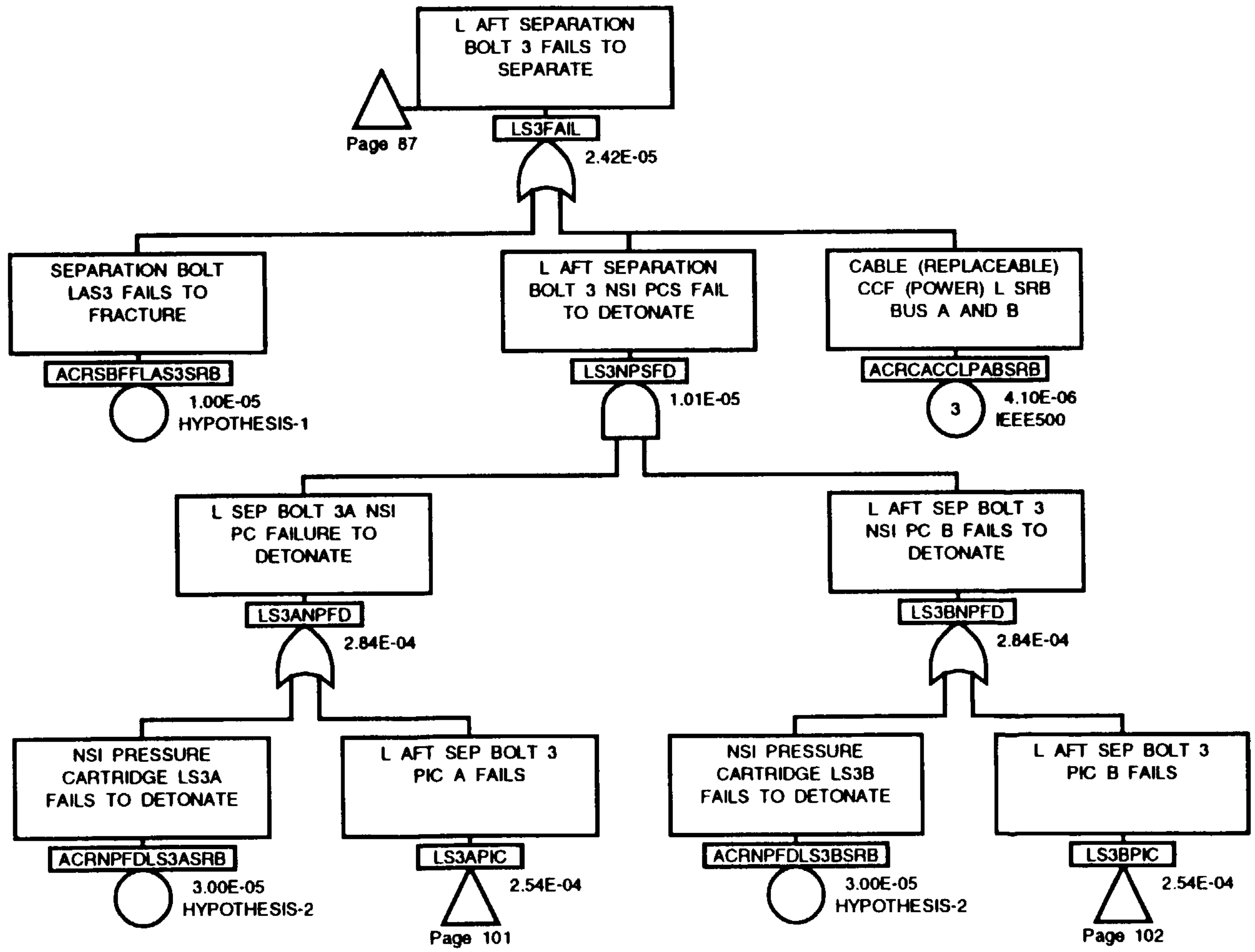
LSEPF2B Outputs:
Page 143, Page 108, Page 93, Page 99, Page 102, Page 105

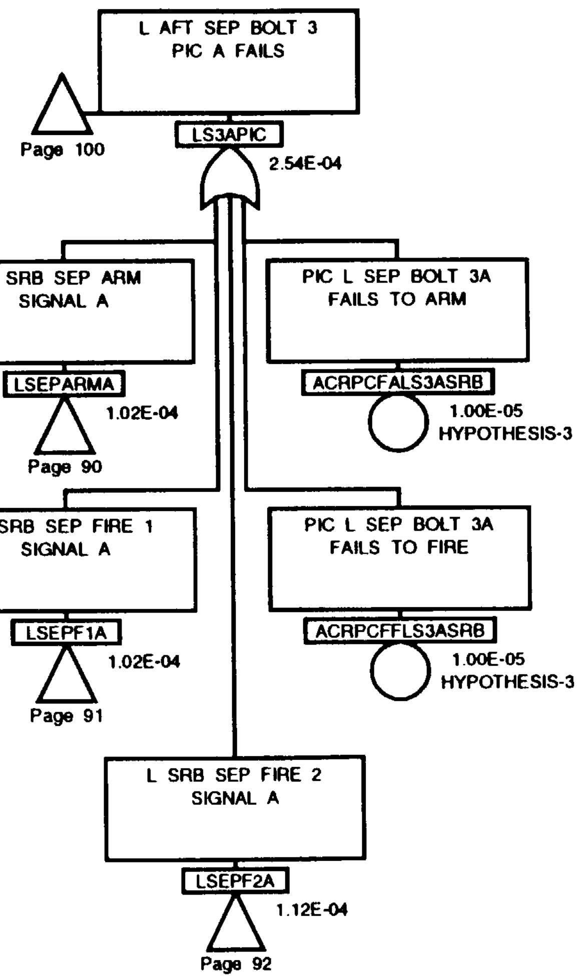


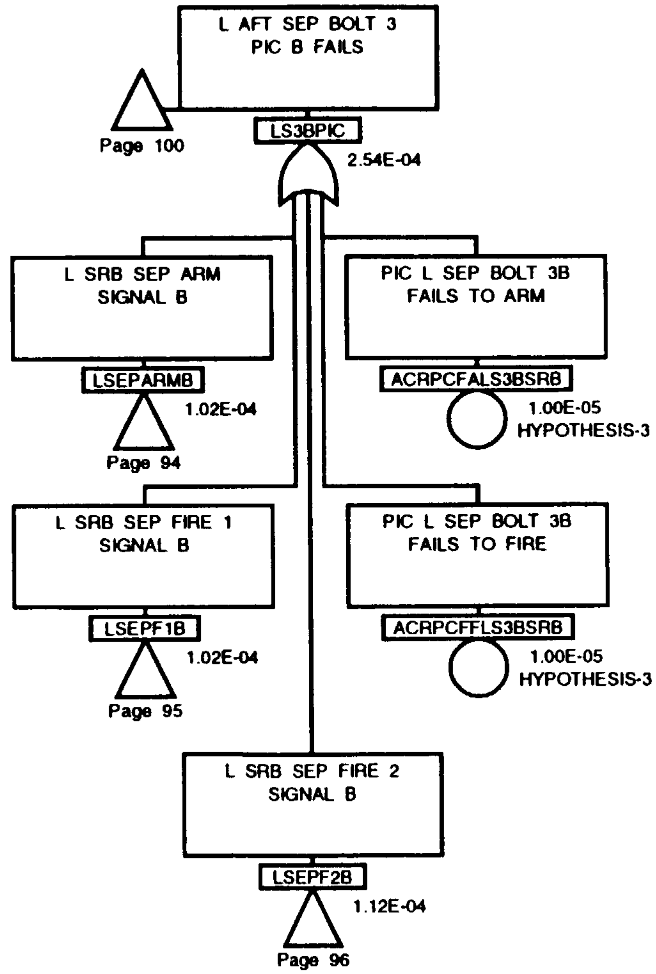

L AFT SEPARATION BOLT 2 FAILS TO SEPARATE
Page 87
LS2FAIL
2.42E-05
SEPARATION BOLT LAS2 FAILS TO FRACTURE
ACRSBFFLAS2SRB
1.00E-05
HYPOTHESIS-1
L AFT SEPARATION BOLT 2 NSI PCS FAIL TO DETONATE
LS2NPSFD
1.01E-05
CABLE (REPLACEABLE) CCF (POWER) L SRB BUS A AND B
ACRCACCLPABSRB
3
4.10E-06
IEEE500
L SEP BOLT 2A NSI PC FAILURE TO DETONATE
LS2ANPFD
2.84E-04
L AFT SEP BOLT 2 NSI PC B FAILS TO DETONATE
LS2BNPFD
2.84E-04
NSI PRESSURE CARTRIDGE LS2A FAILS TO DETONATE
ACRNPFDLS2ASRB
3.00E-05
HYPOTHESIS-2
L AFT SEP BOLT 2 PIC A FAILS
LS2APIC
2.54E-04
Page 98
NSI PRESSURE CARTRIDGE LS2B FAILS TO DETONATE
ACRNPFDLS2BSRB
3.00E-05
HYPOTHESIS-2
L AFT SEP BOLT 2 PIC B FAILS
LS2BPIC
2.54E-04
Page 99


L AFT SEP BOLT 2
PIC A FAILS
LS2APIC
2.54E-04
Page 97
L SRB SEP ARM
SIGNAL A
LSEPARMA
1.02E-04
Page 90
PIC L SEP BOLT 2A
FAILS TO ARM
ACRPCFALS2ASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1
SIGNAL A
LSEPF1A
1.02E-04
Page 91
PIC L SEP BOLT 2A
FAILS TO FIRE
ACRPCFFLS2ASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2
SIGNAL A
LSEPF2A
1.12E-04
Page 92

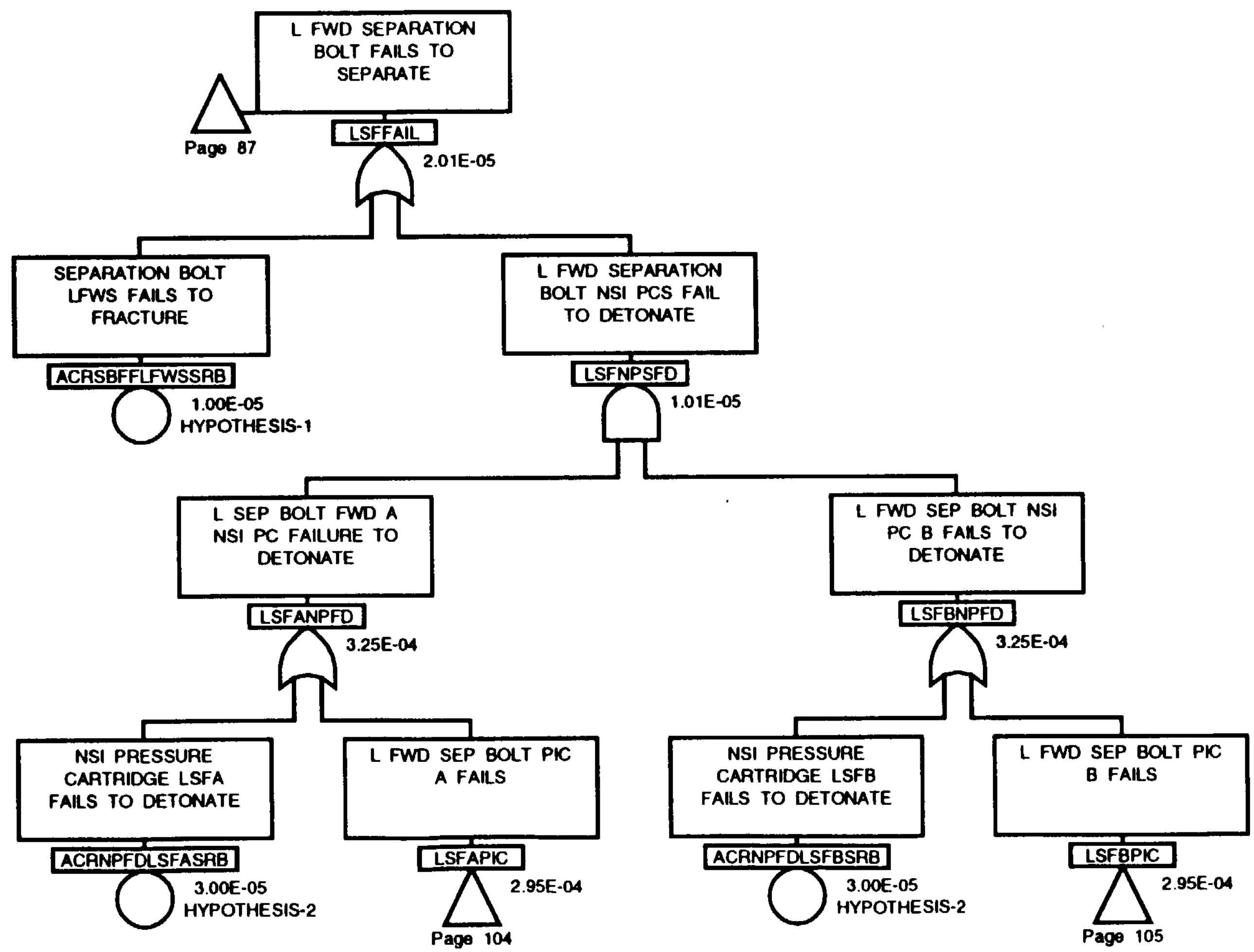

L AFT SEP BOLT 2
PIC B FAILS
Page 97
LS2BPIC
2.54E-04
L SRB SEP ARM
SIGNAL B
LSEPARMB
1.02E-04
Page 94
PIC L SEP BOLT 2B
FAILS TO ARM
ACRPCFALS2BSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1
SIGNAL B
LSEPF1B
1.02E-04
Page 95
PIC L SEP BOLT 2B
FAILS TO FIRE
ACRPCFFLS2BSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2
SIGNAL B
LSEPF2B
1.12E-04
Page 96

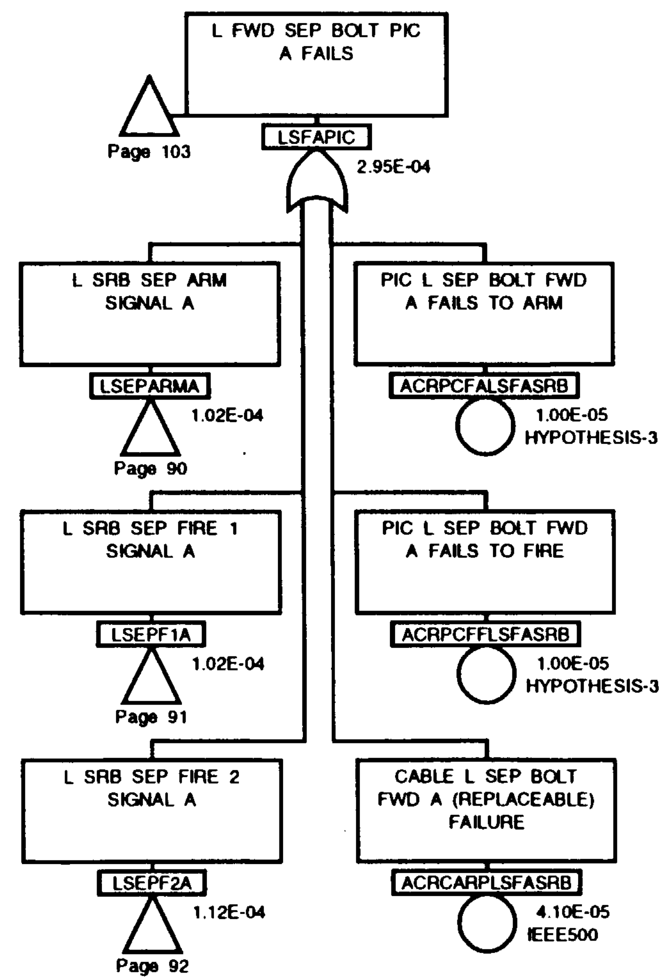

L AFT SEPARATION BOLT 3 FAILS TO SEPARATE
Page 87
LS3FAIL
2.42E-05
SEPARATION BOLT LAS3 FAILS TO FRACTURE
ACRSBFFLAS3SRB
1.00E-05
HYPOTHESIS-1
L AFT SEPARATION BOLT 3 NSI PCS FAIL TO DETONATE
LS3NPSFD
1.01E-05
CABLE (REPLACEABLE) CCF (POWER) L SRB BUS A AND B
ACRCACCLPABSRB
3
4.10E-06
IEEE500
L SEP BOLT 3A NSI PC FAILURE TO DETONATE
LS3ANPFD
2.84E-04
L AFT SEP BOLT 3 NSI PC B FAILS TO DETONATE
LS3BNPFD
2.84E-04
NSI PRESSURE CARTRIDGE LS3A FAILS TO DETONATE
ACRNPFDLS3ASRB
3.00E-05
HYPOTHESIS-2
L AFT SEP BOLT 3 PIC A FAILS
LS3APIC
2.54E-04
Page 101
NSI PRESSURE CARTRIDGE LS3B FAILS TO DETONATE
ACRNPFDLS3BSRB
3.00E-05
HYPOTHESIS-2
L AFT SEP BOLT 3 PIC B FAILS
LS3BPIC
2.54E-04
Page 102

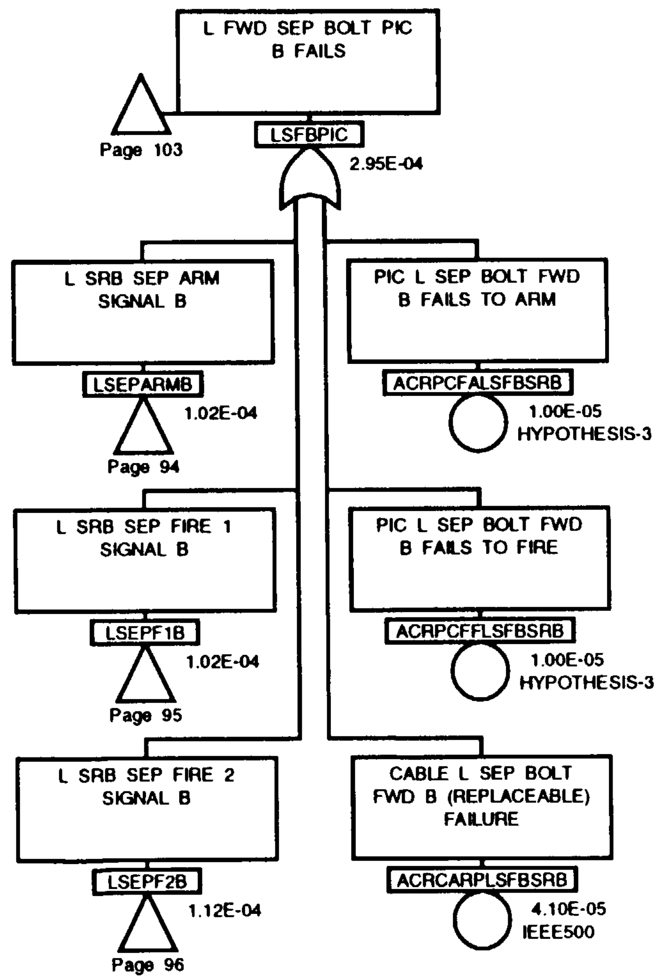

L AFT SEP BOLT 3
PIC A FAILS
Page 100
LS3APIC
2.54E-04
L SRB SEP ARM
SIGNAL A
LSEPARMA
1.02E-04
Page 90
PIC L SEP BOLT 3A
FAILS TO ARM
ACRPCFALS3ASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1
SIGNAL A
LSEPF1A
1.02E-04
Page 91
PIC L SEP BOLT 3A
FAILS TO FIRE
ACRPCFFLS3ASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2
SIGNAL A
LSEPF2A
1.12E-04
Page 92

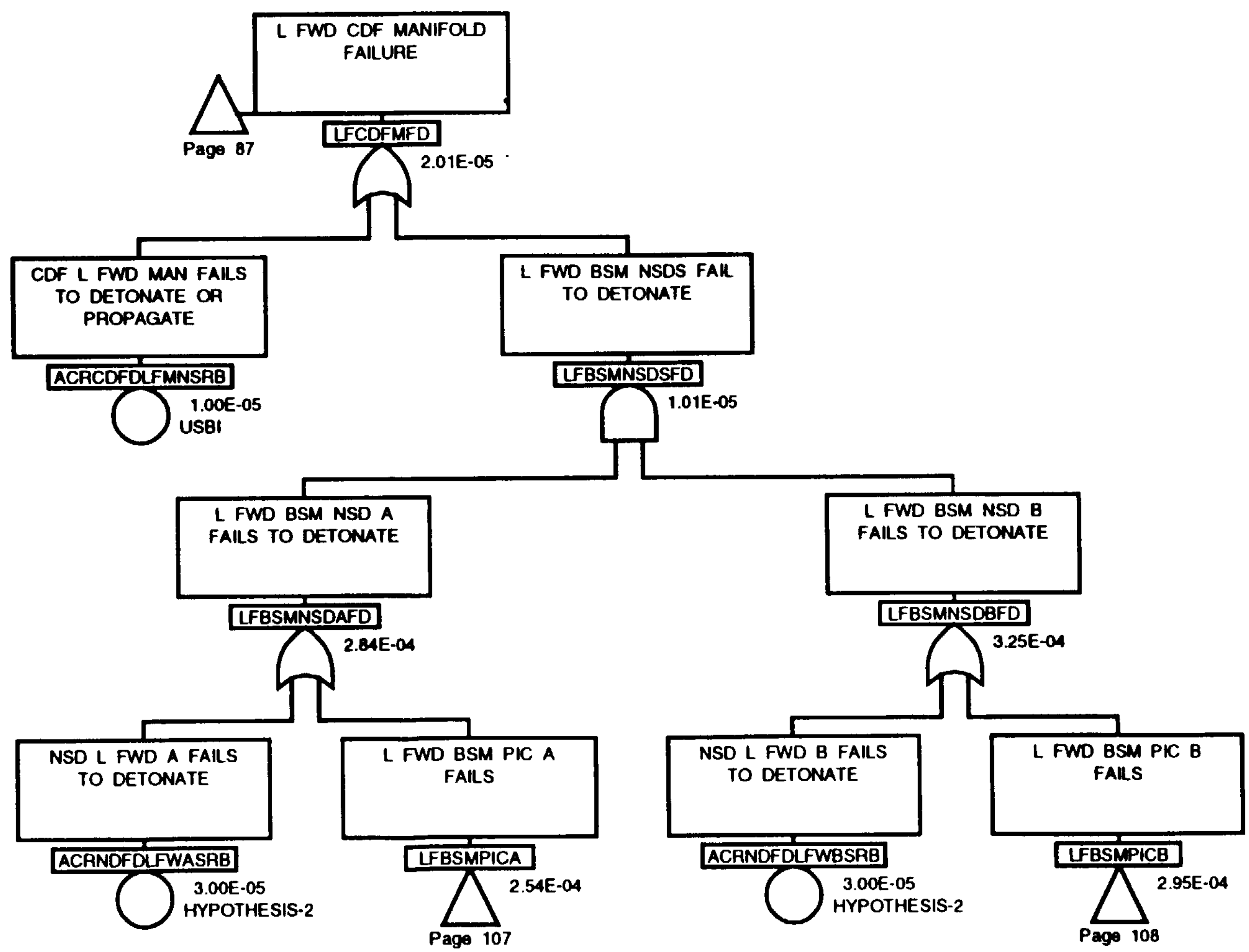


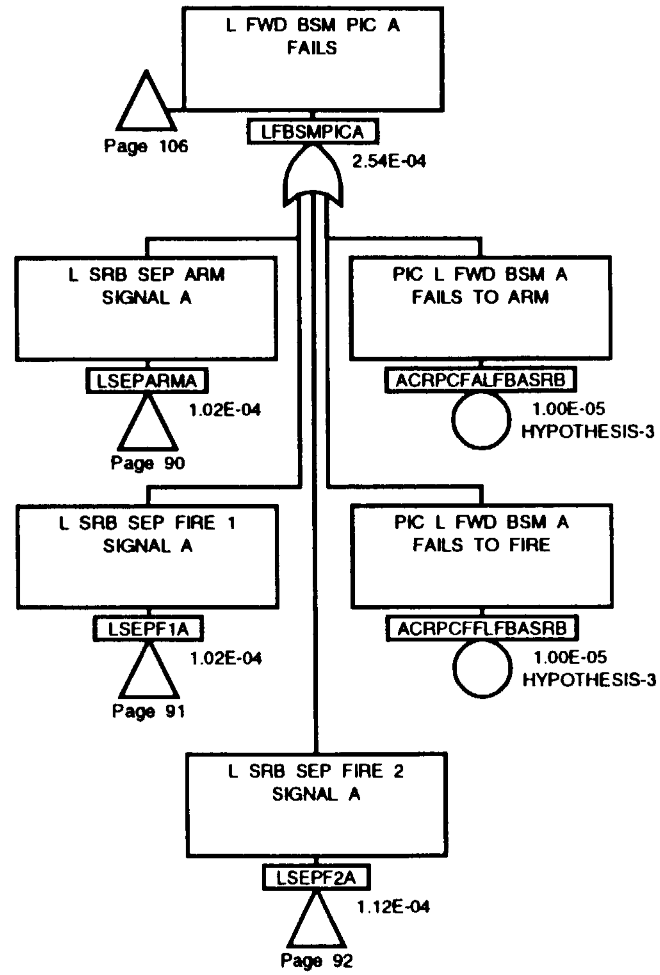
L AFT SEP BOLT 3
PIC B FAILS
LS3BPIC
2.54E-04
Page 100
L SRB SEP ARM
SIGNAL B
LSEPARMB
1.02E-04
Page 94
PIC L SEP BOLT 3B
FAILS TO ARM
ACRPCFALS3BSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1
SIGNAL B
LSEPF1B
1.02E-04
Page 95
PIC L SEP BOLT 3B
FAILS TO FIRE
ACRPCFFLS3BSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2
SIGNAL B
LSEPF2B
1.12E-04
Page 96

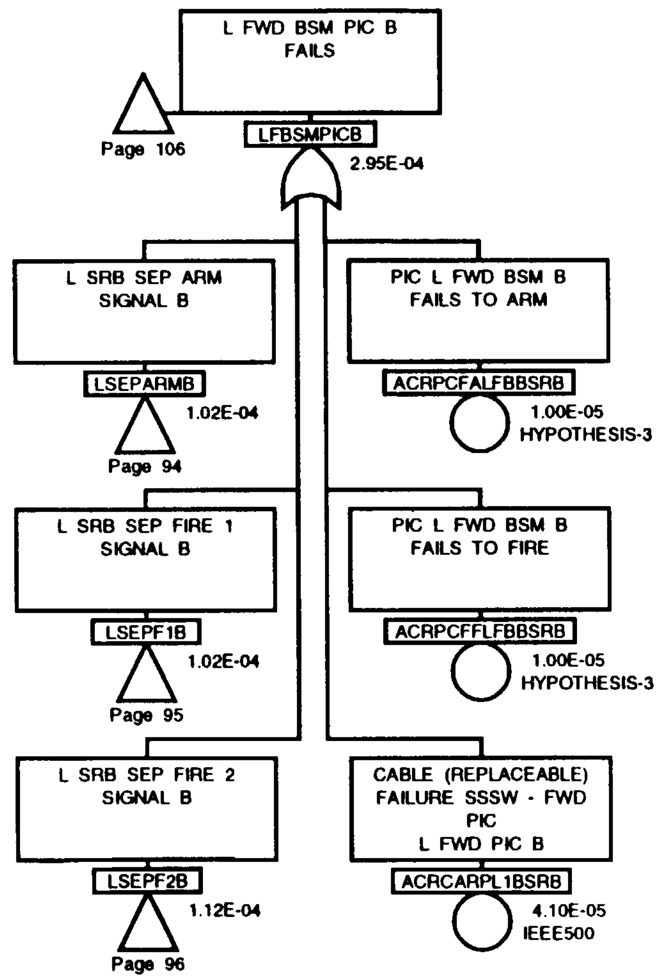

L FWD SEPARATION BOLT FAILS TO SEPARATE
Page 87
LSFFAIL
2.01E-05
SEPARATION BOLT LFWS FAILS TO FRACTURE
ACRSBFFLFWSSRB
1.00E-05
HYPOTHESIS-1
L FWD SEPARATION BOLT NSI PCS FAIL TO DETONATE
LSFNPSFD
1.01E-05
L SEP BOLT FWD A NSI PC FAILURE TO DETONATE
LSFANPFD
3.25E-04
L FWD SEP BOLT NSI PC B FAILS TO DETONATE
LSFBNPFD
3.25E-04
NSI PRESSURE CARTRIDGE LSFA FAILS TO DETONATE
ACRNPFDLSFASRB
3.00E-05
HYPOTHESIS-2
L FWD SEP BOLT PIC A FAILS
LSFAPIC
2.95E-04
Page 104
NSI PRESSURE CARTRIDGE LSFB FAILS TO DETONATE
ACRNPFDLSFBSRB
3.00E-05
HYPOTHESIS-2
L FWD SEP BOLT PIC B FAILS
LSFBPIC
2.95E-04
Page 105

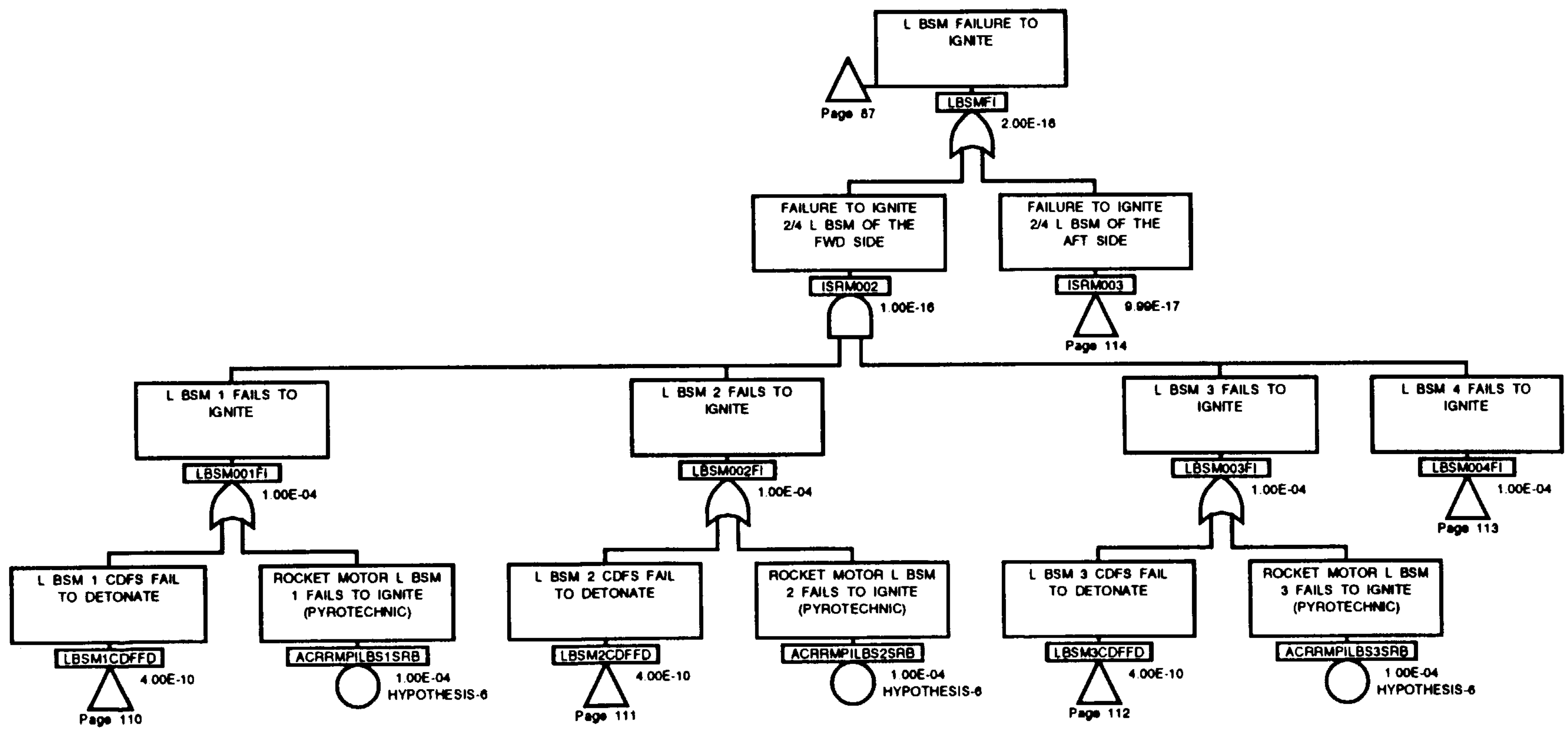

L FWD SEP BOLT PIC A FAILS
Page 103
LSFAPIC
2.95E-04
L SRB SEP ARM SIGNAL A
LSEPARMA
1.02E-04
Page 90
PIC L SEP BOLT FWD A FAILS TO ARM
ACRPCFALSFASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1 SIGNAL A
LSEPF1A
1.02E-04
Page 91
PIC L SEP BOLT FWD A FAILS TO FIRE
ACRPCFFLSFASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2 SIGNAL A
LSEPF2A
1.12E-04
Page 92
CABLE L SEP BOLT FWD A (REPLACEABLE) FAILURE
ACRCARPLSFASRB
4.10E-05
IEEE500

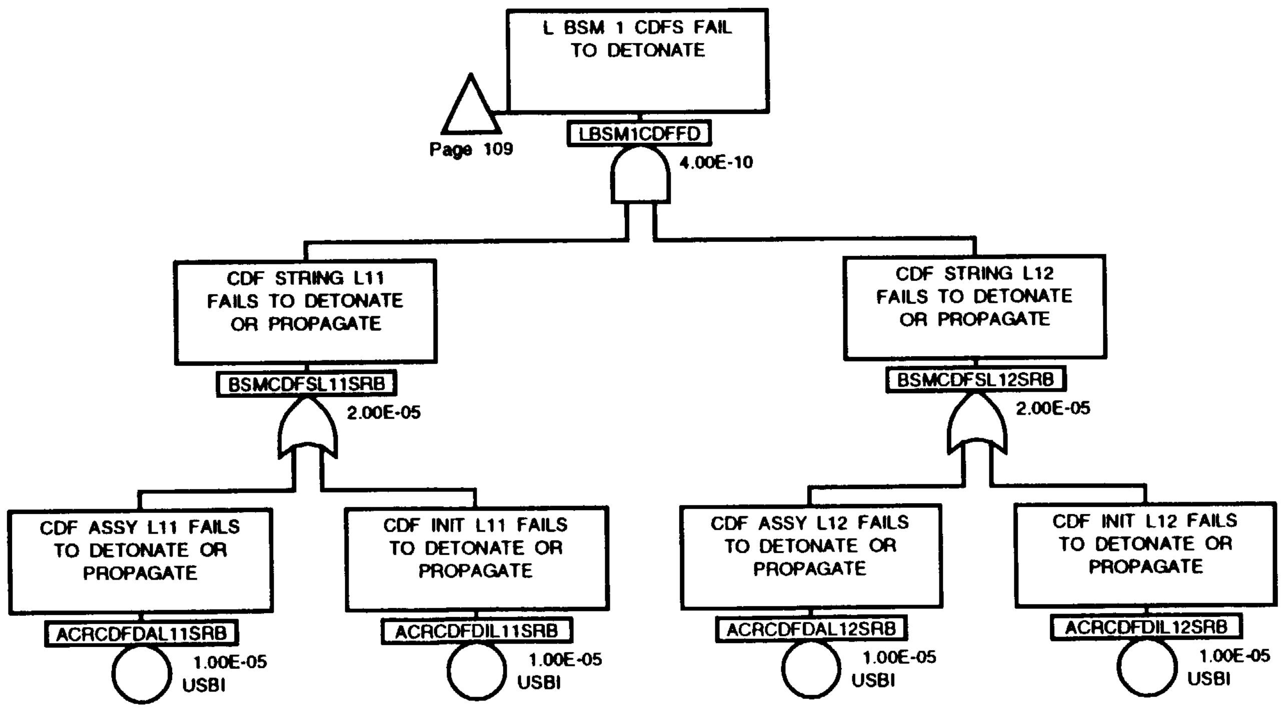

L FWD SEP BOLT PIC B FAILS
Page 103
LSFBPIC
2.95E-04
L SRB SEP ARM SIGNAL B
LSEPARMB
1.02E-04
Page 94
PIC L SEP BOLT FWD B FAILS TO ARM
ACRPCFALSFBSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1 SIGNAL B
LSEPF1B
1.02E-04
Page 95
PIC L SEP BOLT FWD B FAILS TO FIRE
ACRPCFFLSFBSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2 SIGNAL B
LSEPF2B
1.12E-04
Page 96
CABLE L SEP BOLT FWD B (REPLACEABLE) FAILURE
ACRCARPLSFBSRB
4.10E-05
IEEE500

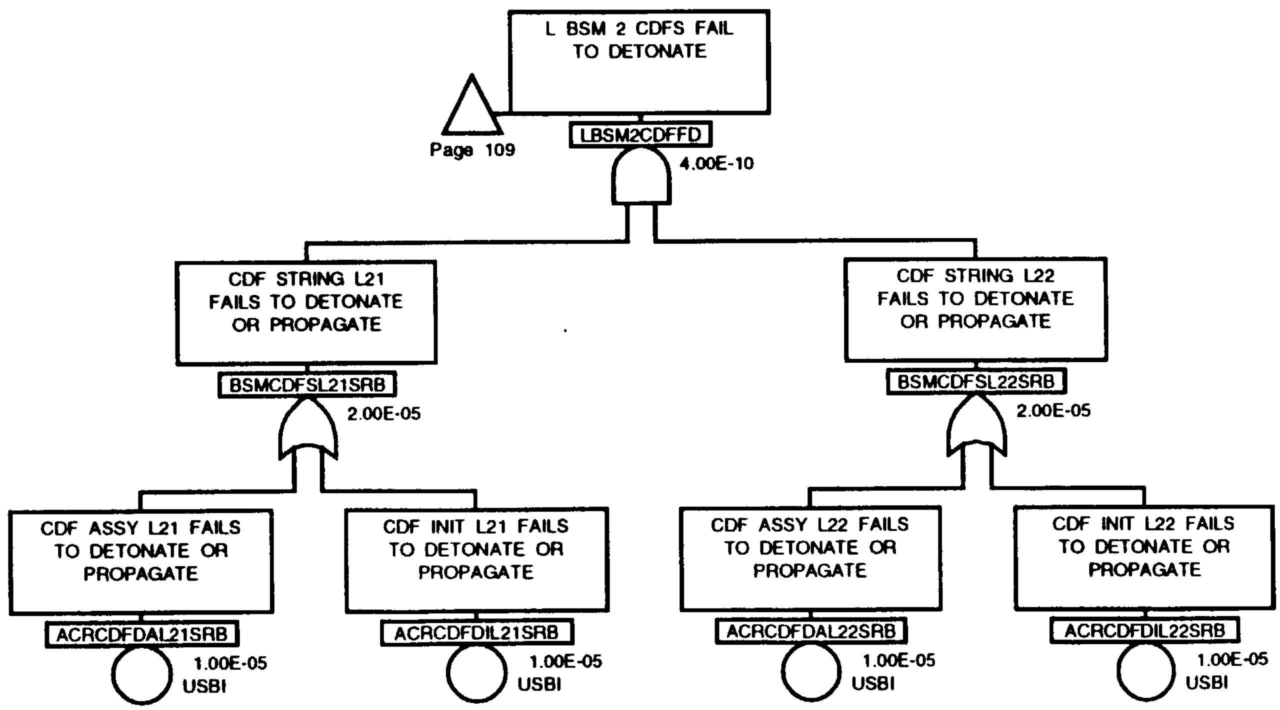

L FWD CDF MANIFOLD FAILURE
Page 87
LFCDFMFD
2.01E-05
CDF L FWD MAN FAILS TO DETONATE OR PROPAGATE
ACRCDFDLFMNSRB
1.00E-05
USBI
L FWD BSM NSDS FAIL TO DETONATE
LFBSMNSDSFD
1.01E-05
L FWD BSM NSD A FAILS TO DETONATE
LFBSMNSDAFD
2.84E-04
L FWD BSM NSD B FAILS TO DETONATE
LFBSMNSDBFD
3.25E-04
NSD L FWD A FAILS TO DETONATE
ACRNDFDLFWASRB
3.00E-05
HYPOTHESIS-2
L FWD BSM PIC A FAILS
LFBSMPICA
2.54E-04
Page 107
NSD L FWD B FAILS TO DETONATE
ACRNDFDLFWBSRB
3.00E-05
HYPOTHESIS-2
L FWD BSM PIC B FAILS
LFBSMPICB
2.95E-04
Page 108


L FWD BSM PIC A
FAILS
LFBSMPICA
2.54E-04
Page 106
L SRB SEP ARM
SIGNAL A
LSEPARMA
1.02E-04
Page 90
PIC L FWD BSM A
FAILS TO ARM
ACRPCFALFBASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1
SIGNAL A
LSEPF1A
1.02E-04
Page 91
PIC L FWD BSM A
FAILS TO FIRE
ACRPCFFLFBASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2
SIGNAL A
LSEPF2A
1.12E-04
Page 92

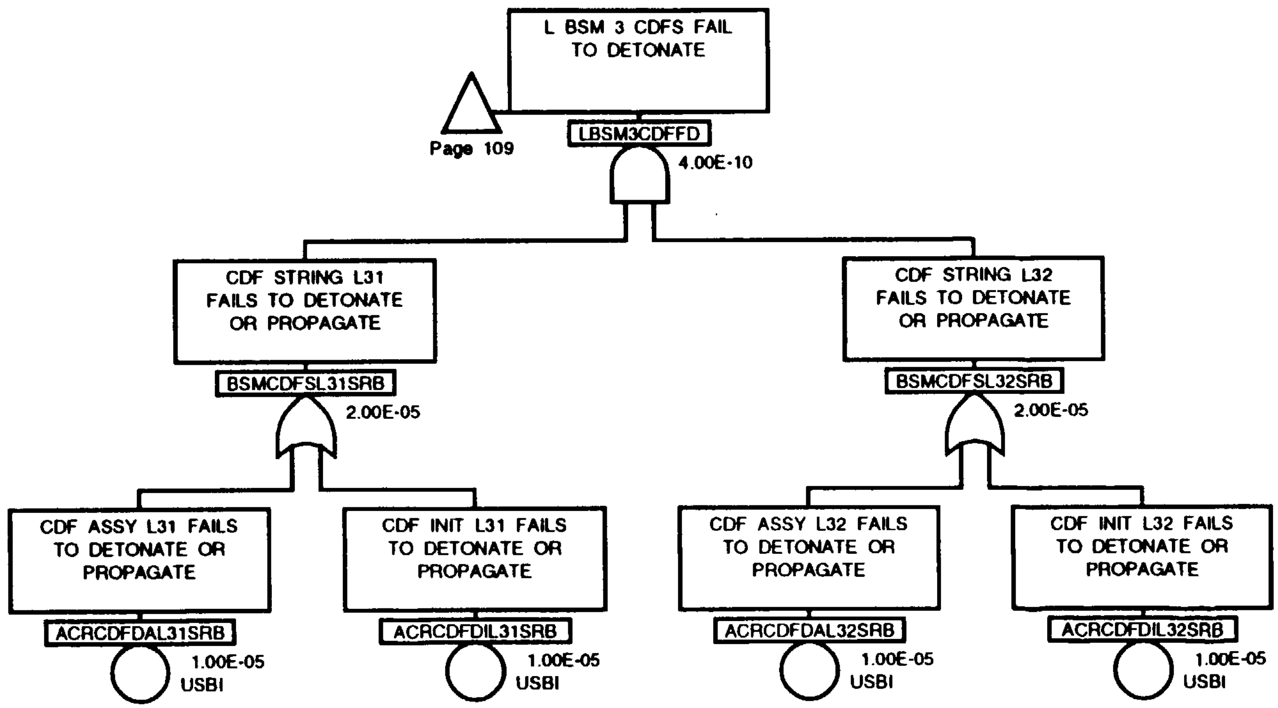

L FWD BSM PIC B
FAILS
LFBSMPICB
2.95E-04
Page 106
L SRB SEP ARM
SIGNAL B
LSEPARMB
1.02E-04
Page 94
PIC L FWD BSM B
FAILS TO ARM
ACRPCFALFBBSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1
SIGNAL B
LSEPF1B
1.02E-04
Page 95
PIC L FWD BSM B
FAILS TO FIRE
ACRPCFFLFBBSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2
SIGNAL B
LSEPF2B
1.12E-04
Page 96
CABLE (REPLACEABLE)
FAILURE SSSW - FWD
PIC
L FWD PIC B
ACRCARPL1BSRB
4.10E-05
IEEE500

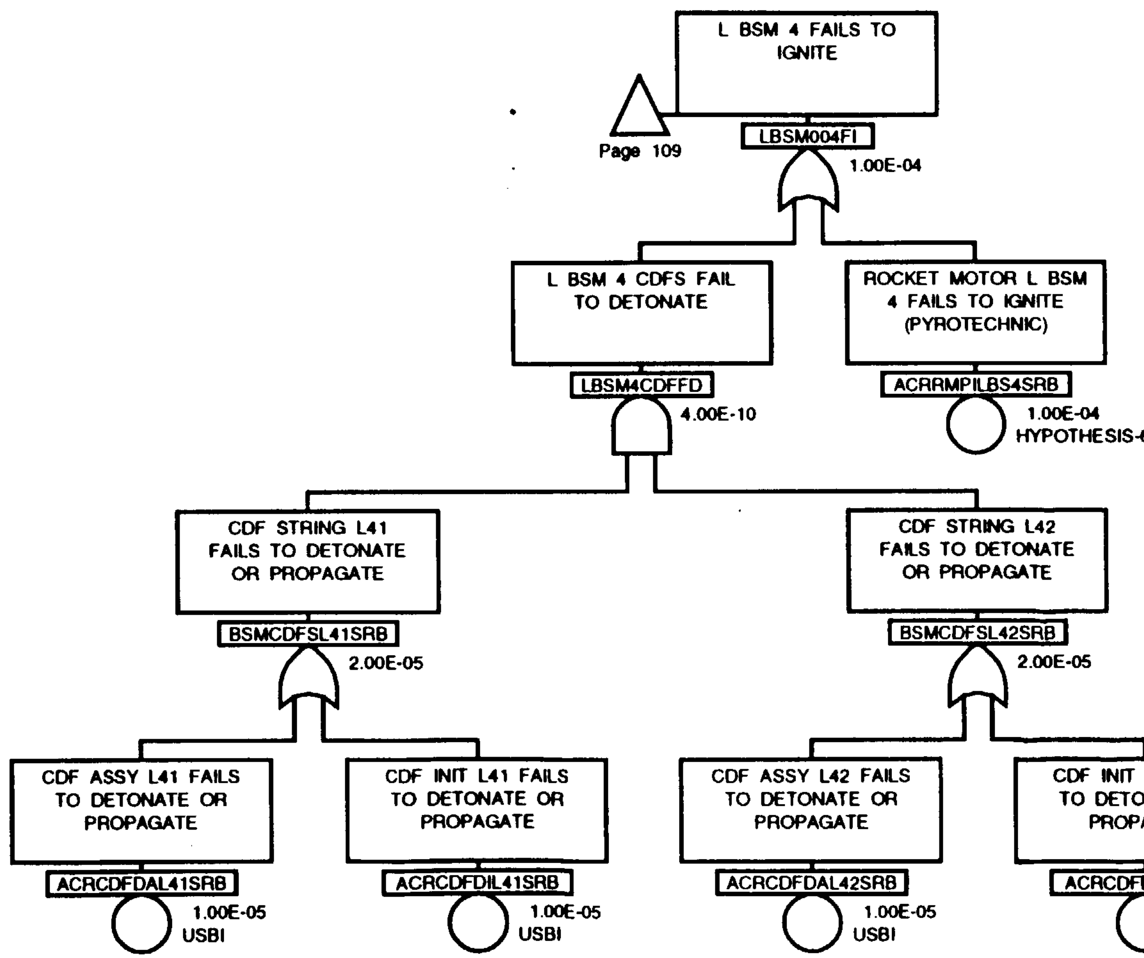

L BSM FAILURE TO IGNITE
Page 87
LBSMFI
2.00E-16
FAILURE TO IGNITE 2/4 L BSM OF THE FWD SIDE
FAILURE TO IGNITE 2/4 L BSM OF THE AFT SIDE
ISRM002
1.00E-16
ISRM003
9.99E-17
Page 114
L BSM 1 FAILS TO IGNITE
LBSM001FI
1.00E-04
L BSM 2 FAILS TO IGNITE
LBSM002FI
1.00E-04
L BSM 3 FAILS TO IGNITE
LBSM003FI
1.00E-04
L BSM 4 FAILS TO IGNITE
LBSM004FI
1.00E-04
Page 113
L BSM 1 CDFS FAIL TO DETONATE
LBSM1CDFFD
4.00E-10
Page 110
ROCKET MOTOR L BSM 1 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPILBS1SRB
1.00E-04
HYPOTHESIS-6
L BSM 2 CDFS FAIL TO DETONATE
LBSM2CDFFD
4.00E-10
Page 111
ROCKET MOTOR L BSM 2 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPILBS2SRB
1.00E-04
HYPOTHESIS-6
L BSM 3 CDFS FAIL TO DETONATE
LBSM3CDFFD
4.00E-10
Page 112
ROCKET MOTOR L BSM 3 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPILBS3SRB
1.00E-04
HYPOTHESIS-6

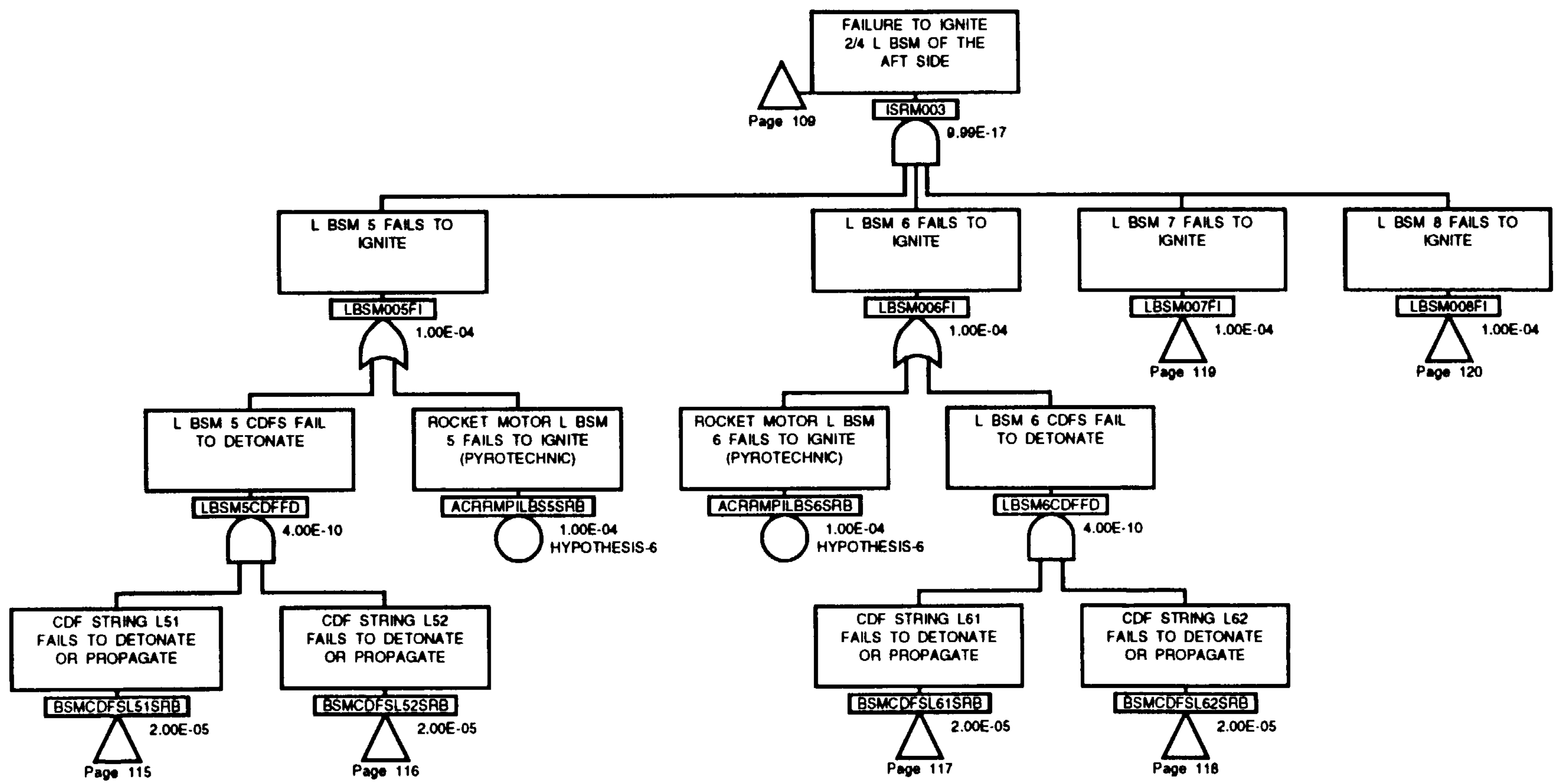

L BSM 1 CDFS FAIL TO DETONATE
LBSM1CDFFD
4.00E-10
Page 109
CDF STRING L11 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL11SRB
2.00E-05
CDF STRING L12 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL12SRB
2.00E-05
CDF ASSY L11 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL11SRB
1.00E-05
USBI
CDF INIT L11 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL11SRB
1.00E-05
USBI
CDF ASSY L12 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL12SRB
1.00E-05
USBI
CDF INIT L12 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL12SRB
1.00E-05
USBI

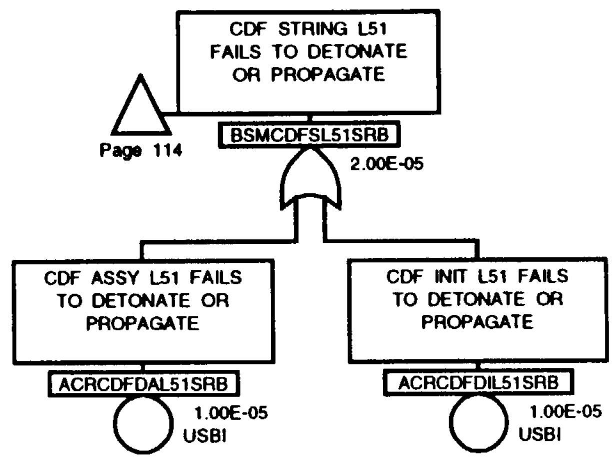


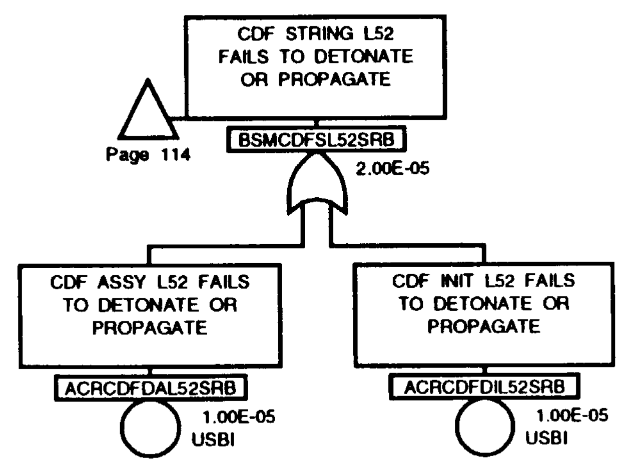
L BSM 2 CDFS FAIL TO DETONATE
Page 109
LBSM2CDFFD
4.00E-10
CDF STRING L21 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL21SRB
2.00E-05
CDF STRING L22 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL22SRB
2.00E-05
CDF ASSY L21 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL21SRB
1.00E-05
USBI
CDF INIT L21 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL21SRB
1.00E-05
USBI
CDF ASSY L22 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL22SRB
1.00E-05
USBI
CDF INIT L22 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL22SRB
1.00E-05
USBI

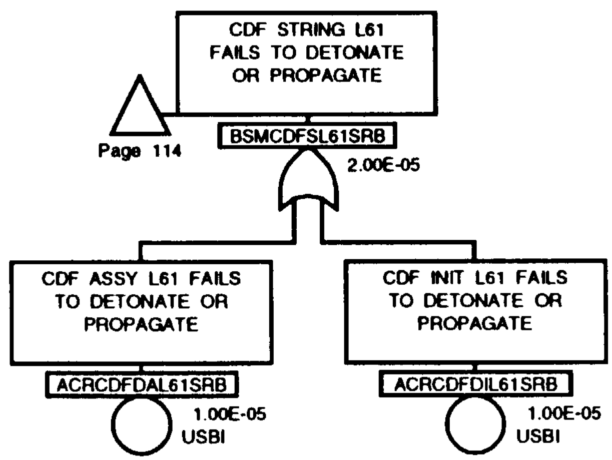

L BSM 3 CDFS FAIL TO DETONATE
Page 109
LBSM3CDFFD
4.00E-10
CDF STRING L31 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL31SRB
2.00E-05
CDF STRING L32 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL32SRB
2.00E-05
CDF ASSY L31 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL31SRB
1.00E-05
USBI
CDF INIT L31 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL31SRB
1.00E-05
USBI
CDF ASSY L32 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL32SRB
1.00E-05
USBI
CDF INIT L32 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL32SRB
1.00E-05
USBI

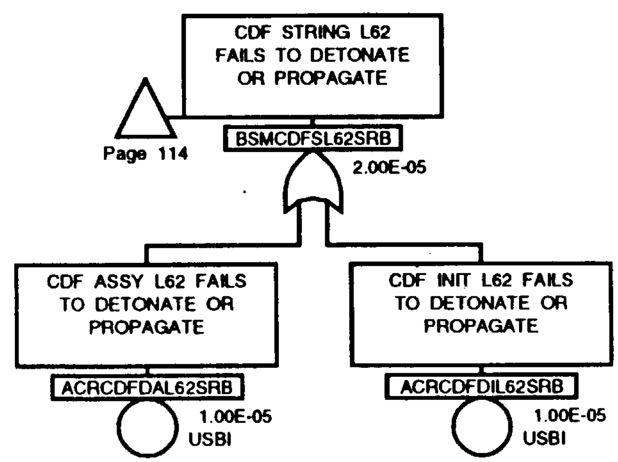

L BSM 4 FAILS TO IGNITE
Page 109
LBSM004FI
1.00E-04
L BSM 4 CDFS FAIL TO DETONATE
LBSM4CDFFD
4.00E-10
ROCKET MOTOR L BSM 4 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPILBS4SRB
1.00E-04
HYPOTHESIS-6
CDF STRING L41 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL41SRB
2.00E-05
CDF STRING L42 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL42SRB
2.00E-05
CDF ASSY L41 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL41SRB
1.00E-05
USBI
CDF INIT L41 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL41SRB
1.00E-05
USBI
CDF ASSY L42 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL42SRB
1.00E-05
USBI
CDF INIT L42 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL42SRB
1.00E-05
USBI

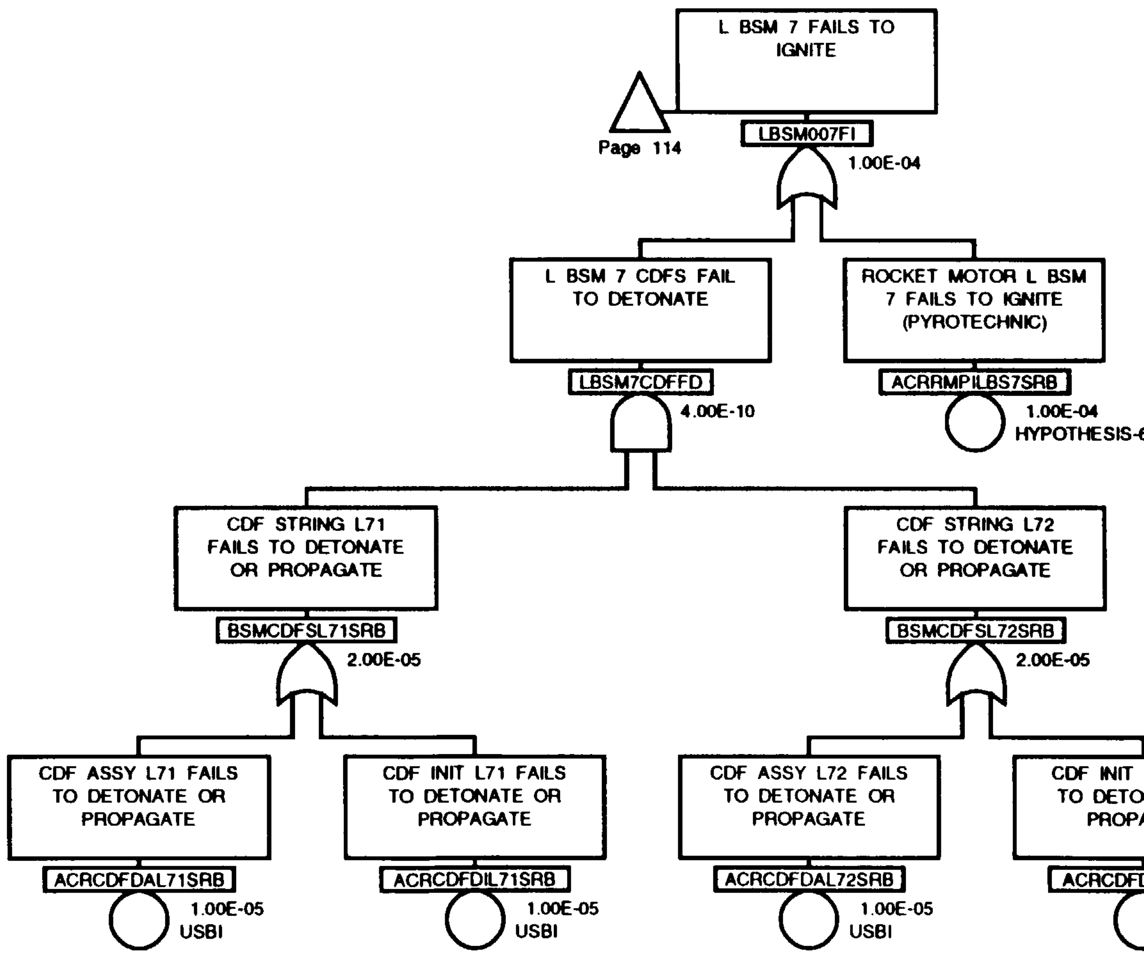

FAILURE TO IGNITE 2/4 L BSM OF THE AFT SIDE
ISRM003
9.99E-17
Page 109
L BSM 5 FAILS TO IGNITE
LBSM005FI
1.00E-04
L BSM 6 FAILS TO IGNITE
LBSM006FI
1.00E-04
L BSM 7 FAILS TO IGNITE
LBSM007FI
1.00E-04
Page 119
L BSM 8 FAILS TO IGNITE
LBSM008FI
1.00E-04
Page 120
L BSM 5 CDFS FAIL TO DETONATE
LBSM5CDFFD
4.00E-10
ROCKET MOTOR L BSM 5 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPILBS5SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR L BSM 6 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPILBS6SRB
1.00E-04
HYPOTHESIS-6
L BSM 6 CDFS FAIL TO DETONATE
LBSM6CDFFD
4.00E-10
CDF STRING L51 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL51SRB
2.00E-05
Page 115
CDF STRING L52 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL52SRB
2.00E-05
Page 116
CDF STRING L61 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL61SRB
2.00E-05
Page 117
CDF STRING L62 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL62SRB
2.00E-05
Page 118

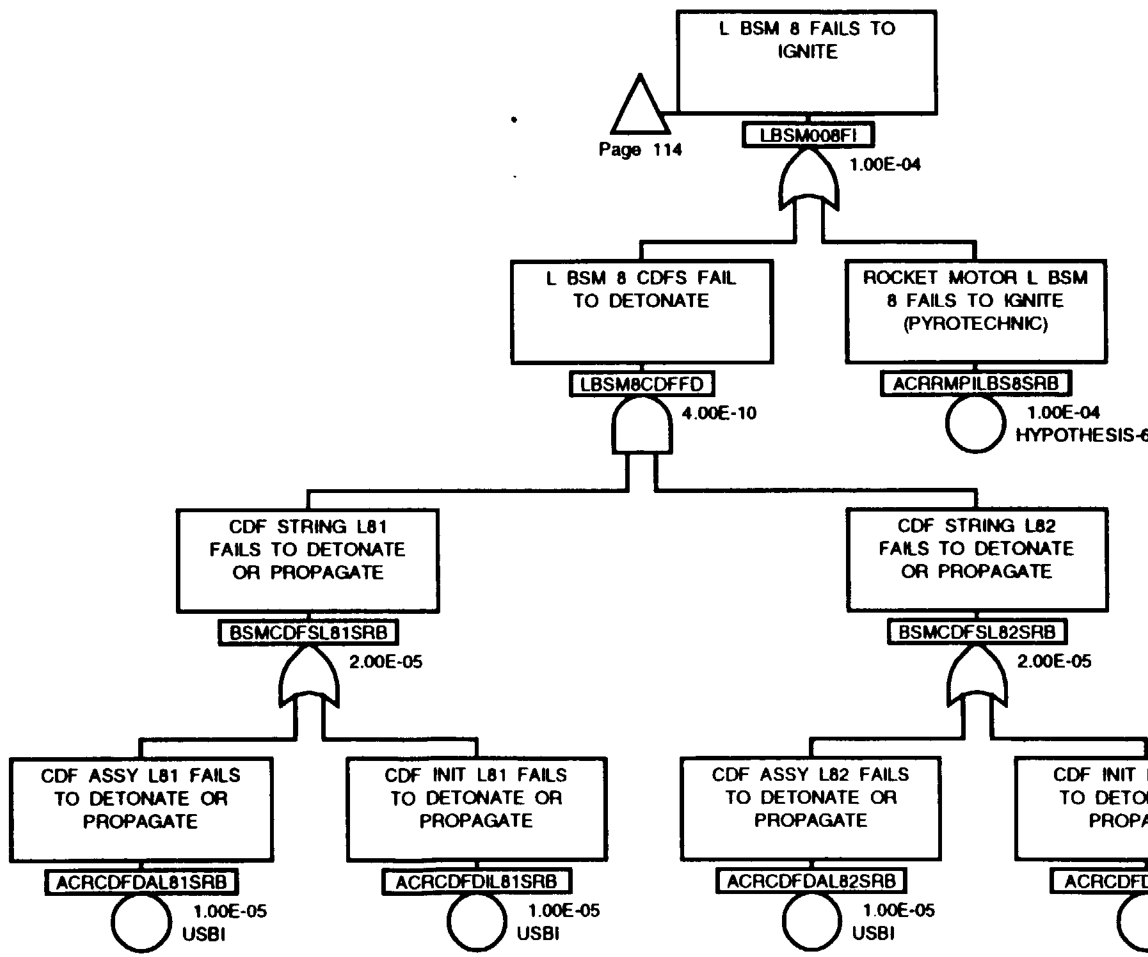

CDF STRING L51 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL51SRB
2.00E-05
Page 114
CDF ASSY L51 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL51SRB
1.00E-05
USBI
CDF INIT L51 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL51SRB
1.00E-05
USBI


CDF STRING L52 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL52SRB
2.00E-05
Page 114
CDF ASSY L52 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL52SRB
1.00E-05
USBI
CDF INIT L52 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL52SRB
1.00E-05
USBI

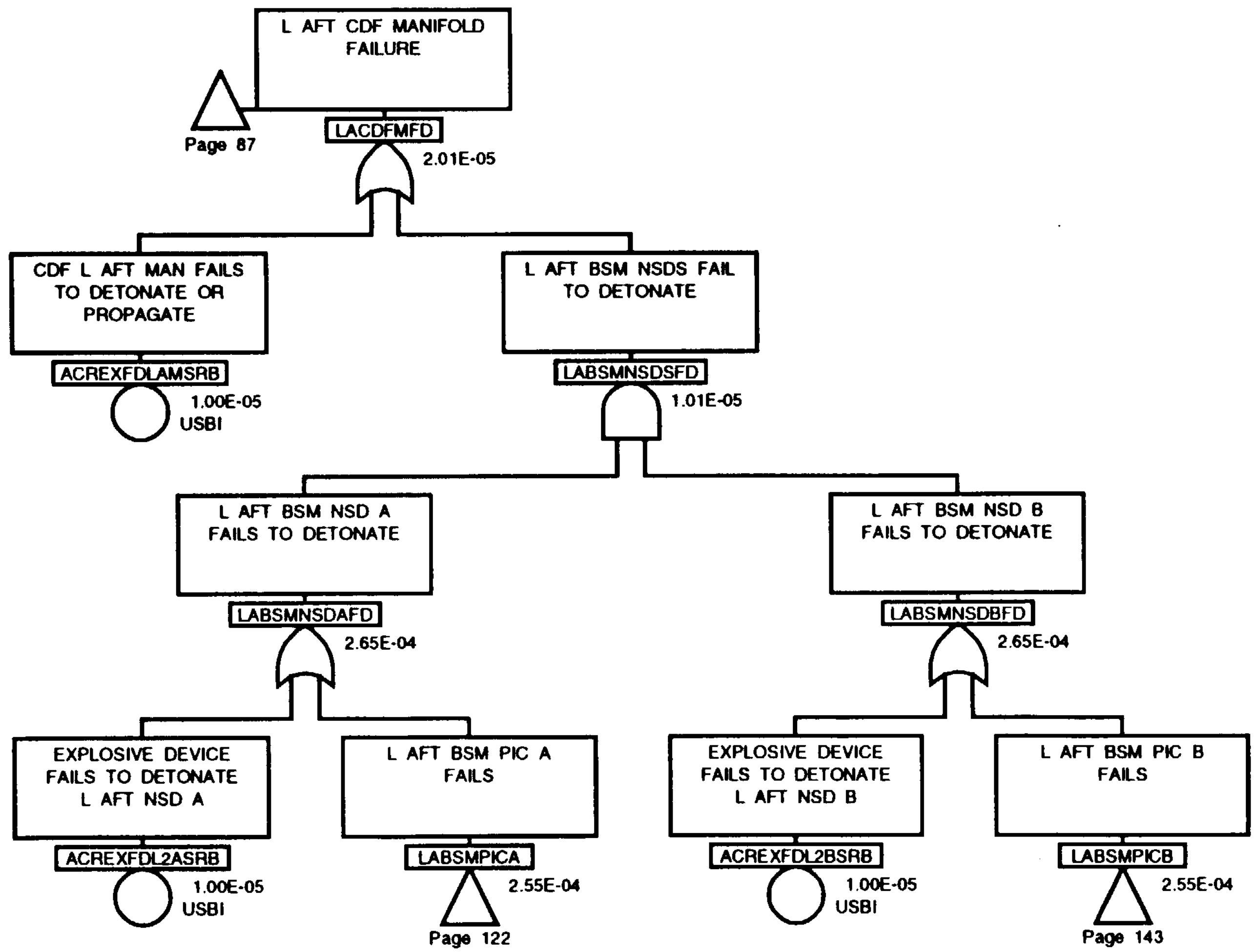

CDF STRING L61
FAILS TO DETONATE
OR PROPAGATE
BSMCDFSL61SRB
2.00E-05
Page 114
CDF ASSY L61 FAILS
TO DETONATE OR
PROPAGATE
ACRCDFDAL61SRB
1.00E-05
USBI
CDF INIT L61 FAILS
TO DETONATE OR
PROPAGATE
ACRCDFDIL61SRB
1.00E-05
USBI


CDF STRING L62 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL62SRB
2.00E-05
Page 114
CDF ASSY L62 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL62SRB
1.00E-05
USBI
CDF INIT L62 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL62SRB
1.00E-05
USBI

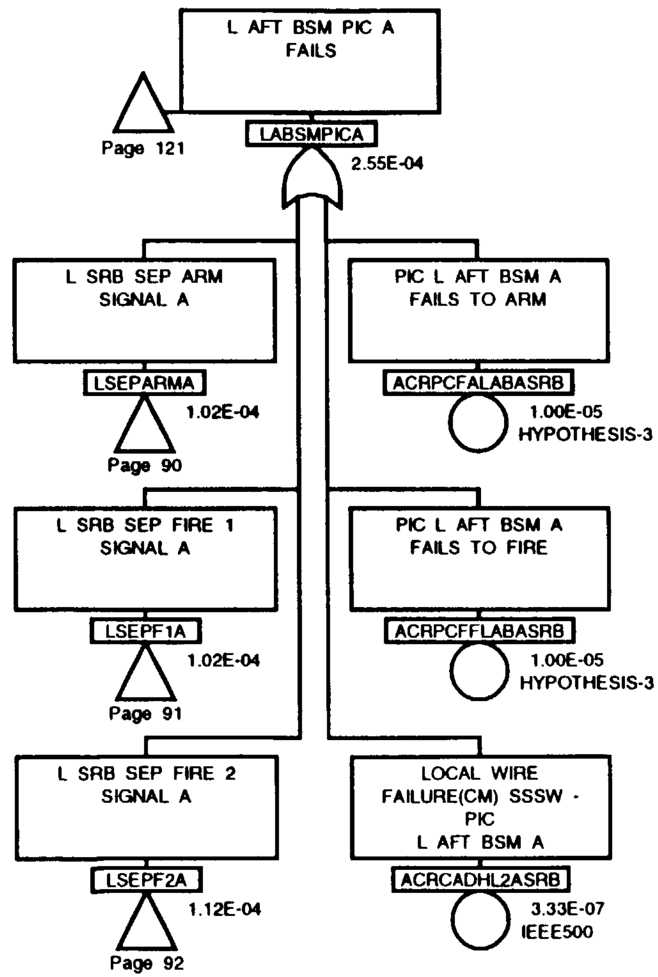

L BSM 7 FAILS TO IGNITE
LBSM007FI
1.00E-04
Page 114
L BSM 7 CDFS FAIL TO DETONATE
LBSM7CDFFD
4.00E-10
ROCKET MOTOR L BSM 7 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPILBS7SRB
1.00E-04
HYPOTHESIS-6
CDF STRING L71 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL71SRB
2.00E-05
CDF STRING L72 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL72SRB
2.00E-05
CDF ASSY L71 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL71SRB
1.00E-05
USBI
CDF INIT L71 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL71SRB
1.00E-05
USBI
CDF ASSY L72 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL72SRB
1.00E-05
USBI
CDF INIT L72 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIL72SRB
1.00E-05
USBI

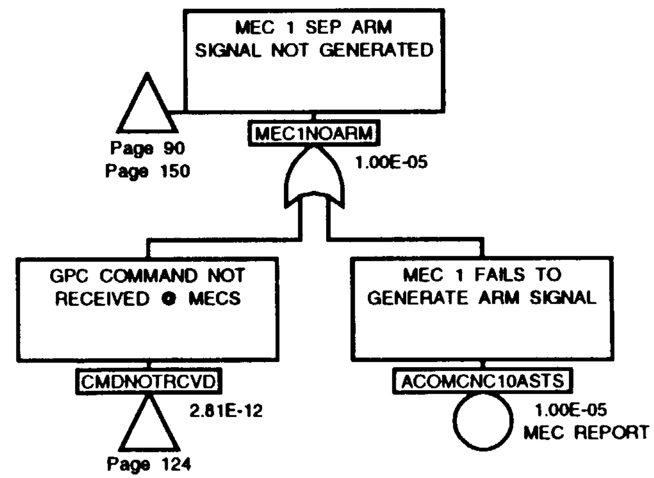


L BSM 8 FAILS TO IGNITE
Page 114
LBSM008FI
1.00E-04
L BSM 8 CDFS FAIL TO DETONATE
ROCKET MOTOR L BSM 8 FAILS TO IGNITE (PYROTECHNIC)
LBSM8CDFFD
4.00E-10
ACRRMPILBS8SRB
1.00E-04
HYPOTHESIS-6
CDF STRING L81 FAILS TO DETONATE OR PROPAGATE
CDF STRING L82 FAILS TO DETONATE OR PROPAGATE
BSMCDFSL81SRB
2.00E-05
BSMCDFSL82SRB
2.00E-05
CDF ASSY L81 FAILS TO DETONATE OR PROPAGATE
CDF INIT L81 FAILS TO DETONATE OR PROPAGATE
CDF ASSY L82 FAILS TO DETONATE OR PROPAGATE
CDF INIT L82 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAL81SRB
1.00E-05
USBI
ACRCDFDIL81SRB
1.00E-05
USBI
ACRCDFDAL82SRB
1.00E-05
USBI
ACRCDFDIL82SRB
1.00E-05
USBI

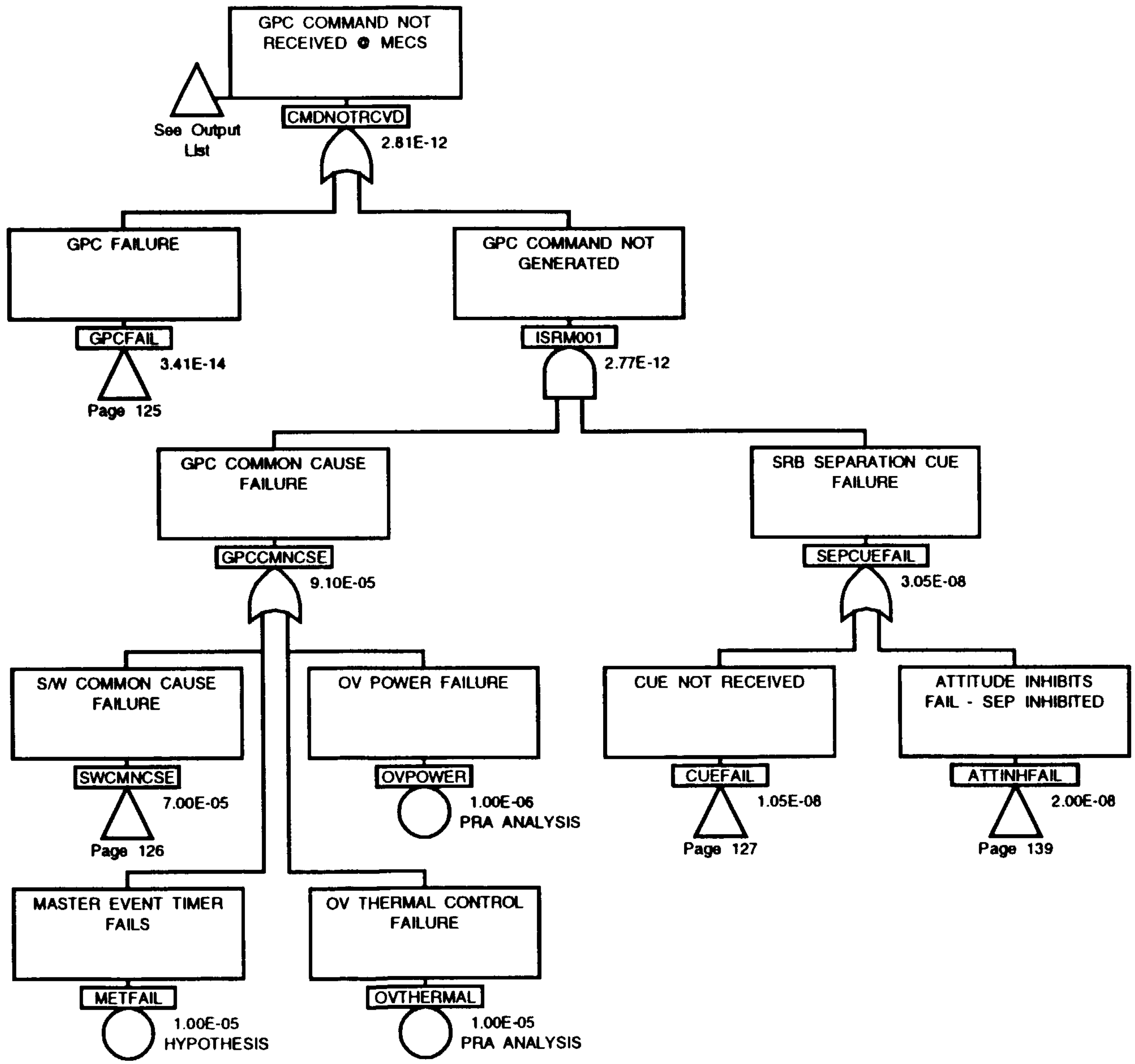


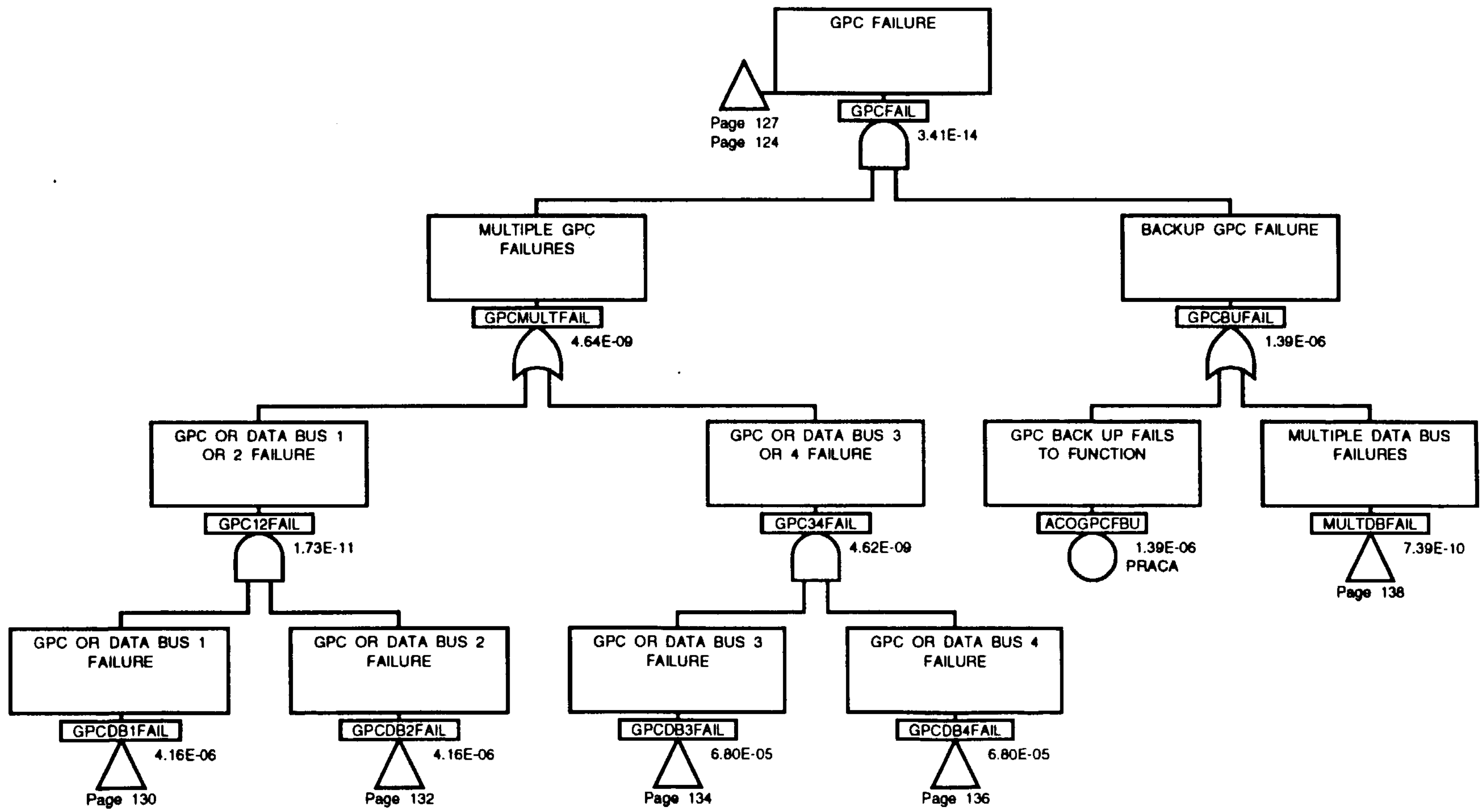
L AFT CDF MANIFOLD FAILURE
LACDFMFD
2.01E-05
Page 87
CDF L AFT MAN FAILS TO DETONATE OR PROPAGATE
ACREXFDLAMSRB
1.00E-05
USBI
L AFT BSM NSDS FAIL TO DETONATE
LABSMNSDSFD
1.01E-05
L AFT BSM NSD A FAILS TO DETONATE
LABSMNSDAFD
2.65E-04
L AFT BSM NSD B FAILS TO DETONATE
LABSMNSDBFD
2.65E-04
EXPLOSIVE DEVICE FAILS TO DETONATE L AFT NSD A
ACREXFDL2ASRB
1.00E-05
USBI
L AFT BSM PIC A FAILS
LABSMPICA
2.55E-04
Page 122
EXPLOSIVE DEVICE FAILS TO DETONATE L AFT NSD B
ACREXFDL2BSRB
1.00E-05
USBI
L AFT BSM PIC B FAILS
LABSMPICB
2.55E-04
Page 143

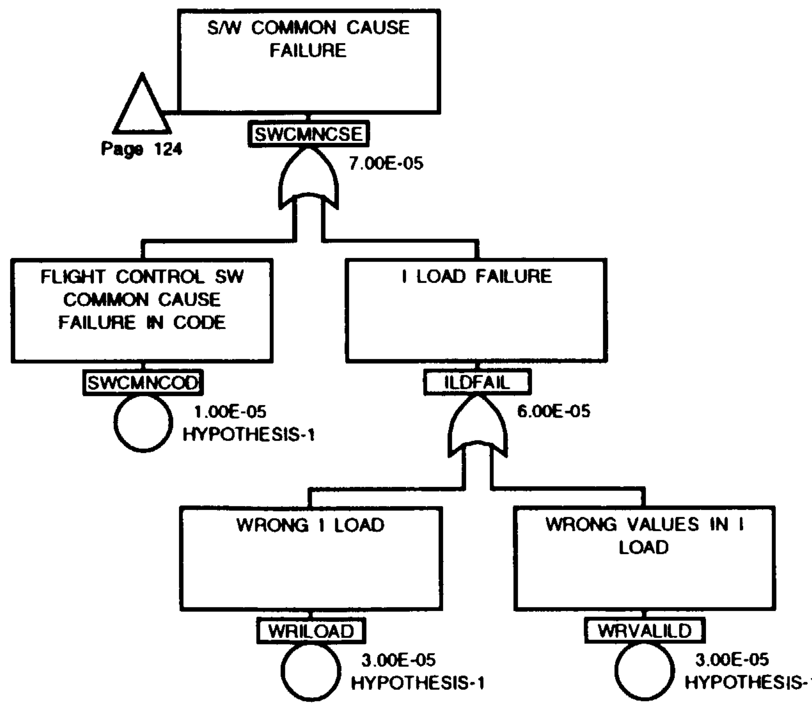

L AFT BSM PIC A FAILS
Page 121
LABSMPICA
2.55E-04
L SRB SEP ARM SIGNAL A
LSEPARMA
1.02E-04
Page 90
PIC L AFT BSM A FAILS TO ARM
ACRPCFALABASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1 SIGNAL A
LSEPF1A
1.02E-04
Page 91
PIC L AFT BSM A FAILS TO FIRE
ACRPCFFLABASRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2 SIGNAL A
LSEPF2A
1.12E-04
Page 92
LOCAL WIRE FAILURE(CM) SSSW - PIC L AFT BSM A
ACRCADHL2ASRB
3.33E-07
IEEE500

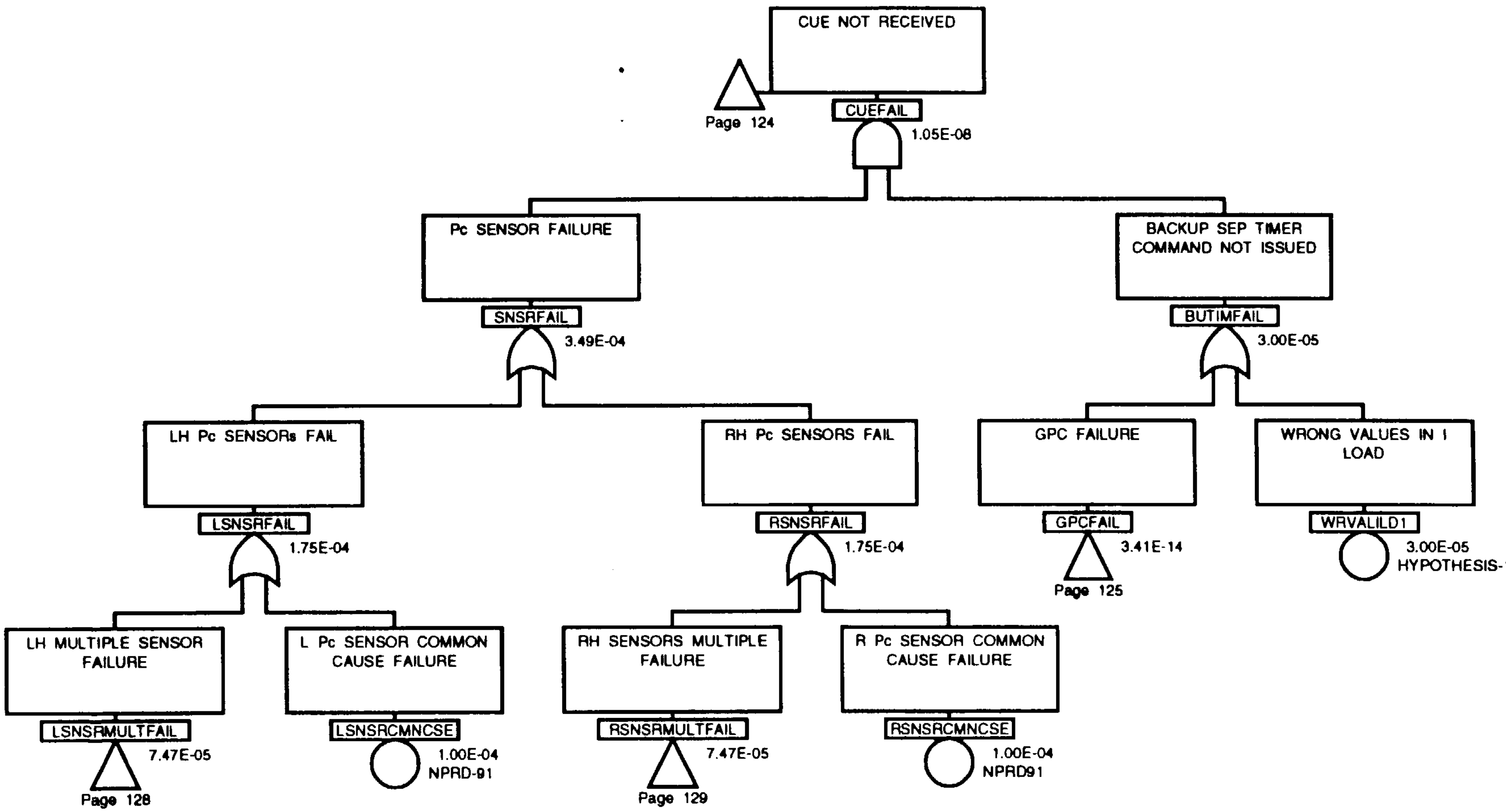

MEC 1 SEP ARM
SIGNAL NOT GENERATED
MEC1NOARM
1.00E-05
Page 90
Page 150
GPC COMMAND NOT
RECEIVED @ MECS
CMDNOTRCVD
2.81E-12
Page 124
MEC 1 FAILS TO
GENERATE ARM SIGNAL
ACOMCNC10ASTS
1.00E-05
MEC REPORT

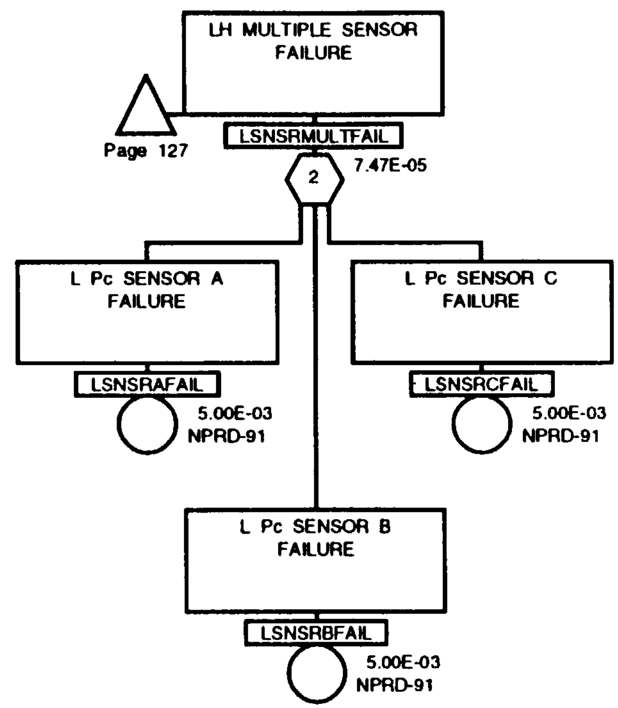
CMDNOTRCVD Outputs:
Page 123, Page 141, Page 142, Page 144, Page 146, Page 147

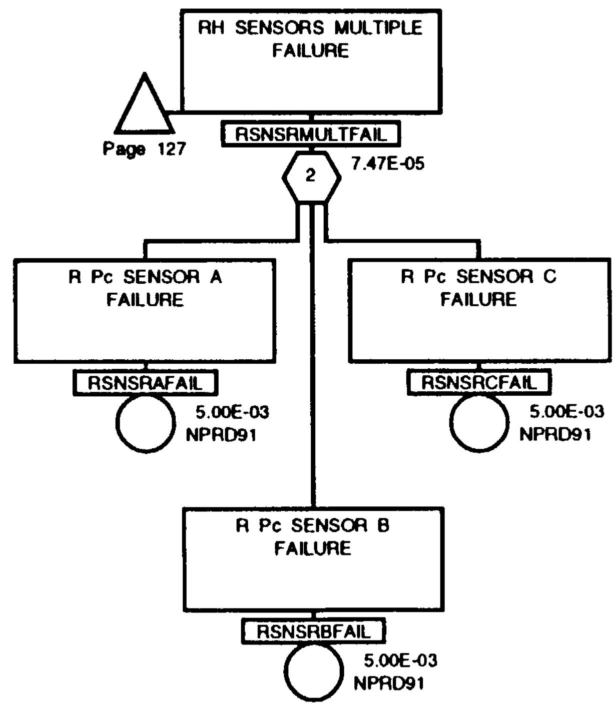


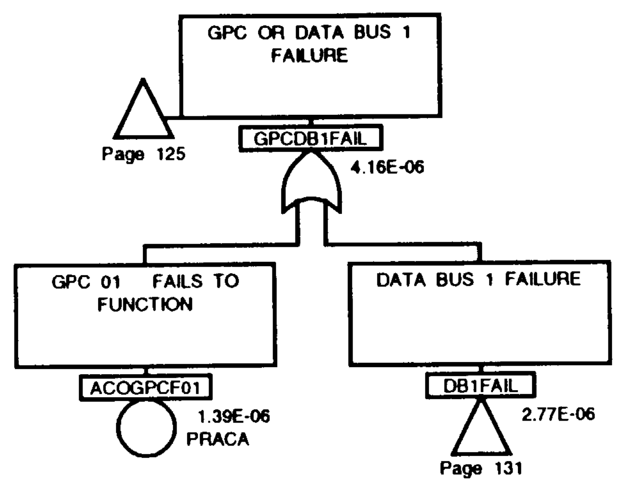

GPC FAILURE
GPCFAIL
3.41E-14
Page 127
Page 124
MULTIPLE GPC FAILURES
GPCMULTFAIL
4.64E-09
BACKUP GPC FAILURE
GPCBUFAIL
1.39E-06
GPC OR DATA BUS 1 OR 2 FAILURE
GPC12FAIL
1.73E-11
GPC OR DATA BUS 3 OR 4 FAILURE
GPC34FAIL
4.62E-09
GPC BACK UP FAILS TO FUNCTION
ACOGPCFBU
1.39E-06
PRACA
MULTIPLE DATA BUS FAILURES
MULTDBFAIL
7.39E-10
Page 138
GPC OR DATA BUS 1 FAILURE
GPCDB1FAIL
4.16E-06
Page 130
GPC OR DATA BUS 2 FAILURE
GPCDB2FAIL
4.16E-06
Page 132
GPC OR DATA BUS 3 FAILURE
GPCDB3FAIL
6.80E-05
Page 134
GPC OR DATA BUS 4 FAILURE
GPCDB4FAIL
6.80E-05
Page 136

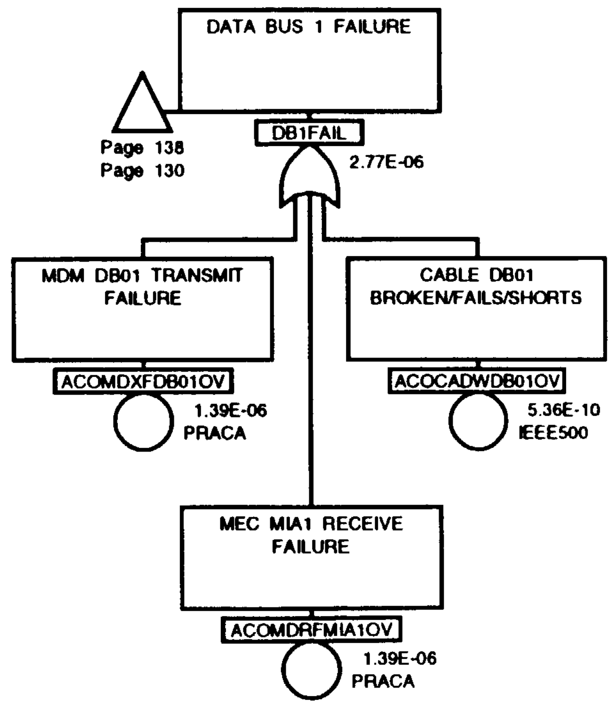

S/W COMMON CAUSE FAILURE
SWCMNCSE
7.00E-05
Page 124
FLIGHT CONTROL SW COMMON CAUSE FAILURE IN CODE
SWCMNCOD
1.00E-05
HYPOTHESIS-1
I LOAD FAILURE
ILDFAIL
6.00E-05
WRONG I LOAD
WRILOAD
3.00E-05
HYPOTHESIS-1
WRONG VALUES IN I LOAD
WRVALILD
3.00E-05
HYPOTHESIS-1

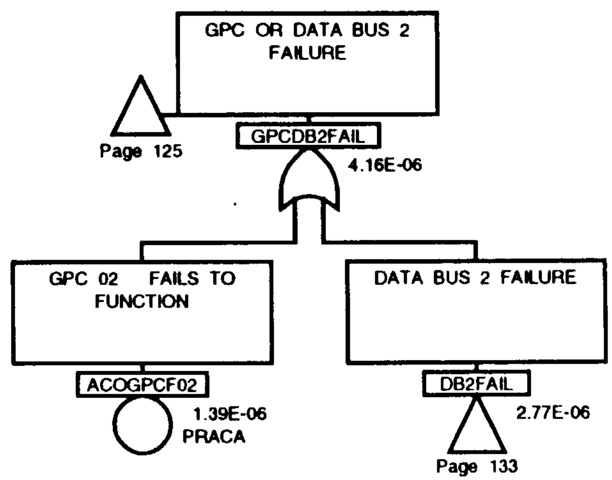

CUE NOT RECEIVED
Page 124
CUEFAIL
1.05E-08
Pc SENSOR FAILURE
SNSRFAIL
3.49E-04
BACKUP SEP TIMER COMMAND NOT ISSUED
BUTIMFAIL
3.00E-05
LH Pc SENSORs FAIL
LSNSRFAIL
1.75E-04
RH Pc SENSORS FAIL
RSNSRFAIL
1.75E-04
GPC FAILURE
GPCFAIL
3.41E-14
Page 125
WRONG VALUES IN I LOAD
WRVALILD1
3.00E-05
HYPOTHESIS-1
LH MULTIPLE SENSOR FAILURE
LSNSRMULTFAIL
7.47E-05
Page 128
L Pc SENSOR COMMON CAUSE FAILURE
LSNSRCMNCSE
1.00E-04
NPRD-91
RH SENSORS MULTIPLE FAILURE
RSNSRMULTFAIL
7.47E-05
Page 129
R Pc SENSOR COMMON CAUSE FAILURE
RSNSRCMNCSE
1.00E-04
NPRD91

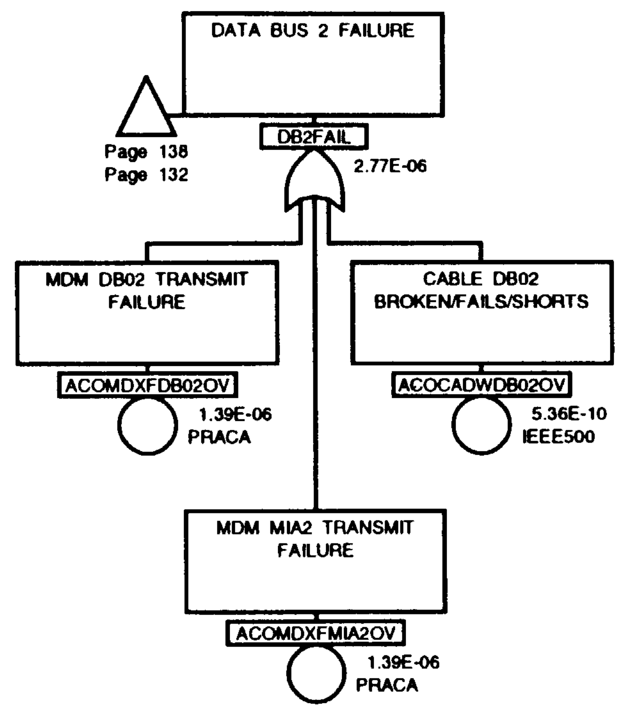

LH MULTIPLE SENSOR FAILURE
LSNSRMULTFAIL
Page 127
2
7.47E-05
L Pc SENSOR A FAILURE
LSNSRAFAIL
5.00E-03
NPRD-91
L Pc SENSOR C FAILURE
LSNSRCFAIL
5.00E-03
NPRD-91
L Pc SENSOR B FAILURE
LSNSRBFAIL
5.00E-03
NPRD-91

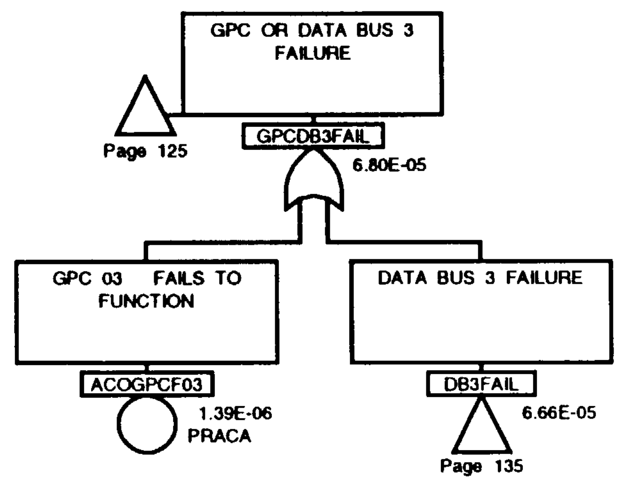

RH SENSORS MULTIPLE FAILURE
RSNSRMULTFAIL
7.47E-05
2
Page 127
R Pc SENSOR A FAILURE
RSNSRAFAIL
5.00E-03
NPRD91
R Pc SENSOR C FAILURE
RSNSRCFAIL
5.00E-03
NPRD91
R Pc SENSOR B FAILURE
RSNSRBFAIL
5.00E-03
NPRD91

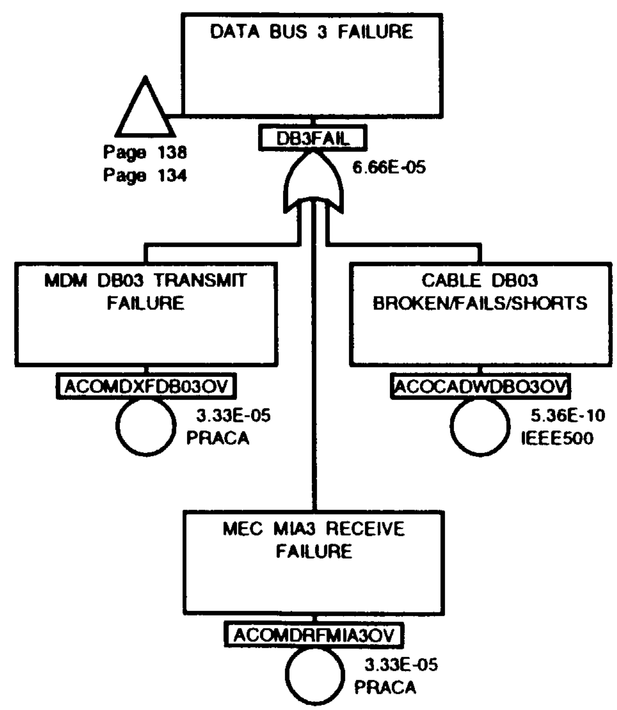

GPC OR DATA BUS 1 FAILURE
Page 125
GPCDB1FAIL
4.16E-06
GPC 01 FAILS TO FUNCTION
ACOGPCF01
1.39E-06
PRACA
DATA BUS 1 FAILURE
DB1FAIL
2.77E-06
Page 131

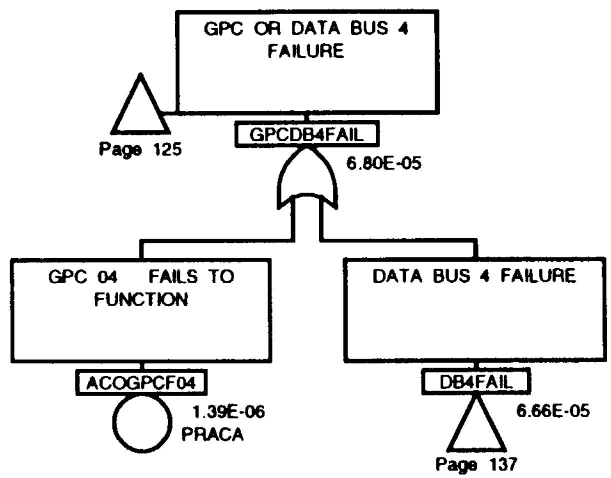

DATA BUS 1 FAILURE
DB1FAIL
2.77E-06
Page 138
Page 130
MDM DB01 TRANSMIT FAILURE
ACOMDXFDB01OV
1.39E-06
PRACA
CABLE DB01 BROKEN/FAILS/SHORTS
ACOCADWDB01OV
5.36E-10
IEEE500
MEC MIA1 RECEIVE FAILURE
ACOMDRFMIA1OV
1.39E-06
PRACA

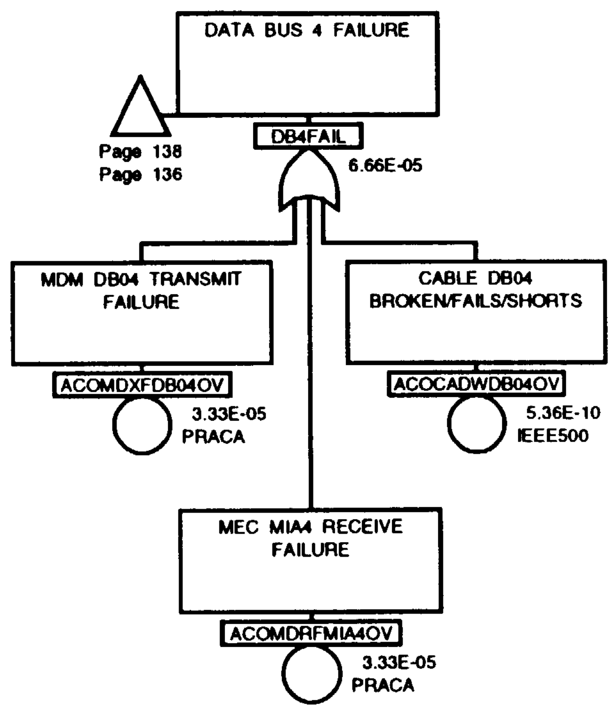

GPC OR DATA BUS 2 FAILURE
GPCDB2FAIL
4.16E-06
Page 125
GPC 02 FAILS TO FUNCTION
ACOGPCF02
1.39E-06
PRACA
DATA BUS 2 FAILURE
DB2FAIL
2.77E-06
Page 133

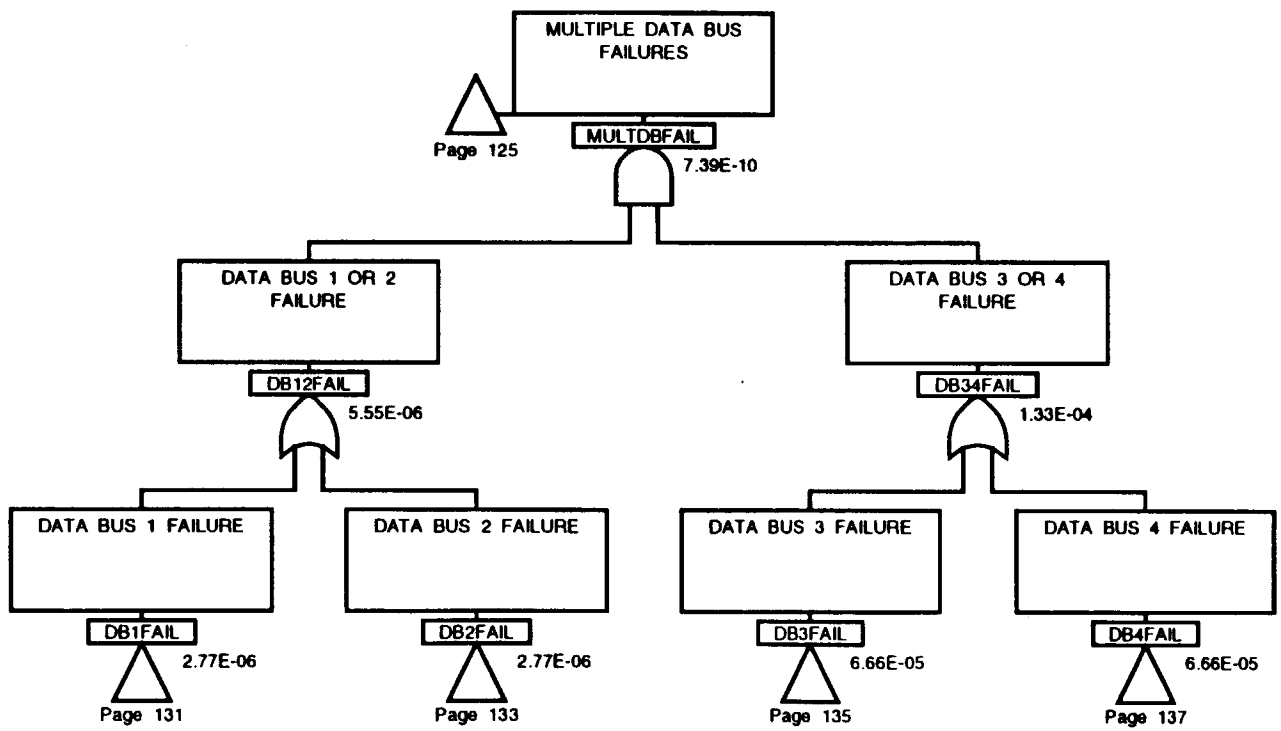

DATA BUS 2 FAILURE
DB2FAIL
2.77E-06
Page 138
Page 132
MDM DB02 TRANSMIT FAILURE
ACOMDXFDB02OV
1.39E-06
PRACA
CABLE DB02 BROKEN/FAILS/SHORTS
ACOCADWDB02OV
5.36E-10
IEEE500
MDM MIA2 TRANSMIT FAILURE
ACOMDXFMIA2OV
1.39E-06
PRACA

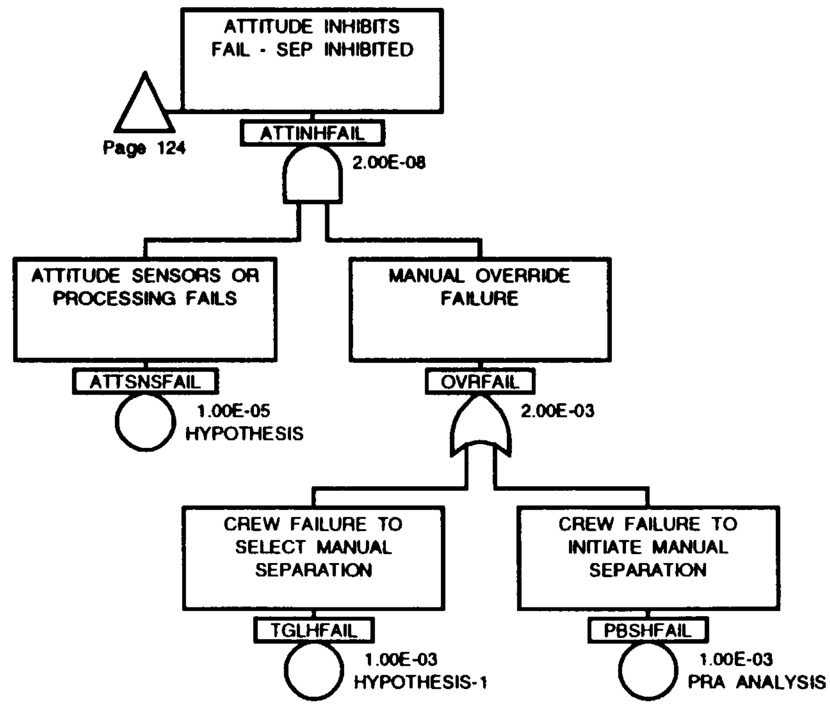

GPC OR DATA BUS 3 FAILURE
GPCDB3FAIL
6.80E-05
Page 125
GPC 03 FAILS TO FUNCTION
ACOGPCF03
1.39E-06
PRACA
DATA BUS 3 FAILURE
DB3FAIL
6.66E-05
Page 135

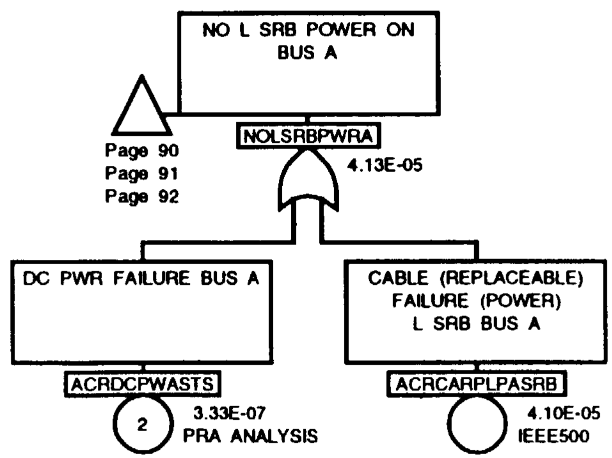

DATA BUS 3 FAILURE
DB3FAIL
6.66E-05
Page 138
Page 134
MDM DB03 TRANSMIT FAILURE
ACOMDXFDB03OV
3.33E-05
PRACA
CABLE DB03 BROKEN/FAILS/SHORTS
ACOCADWDBO3OV
5.36E-10
IEEE500
MEC MIA3 RECEIVE FAILURE
ACOMDRFMIA3OV
3.33E-05
PRACA

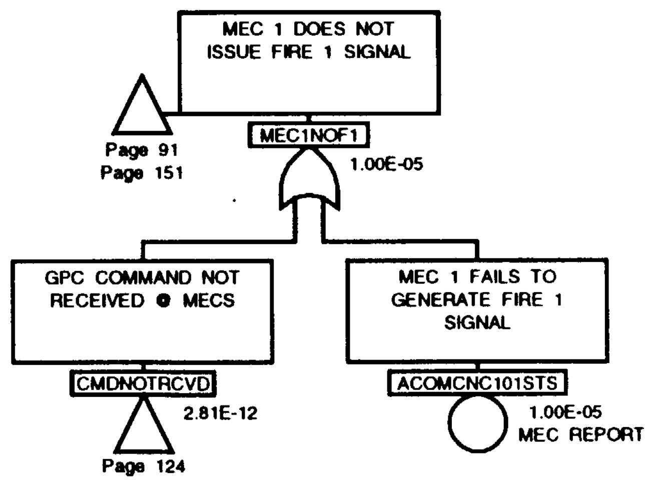

GPC OR DATA BUS 4 FAILURE
Page 125
GPCDB4FAIL
6.80E-05
GPC 04 FAILS TO FUNCTION
ACOGPCF04
1.39E-06
PRACA
DATA BUS 4 FAILURE
DB4FAIL
6.66E-05
Page 137


DATA BUS 4 FAILURE
Page 138
Page 136
DB4FAIL
6.66E-05
MDM DB04 TRANSMIT FAILURE
ACOMDXFDB04OV
3.33E-05
PRACA
CABLE DB04 BROKEN/FAILS/SHORTS
ACOCADWDB04OV
5.36E-10
IEEE500
MEC MIA4 RECEIVE FAILURE
ACOMDRFMIA4OV
3.33E-05
PRACA

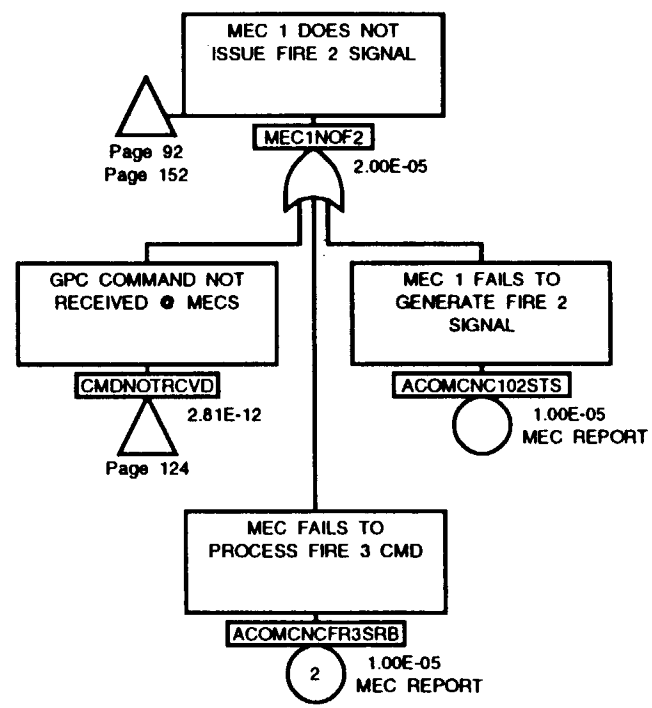

MULTIPLE DATA BUS FAILURES
Page 125
MULTDBFAIL
7.39E-10
DATA BUS 1 OR 2 FAILURE
DB12FAIL
5.55E-06
DATA BUS 3 OR 4 FAILURE
DB34FAIL
1.33E-04
DATA BUS 1 FAILURE
DB1FAIL
2.77E-06
Page 131
DATA BUS 2 FAILURE
DB2FAIL
2.77E-06
Page 133
DATA BUS 3 FAILURE
DB3FAIL
6.66E-05
Page 135
DATA BUS 4 FAILURE
DB4FAIL
6.66E-05
Page 137

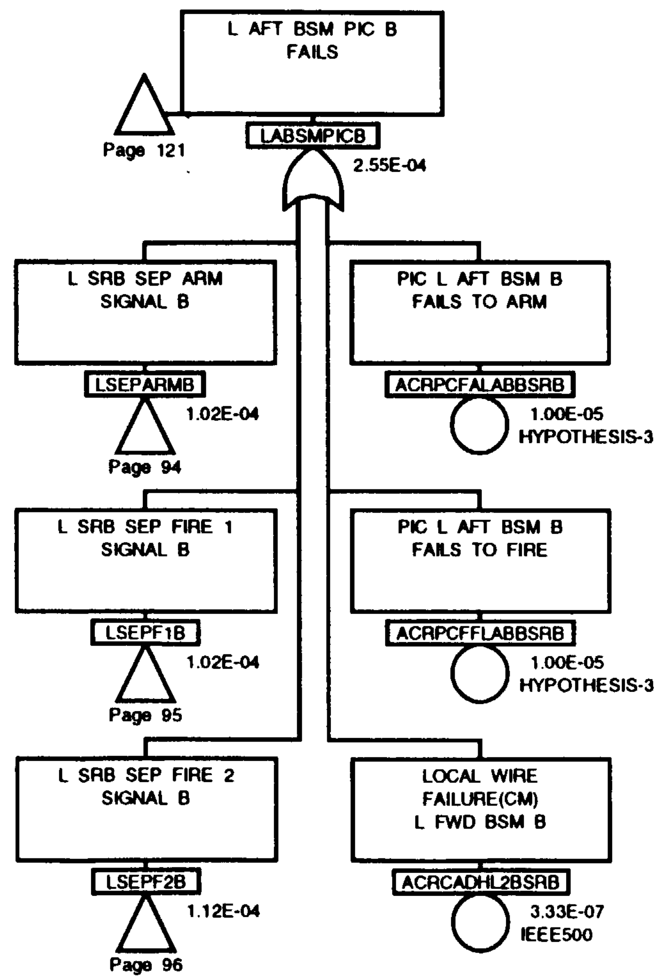

ATTITUDE INHIBITS FAIL - SEP INHIBITED
Page 124
ATTINHFAIL
2.00E-08
ATTITUDE SENSORS OR PROCESSING FAILS
ATTSNSFAIL
1.00E-05
HYPOTHESIS
MANUAL OVERRIDE FAILURE
OVRFAIL
2.00E-03
CREW FAILURE TO SELECT MANUAL SEPARATION
TGLHFAIL
1.00E-03
HYPOTHESIS-1
CREW FAILURE TO INITIATE MANUAL SEPARATION
PBSHFAIL
1.00E-03
PRA ANALYSIS

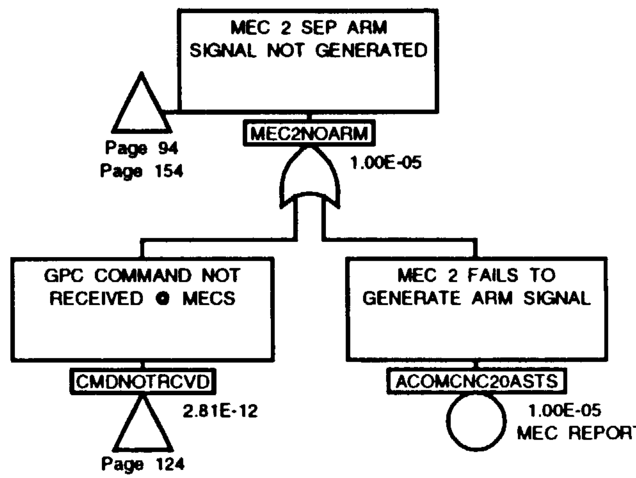

NO L SRB POWER ON BUS A
NOLSRBPWRA
4.13E-05
Page 90
Page 91
Page 92
DC PWR FAILURE BUS A
ACRDCPWASTS
2
3.33E-07
PRA ANALYSIS
CABLE (REPLACEABLE) FAILURE (POWER) L SRB BUS A
ACRCARPLPASRB
4.10E-05
IEEE500

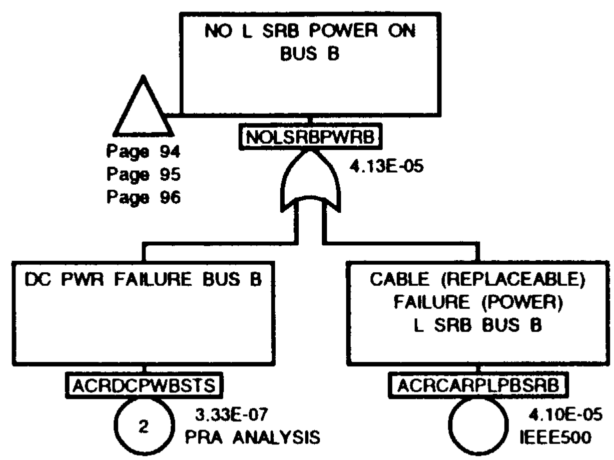


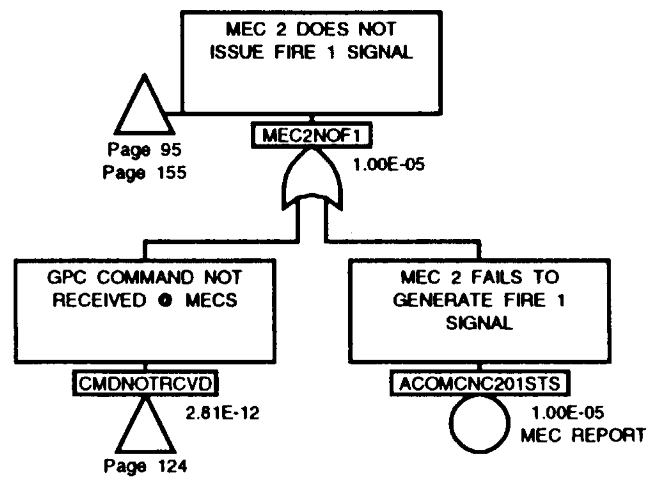
MEC 1 DOES NOT ISSUE FIRE 1 SIGNAL
MEC1NOF1
1.00E-05
Page 91
Page 151
GPC COMMAND NOT RECEIVED @ MECS
CMDNOTRCVD
2.81E-12
Page 124
MEC 1 FAILS TO GENERATE FIRE 1 SIGNAL
ACOMCNC101STS
1.00E-05
MEC REPORT

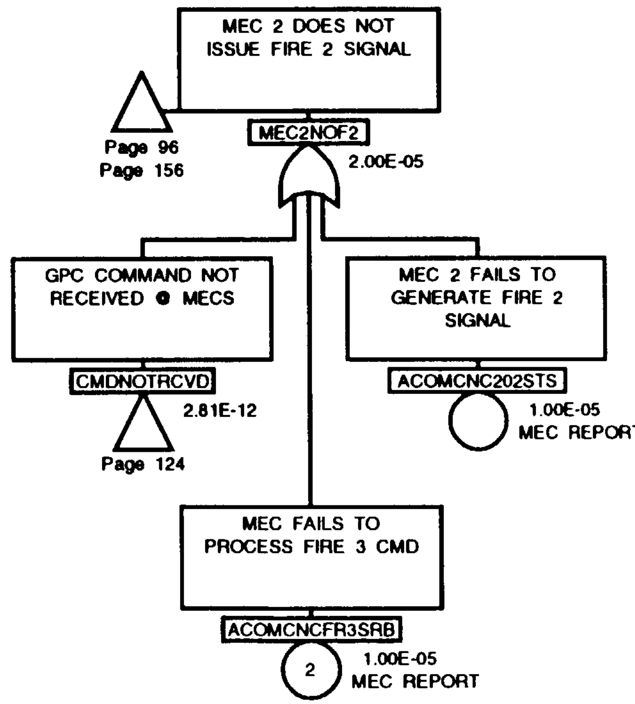

MEC 1 DOES NOT ISSUE FIRE 2 SIGNAL
MEC1NOF2
2.00E-05
Page 92
Page 152
GPC COMMAND NOT RECEIVED @ MECS
CMDNOTRCVD
2.81E-12
Page 124
MEC 1 FAILS TO GENERATE FIRE 2 SIGNAL
ACOMCNC102STS
1.00E-05
MEC REPORT
MEC FAILS TO PROCESS FIRE 3 CMD
ACOMCNCFR3SRB
2
1.00E-05
MEC REPORT

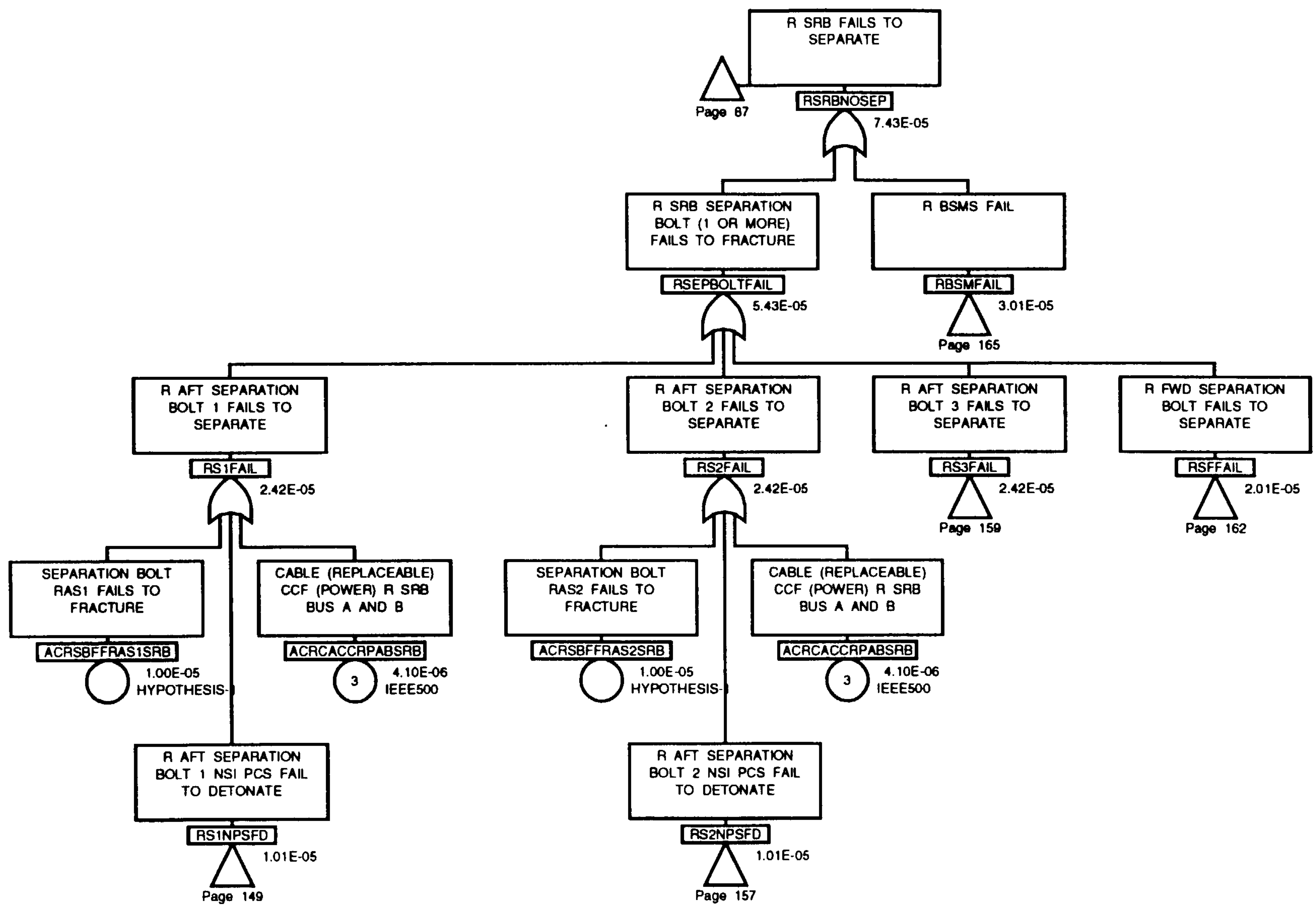

L AFT BSM PIC B FAILS
LABSMPICB
2.55E-04
Page 121
L SRB SEP ARM SIGNAL B
LSEPARMB
1.02E-04
Page 94
PIC L AFT BSM B FAILS TO ARM
ACRPCFALABBSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 1 SIGNAL B
LSEPF1B
1.02E-04
Page 95
PIC L AFT BSM B FAILS TO FIRE
ACRPCFFLABBSRB
1.00E-05
HYPOTHESIS-3
L SRB SEP FIRE 2 SIGNAL B
LSEPF2B
1.12E-04
Page 96
LOCAL WIRE FAILURE(CM) L FWD BSM B
ACRCADHL2BSRB
3.33E-07
IEEE500

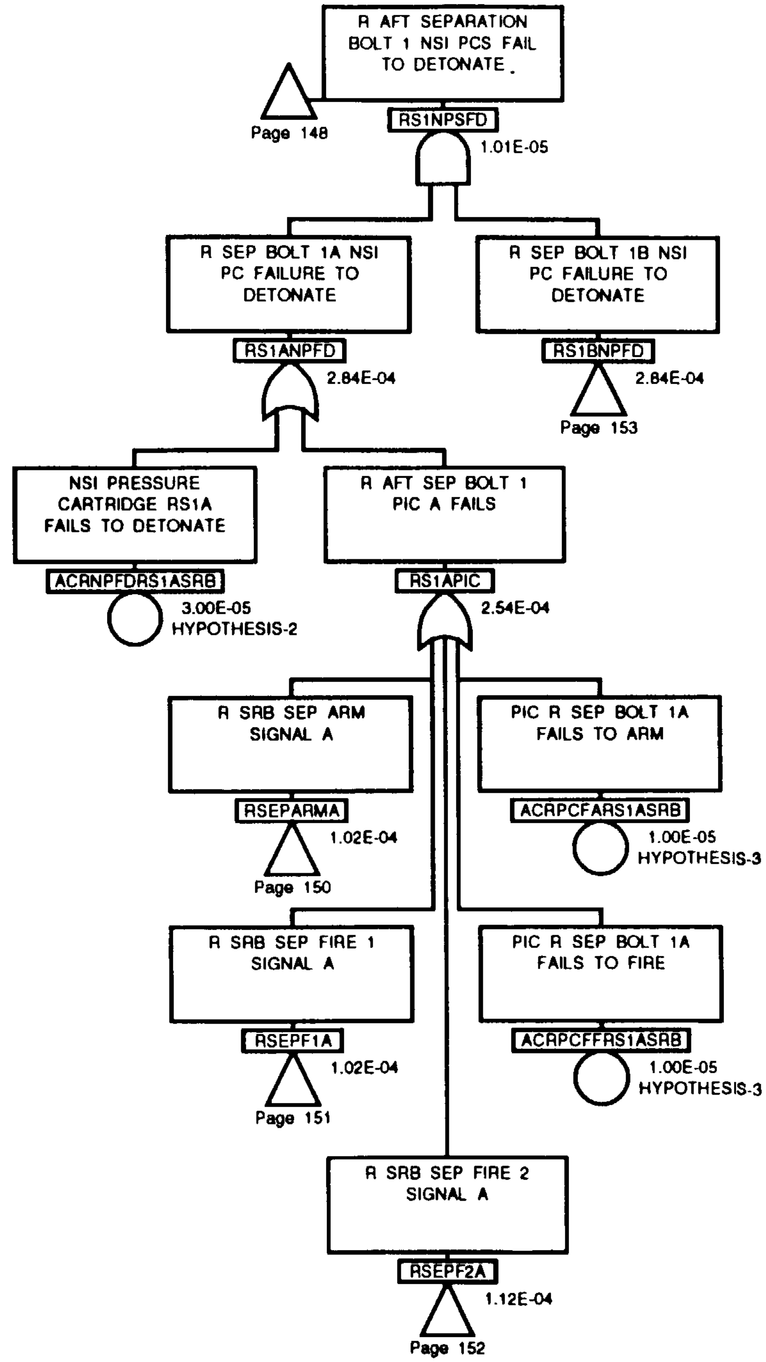

MEC 2 SEP ARM SIGNAL NOT GENERATED
MEC2NOARM
1.00E-05
Page 94
Page 154
GPC COMMAND NOT RECEIVED @ MECS
CMDNOTRCVD
2.81E-12
Page 124
MEC 2 FAILS TO GENERATE ARM SIGNAL
ACOMCNC20ASTS
1.00E-05
MEC REPORT


NO L SRB POWER ON BUS B
NOLSRBPWRB
4.13E-05
Page 94
Page 95
Page 96
DC PWR FAILURE BUS B
ACRDCPWBSTS
2
3.33E-07
PRA ANALYSIS
CABLE (REPLACEABLE) FAILURE (POWER) L SRB BUS B
ACRCARPLPBSRB
4.10E-05
IEEE500

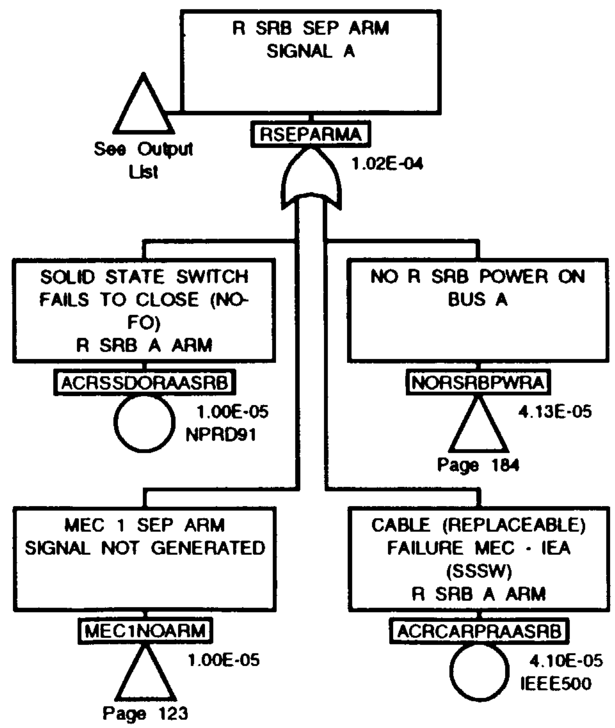

MEC 2 DOES NOT ISSUE FIRE 1 SIGNAL
Page 95
Page 155
MEC2NOF1
1.00E-05
GPC COMMAND NOT RECEIVED @ MECS
CMDNOTRCVD
2.81E-12
Page 124
MEC 2 FAILS TO GENERATE FIRE 1 SIGNAL
ACOMCNC201STS
1.00E-05
MEC REPORT


MEC 2 DOES NOT ISSUE FIRE 2 SIGNAL
MEC2NOF2
2.00E-05
Page 96
Page 156
GPC COMMAND NOT RECEIVED @ MECS
CMDNOTRCVD
2.81E-12
Page 124
MEC 2 FAILS TO GENERATE FIRE 2 SIGNAL
ACOMCNC202STS
1.00E-05
MEC REPORT
MEC FAILS TO PROCESS FIRE 3 CMD
ACOMCNCFR3SRB
2
1.00E-05
MEC REPORT

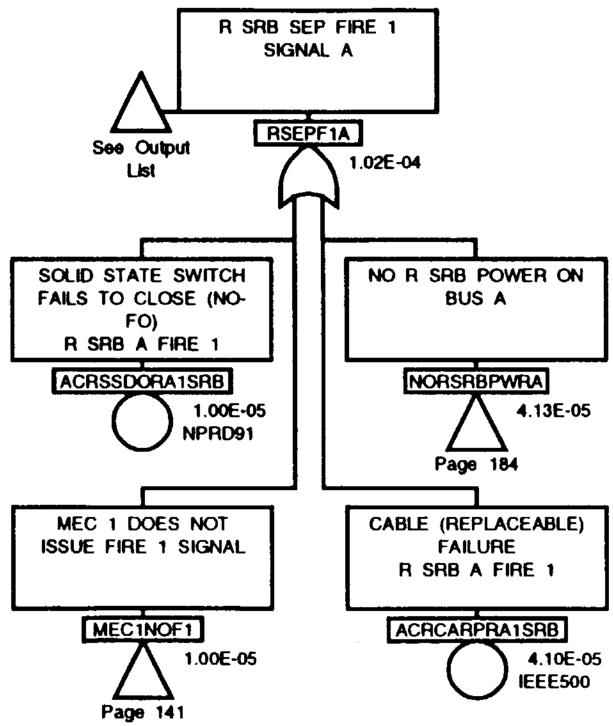

R SRB FAILS TO SEPARATE
Page 87
RSRBNOSEP
7.43E-05
R SRB SEPARATION BOLT (1 OR MORE) FAILS TO FRACTURE
RSEPBOLTFAIL
5.43E-05
R BSMS FAIL
RBSMFAIL
3.01E-05
Page 165
R AFT SEPARATION BOLT 1 FAILS TO SEPARATE
RS1FAIL
2.42E-05
R AFT SEPARATION BOLT 2 FAILS TO SEPARATE
RS2FAIL
2.42E-05
R AFT SEPARATION BOLT 3 FAILS TO SEPARATE
RS3FAIL
2.42E-05
Page 159
R FWD SEPARATION BOLT FAILS TO SEPARATE
RSFFAIL
2.01E-05
Page 162
SEPARATION BOLT RAS1 FAILS TO FRACTURE
ACRSBFFRAS1SRB
1.00E-05
HYPOTHESIS-
CABLE (REPLACEABLE) CCF (POWER) R SRB BUS A AND B
ACRCACCRPABSRB
3
4.10E-06
IEEE500
SEPARATION BOLT RAS2 FAILS TO FRACTURE
ACRSBFFRAS2SRB
1.00E-05
HYPOTHESIS-
CABLE (REPLACEABLE) CCF (POWER) R SRB BUS A AND B
ACRCACCRPABSRB
3
4.10E-06
IEEE500
R AFT SEPARATION BOLT 1 NSI PCS FAIL TO DETONATE
RS1NPSFD
1.01E-05
Page 149
R AFT SEPARATION BOLT 2 NSI PCS FAIL TO DETONATE
RS2NPSFD
1.01E-05
Page 157


R AFT SEPARATION BOLT 1 NSI PCS FAIL TO DETONATE.
RS1NPSFD
1.01E-05
Page 148
R SEP BOLT 1A NSI PC FAILURE TO DETONATE
RS1ANPFD
2.84E-04
R SEP BOLT 1B NSI PC FAILURE TO DETONATE
RS1BNPFD
2.84E-04
Page 153
NSI PRESSURE CARTRIDGE RS1A FAILS TO DETONATE
ACRNPFDRS1ASRB
3.00E-05
HYPOTHESIS-2
R AFT SEP BOLT 1 PIC A FAILS
RS1APIC
2.54E-04
R SRB SEP ARM SIGNAL A
RSEPARMA
1.02E-04
Page 150
PIC R SEP BOLT 1A FAILS TO ARM
ACRPCFARS1ASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1 SIGNAL A
RSEPF1A
1.02E-04
Page 151
PIC R SEP BOLT 1A FAILS TO FIRE
ACRPCFFRS1ASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2 SIGNAL A
RSEPF2A
1.12E-04
Page 152

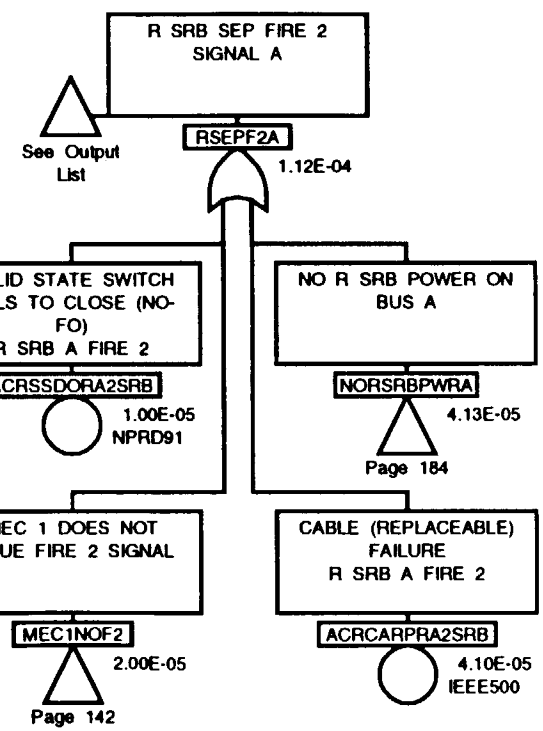
RSEPARMA Outputs:
Page 183, Page 166, Page 149, Page 157, Page 160, Page 163

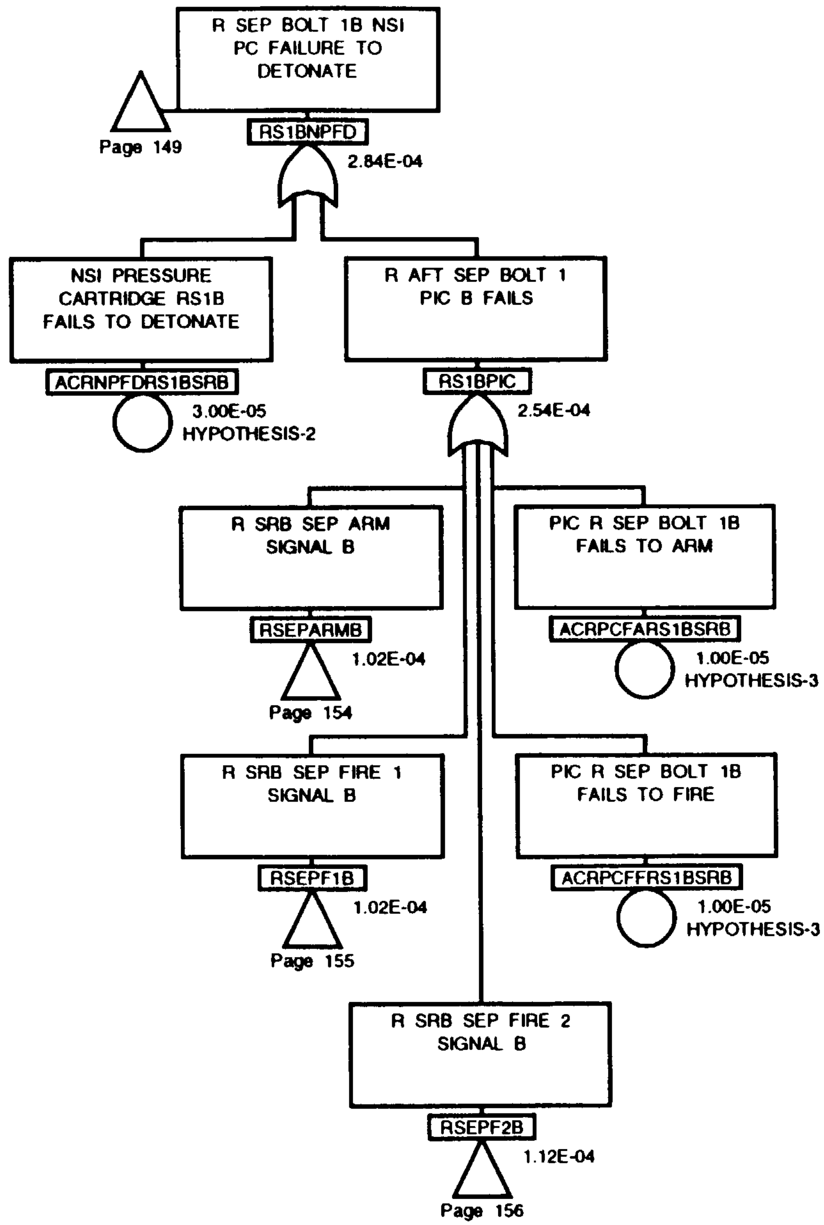


RSEPF1A Outputs:
Page 183, Page 166, Page 149, Page 157, Page 160, Page 163

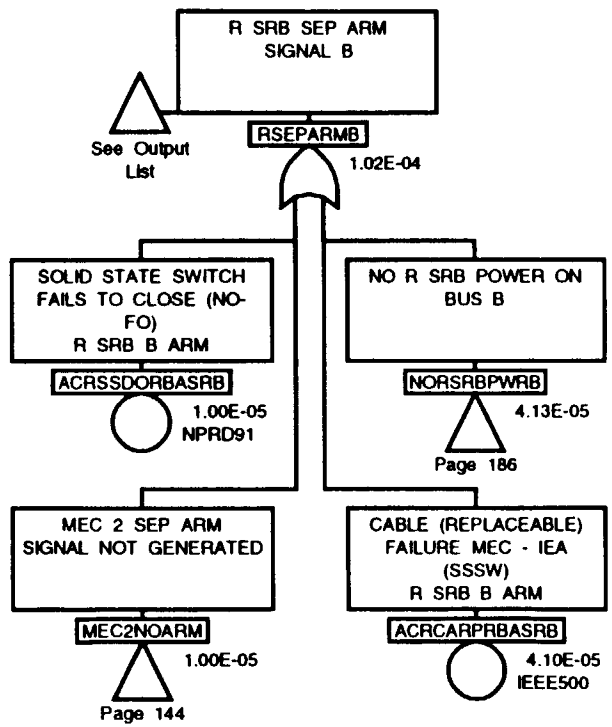


RSEPF2A Outputs:
Page 183, Page 166, Page 149, Page 157, Page 160, Page 163

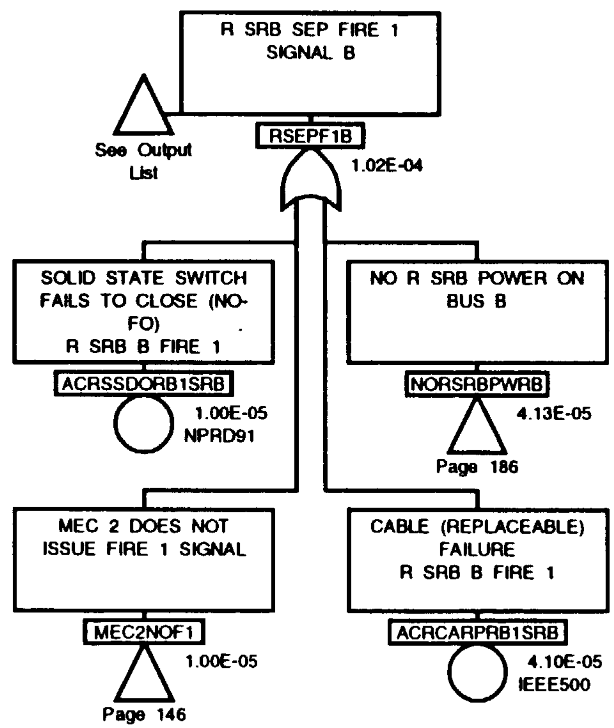



R SEP BOLT 1B NSI PC FAILURE TO DETONATE
Page 149
RS1BNPFD
2.84E-04
NSI PRESSURE CARTRIDGE RS1B FAILS TO DETONATE
ACRNPFDRS1BSRB
3.00E-05
HYPOTHESIS-2
R AFT SEP BOLT 1 PIC B FAILS
RS1BPIC
2.54E-04
R SRB SEP ARM SIGNAL B
RSEPARMB
1.02E-04
Page 154
PIC R SEP BOLT 1B FAILS TO ARM
ACRPCFARS1BSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1 SIGNAL B
RSEPF1B
1.02E-04
Page 155
PIC R SEP BOLT 1B FAILS TO FIRE
ACRPCFFRS1BSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2 SIGNAL B
RSEPF2B
1.12E-04
Page 156

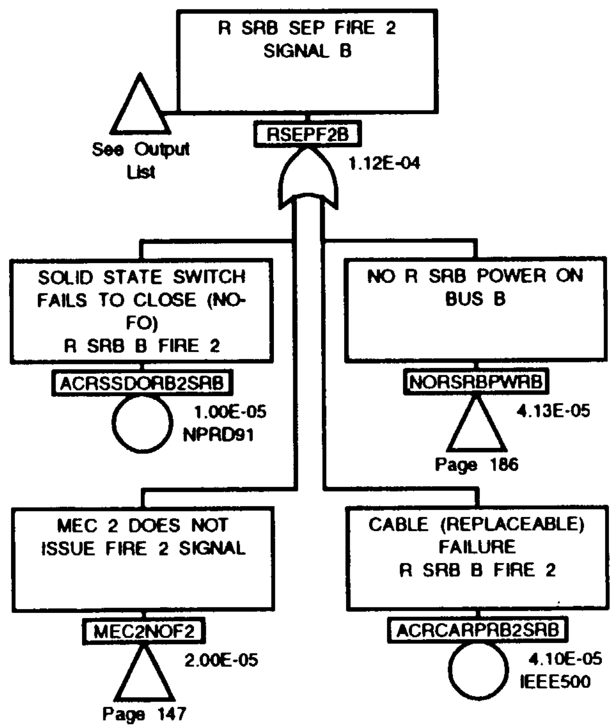
RSEPARMB Outputs:
Page 185, Page 167, Page 153, Page 158, Page 161, Page 164

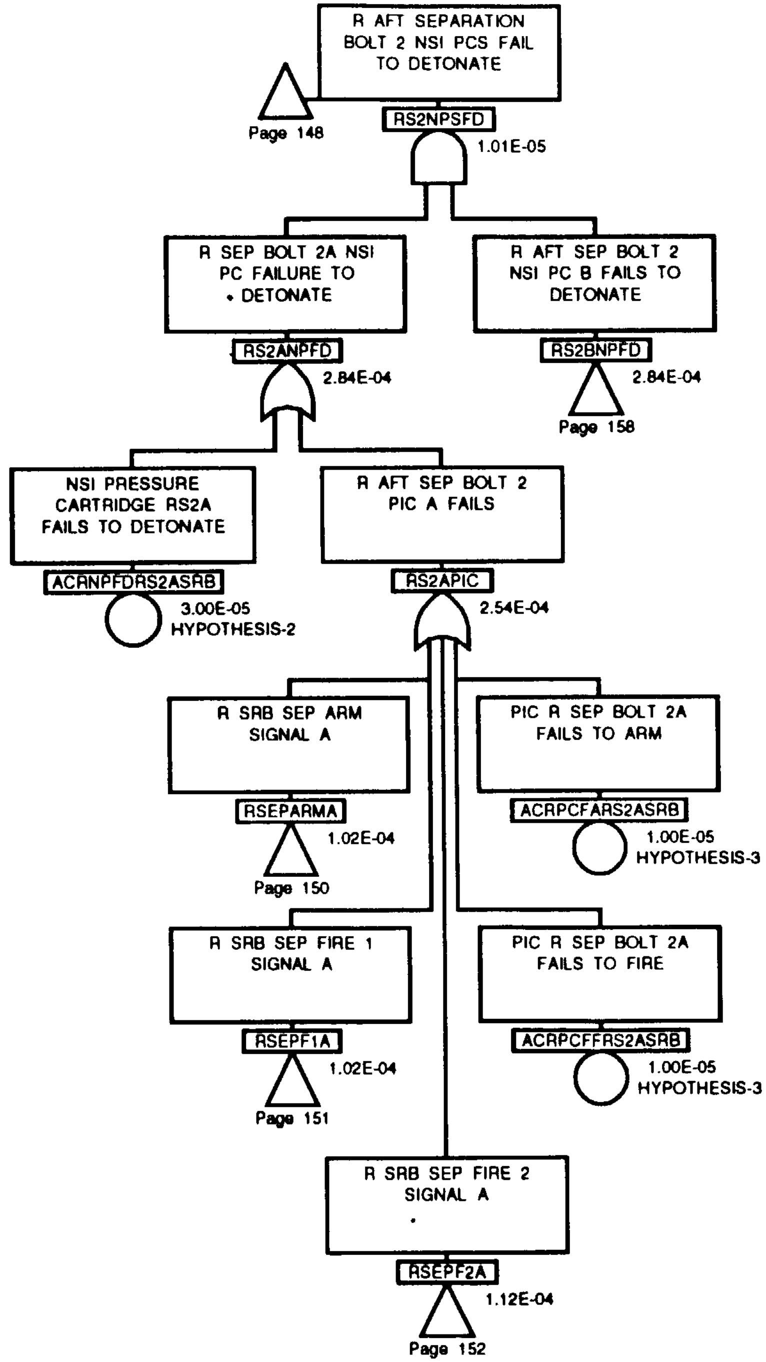


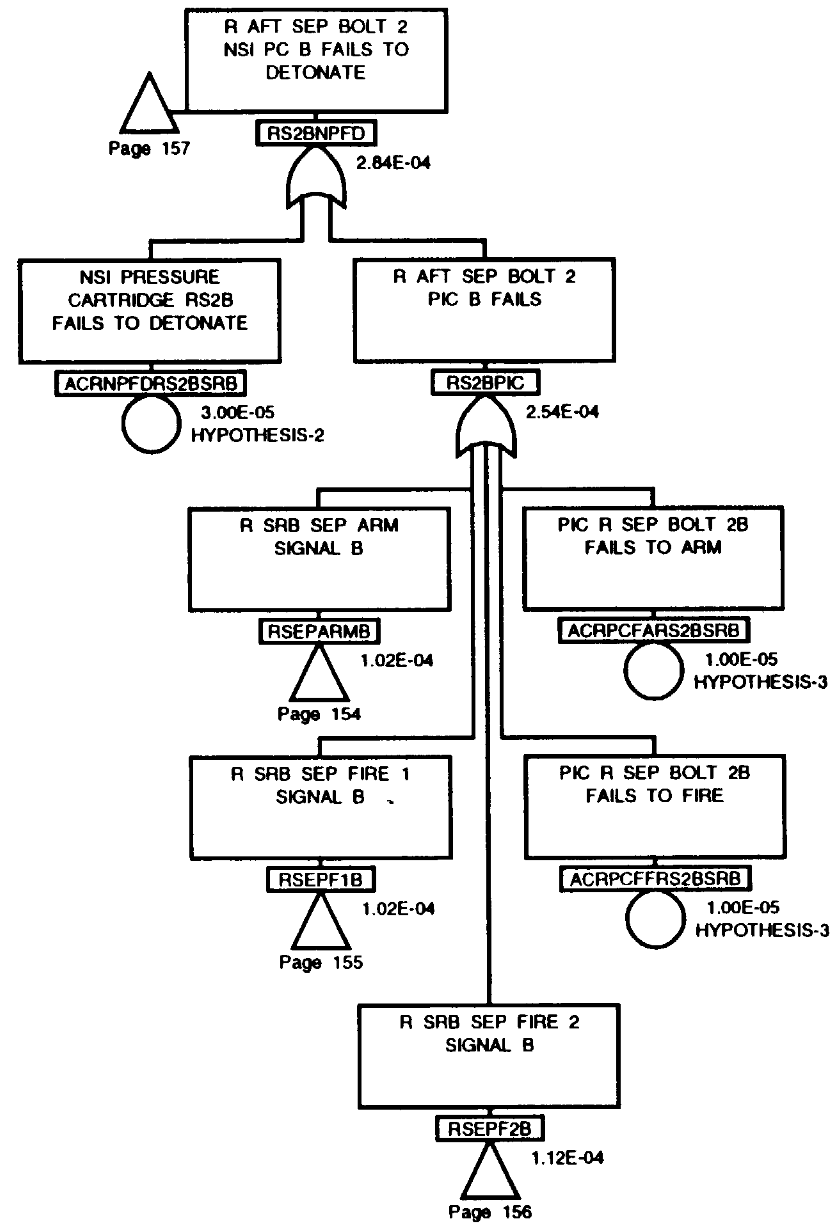
RSEPF1B Outputs:
Page 185, Page 167, Page 153, Page 158, Page 161, Page 164



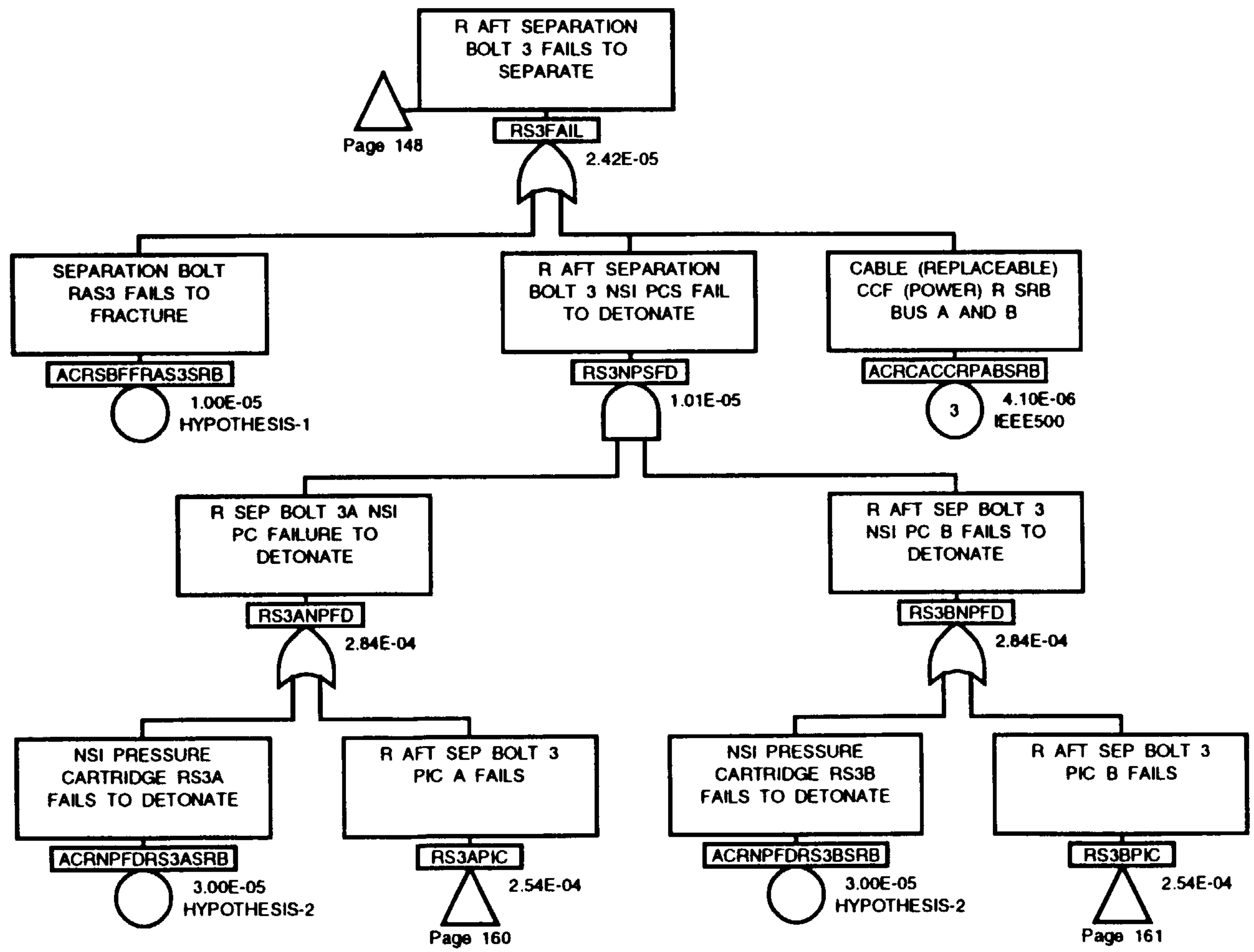
RSEPF2B Outputs:
Page 185, Page 167, Page 153, Page 158, Page 161, Page 164

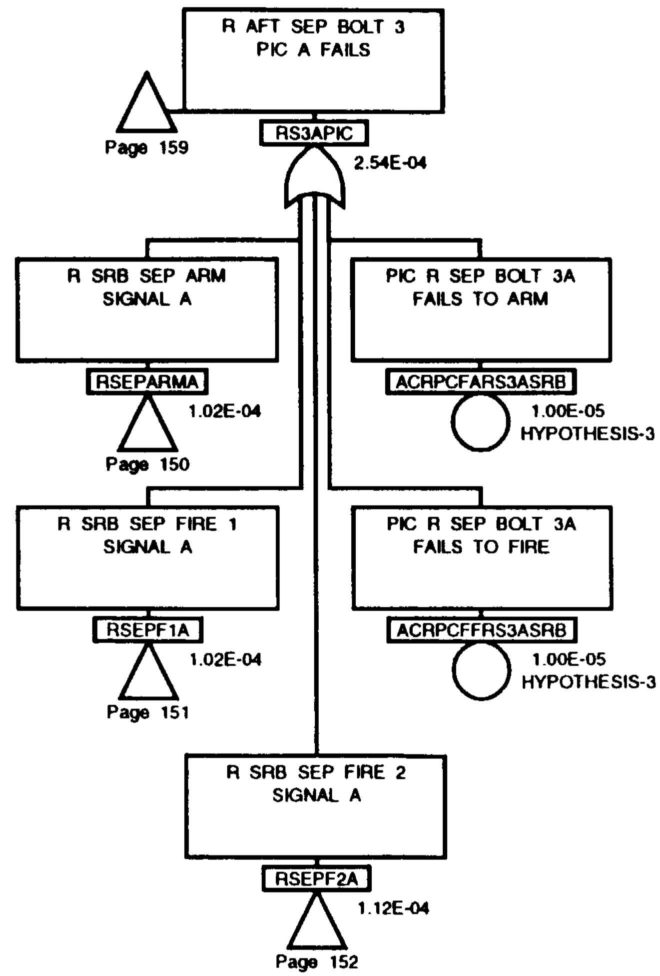


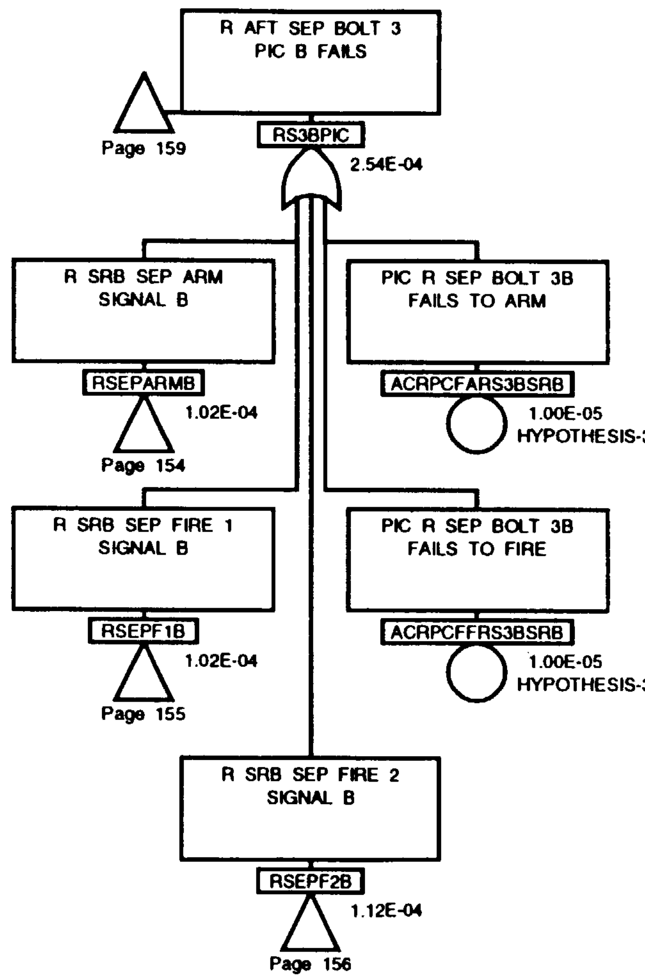

R AFT SEPARATION BOLT 2 NSI PCS FAIL TO DETONATE
Page 148
RS2NPSFD
1.01E-05
R SEP BOLT 2A NSI PC FAILURE TO • DETONATE
RS2ANPFD
2.84E-04
R AFT SEP BOLT 2 NSI PC B FAILS TO DETONATE
RS2BNPFD
2.84E-04
Page 158
NSI PRESSURE CARTRIDGE RS2A FAILS TO DETONATE
ACRNPFDRS2ASRB
3.00E-05
HYPOTHESIS-2
R AFT SEP BOLT 2 PIC A FAILS
RS2APIC
2.54E-04
R SRB SEP ARM SIGNAL A
RSEPARMA
1.02E-04
Page 150
PIC R SEP BOLT 2A FAILS TO ARM
ACRPCFARS2ASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1 SIGNAL A
RSEPF1A
1.02E-04
Page 151
PIC R SEP BOLT 2A FAILS TO FIRE
ACRPCFFRS2ASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2 SIGNAL A
RSEPF2A
1.12E-04
Page 152

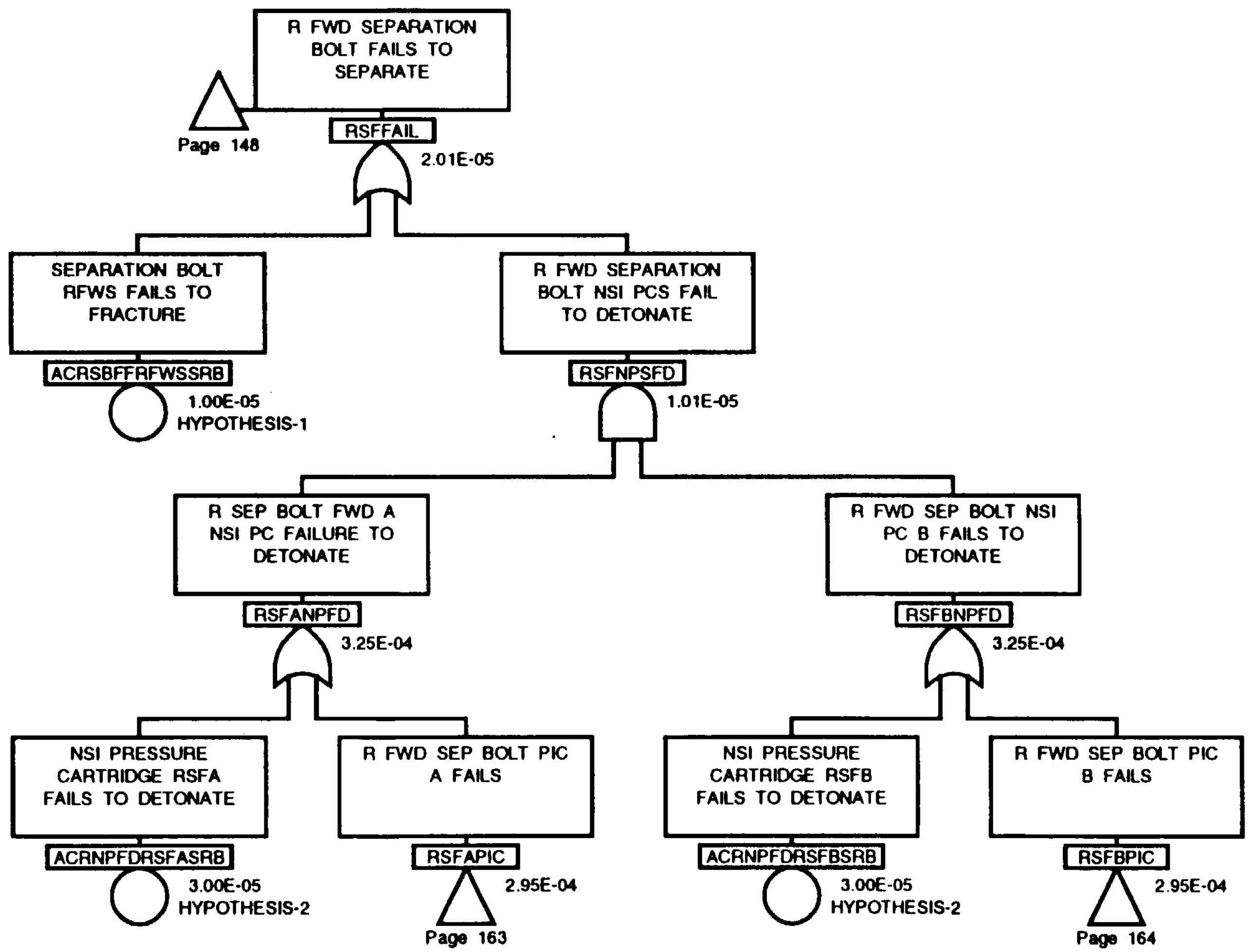


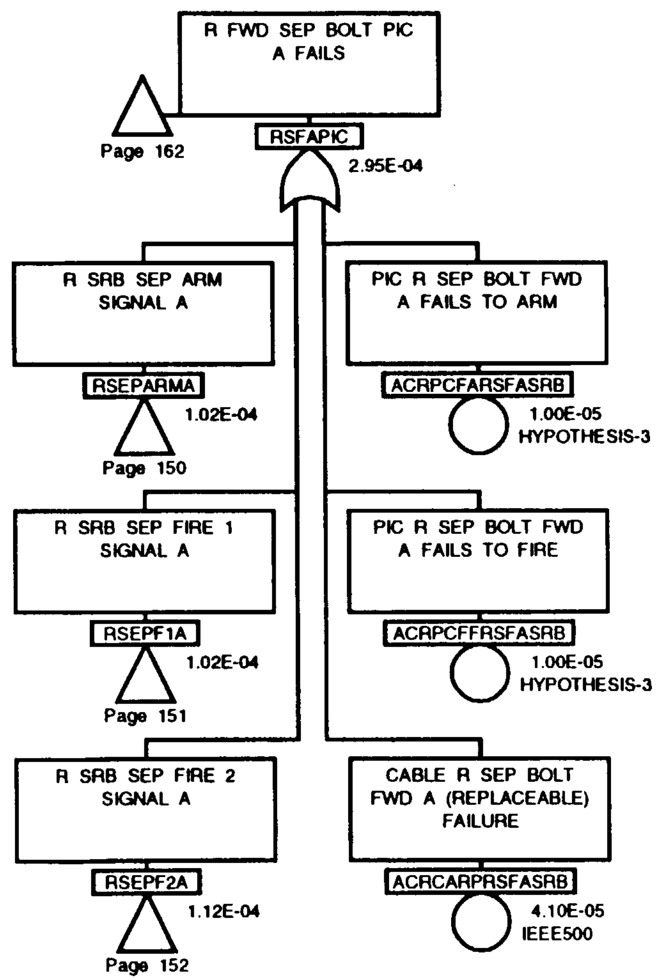
R AFT SEP BOLT 2 NSI PC B FAILS TO DETONATE
RS2BNPFD
2.84E-04
Page 157
NSI PRESSURE CARTRIDGE RS2B FAILS TO DETONATE
ACRNPFDRS2BSRB
3.00E-05
HYPOTHESIS-2
R AFT SEP BOLT 2 PIC B FAILS
RS2BPIC
2.54E-04
R SRB SEP ARM SIGNAL B
RSEPARMB
1.02E-04
Page 154
PIC R SEP BOLT 2B FAILS TO ARM
ACRPCFARS2BSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1 SIGNAL B
RSEPF1B
1.02E-04
Page 155
PIC R SEP BOLT 2B FAILS TO FIRE
ACRPCFFRS2BSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2 SIGNAL B
RSEPF2B
1.12E-04
Page 156

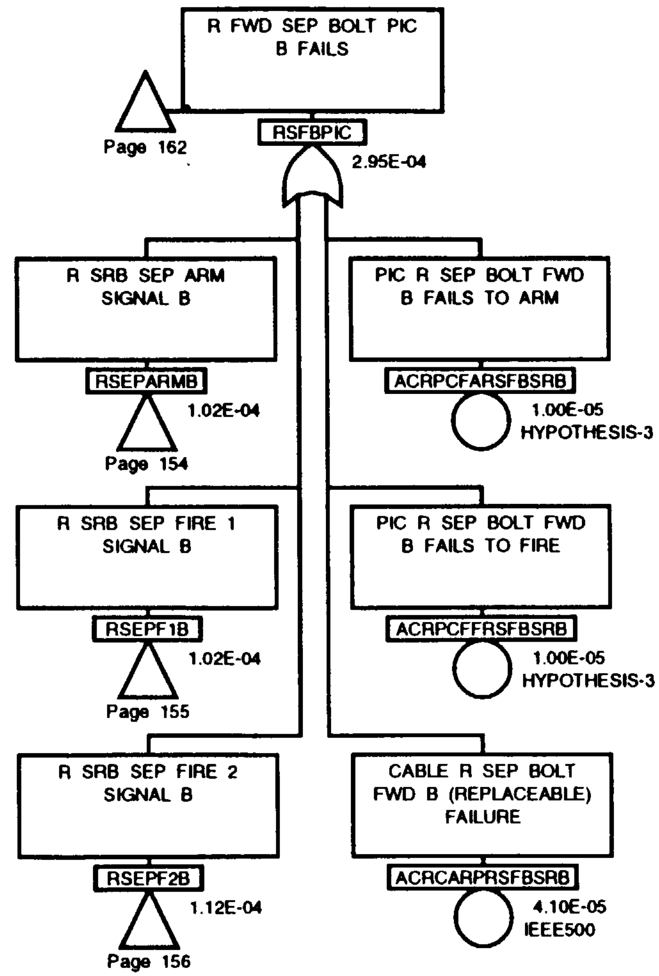

R AFT SEPARATION BOLT 3 FAILS TO SEPARATE
Page 148
RS3FAIL
2.42E-05
SEPARATION BOLT RAS3 FAILS TO FRACTURE
ACRSBFFRAS3SRB
1.00E-05
HYPOTHESIS-1
R AFT SEPARATION BOLT 3 NSI PCS FAIL TO DETONATE
RS3NPSFD
1.01E-05
CABLE (REPLACEABLE) CCF (POWER) R SRB BUS A AND B
ACRCACCRPABSRB
3
4.10E-06
IEEE500
R SEP BOLT 3A NSI PC FAILURE TO DETONATE
RS3ANPFD
2.84E-04
R AFT SEP BOLT 3 NSI PC B FAILS TO DETONATE
RS3BNPFD
2.84E-04
NSI PRESSURE CARTRIDGE RS3A FAILS TO DETONATE
ACRNPFDRS3ASRB
3.00E-05
HYPOTHESIS-2
R AFT SEP BOLT 3 PIC A FAILS
RS3APIC
2.54E-04
Page 160
NSI PRESSURE CARTRIDGE RS3B FAILS TO DETONATE
ACRNPFDRS3BSRB
3.00E-05
HYPOTHESIS-2
R AFT SEP BOLT 3 PIC B FAILS
RS3BPIC
2.54E-04
Page 161

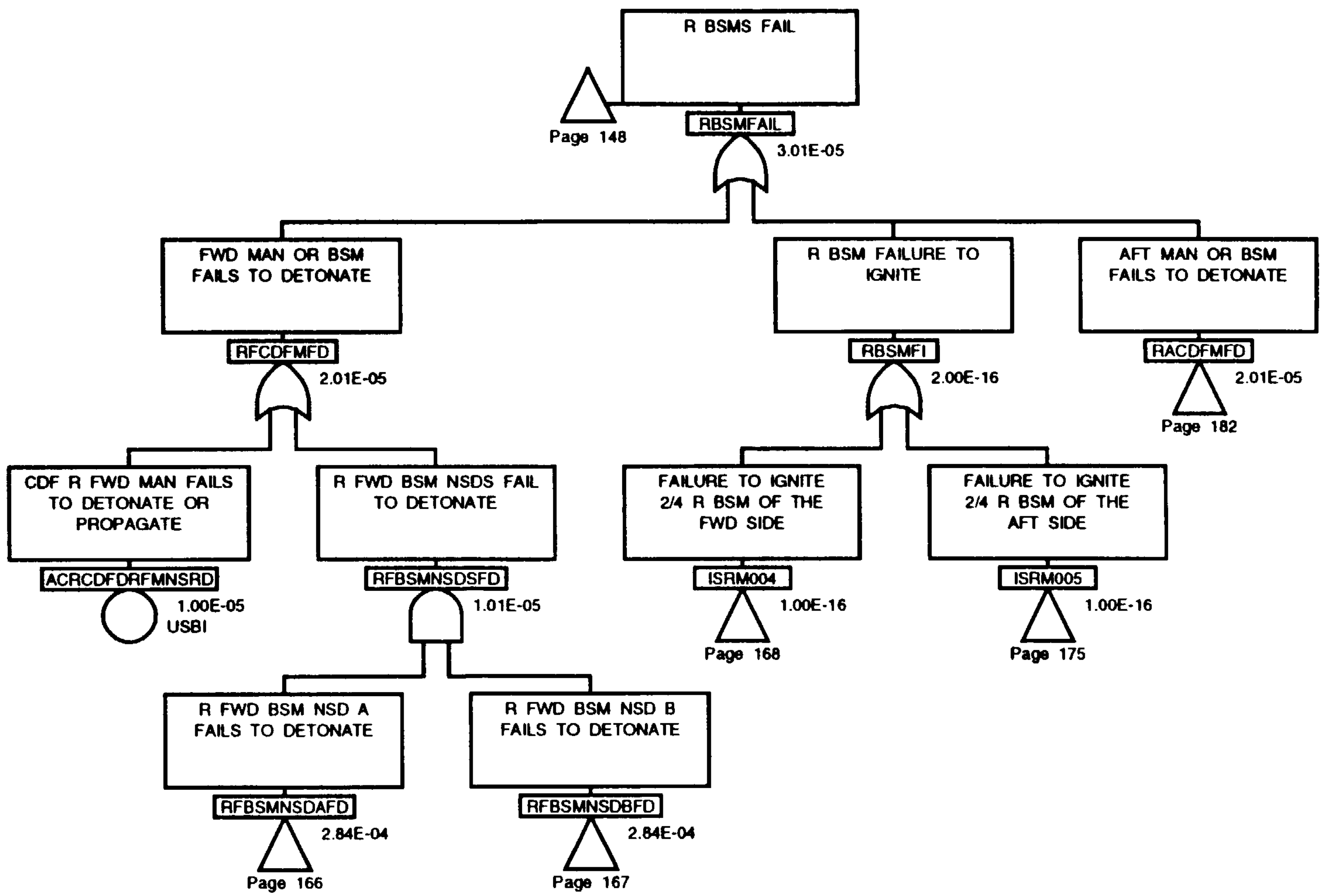

R AFT SEP BOLT 3 PIC A FAILS
RS3APIC
2.54E-04
Page 159
R SRB SEP ARM SIGNAL A
RSEPARMA
1.02E-04
Page 150
PIC R SEP BOLT 3A FAILS TO ARM
ACRPCFARS3ASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1 SIGNAL A
RSEPF1A
1.02E-04
Page 151
PIC R SEP BOLT 3A FAILS TO FIRE
ACRPCFFRS3ASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2 SIGNAL A
RSEPF2A
1.12E-04
Page 152

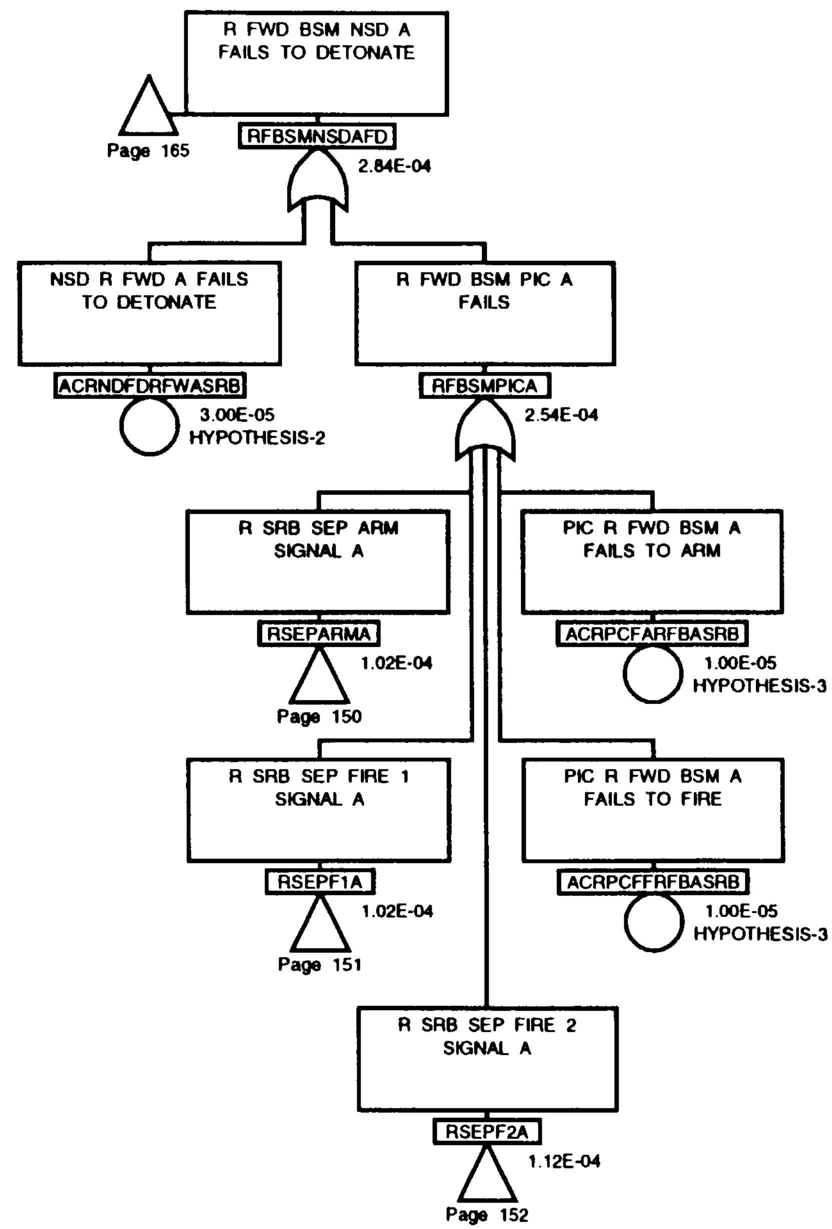

R AFT SEP BOLT 3 PIC B FAILS
Page 159
RS3BPIC
2.54E-04
R SRB SEP ARM SIGNAL B
RSEPARMB
1.02E-04
Page 154
PIC R SEP BOLT 3B FAILS TO ARM
ACRPCFARS3BSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1 SIGNAL B
RSEPF1B
1.02E-04
Page 155
PIC R SEP BOLT 3B FAILS TO FIRE
ACRPCFFRS3BSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2 SIGNAL B
RSEPF2B
1.12E-04
Page 156

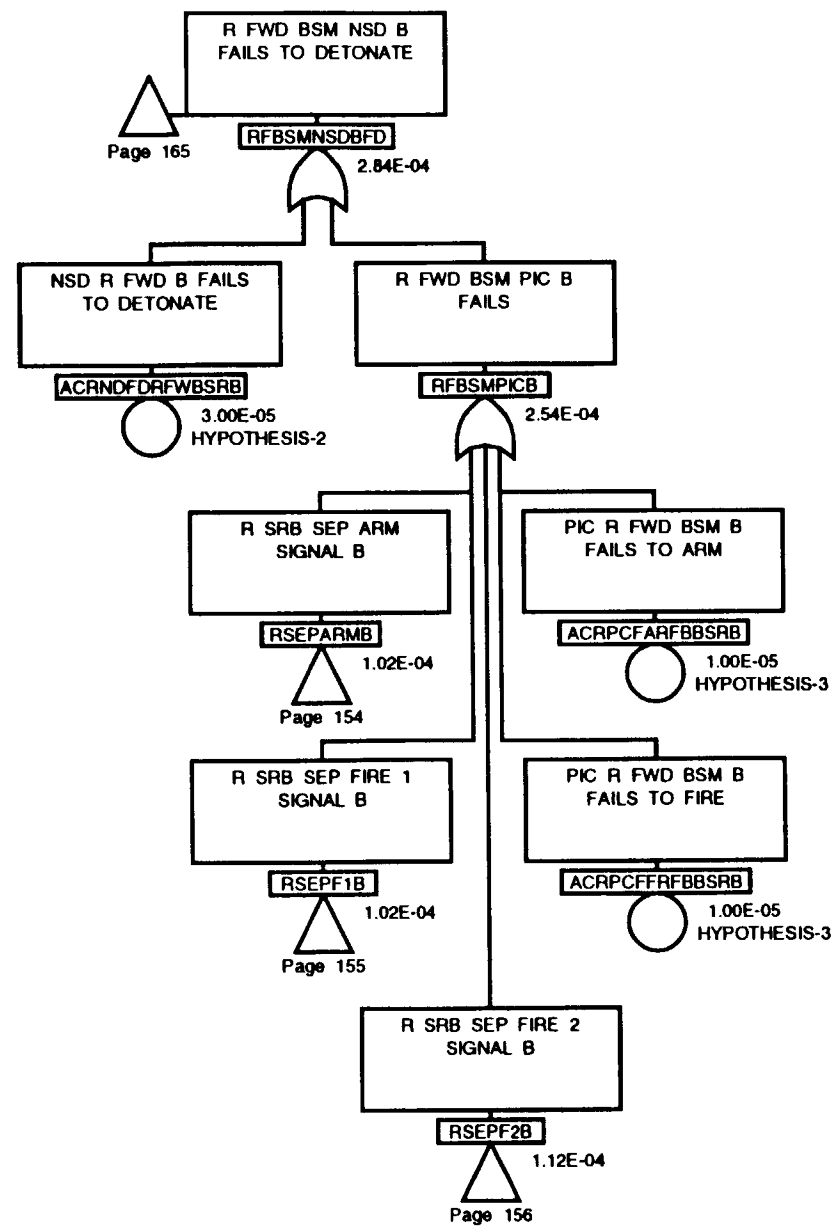

R FWD SEPARATION BOLT FAILS TO SEPARATE
RSFFAIL
2.01E-05
Page 148
SEPARATION BOLT RFWS FAILS TO FRACTURE
ACRSBFFRFWSSRB
1.00E-05
HYPOTHESIS-1
R FWD SEPARATION BOLT NSI PCS FAIL TO DETONATE
RSFNPSFD
1.01E-05
R SEP BOLT FWD A NSI PC FAILURE TO DETONATE
RSFANPFD
3.25E-04
R FWD SEP BOLT NSI PC B FAILS TO DETONATE
RSFBNPFD
3.25E-04
NSI PRESSURE CARTRIDGE RSFA FAILS TO DETONATE
ACRNPFDRSFASRB
3.00E-05
HYPOTHESIS-2
R FWD SEP BOLT PIC A FAILS
RSFAPIC
2.95E-04
Page 163
NSI PRESSURE CARTRIDGE RSFB FAILS TO DETONATE
ACRNPFDRSFBSRB
3.00E-05
HYPOTHESIS-2
R FWD SEP BOLT PIC B FAILS
RSFBPIC
2.95E-04
Page 164

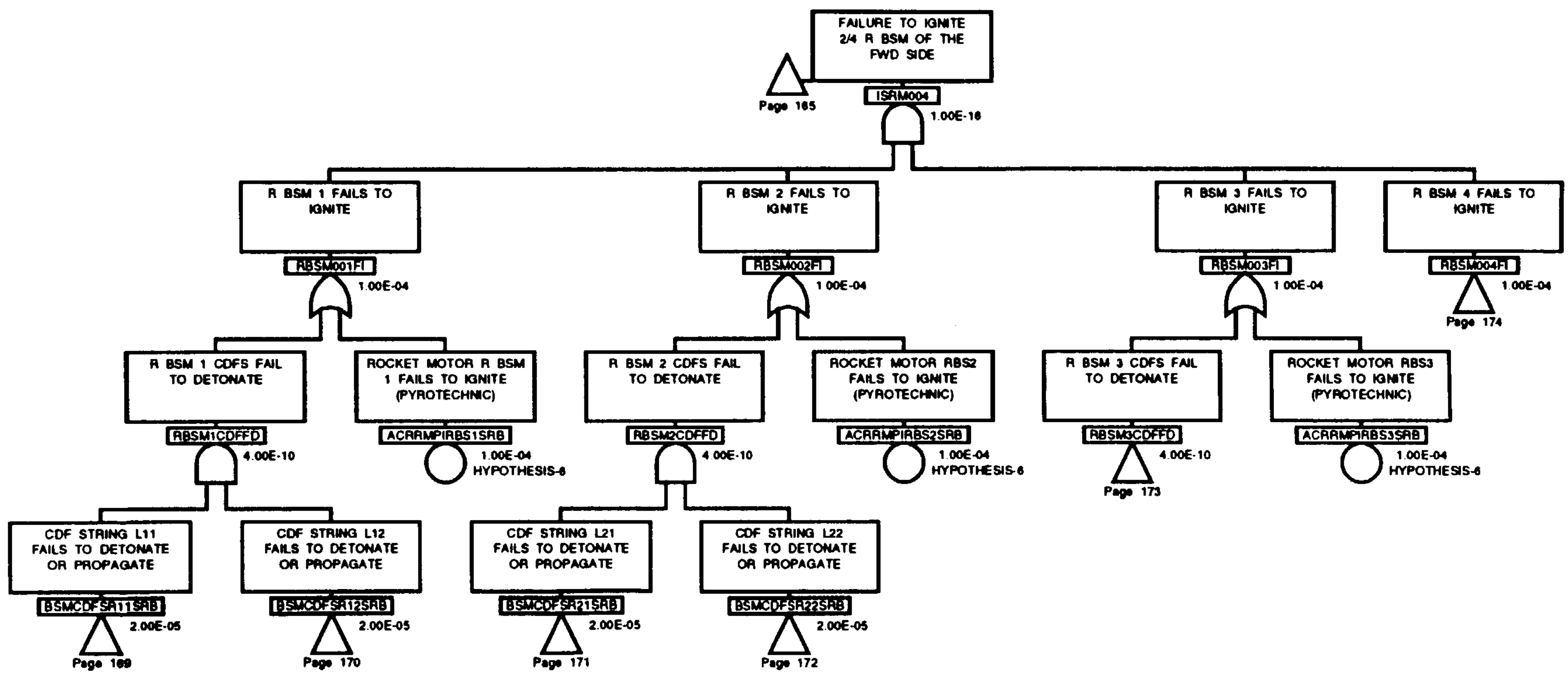

R FWD SEP BOLT PIC A FAILS
RSFAPIC
2.95E-04
Page 162
R SRB SEP ARM SIGNAL A
RSEPARMA
1.02E-04
Page 150
PIC R SEP BOLT FWD A FAILS TO ARM
ACRPCFARSFASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1 SIGNAL A
RSEPF1A
1.02E-04
Page 151
PIC R SEP BOLT FWD A FAILS TO FIRE
ACRPCFFRSFASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2 SIGNAL A
RSEPF2A
1.12E-04
Page 152
CABLE R SEP BOLT FWD A (REPLACEABLE) FAILURE
ACRCARPRSFASRB
4.10E-05
IEEE500


R FWD SEP BOLT PIC
B FAILS
RSFBPIC
2.95E-04
Page 162
R SRB SEP ARM
SIGNAL B
RSEPARMB
1.02E-04
Page 154
PIC R SEP BOLT FWD
B FAILS TO ARM
ACRPCFARSFBSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1
SIGNAL B
RSEPF1B
1.02E-04
Page 155
PIC R SEP BOLT FWD
B FAILS TO FIRE
ACRPCFFRSFBSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2
SIGNAL B
RSEPF2B
1.12E-04
Page 156
CABLE R SEP BOLT
FWD B (REPLACEABLE)
FAILURE
ACRCARPRSFBSRB
4.10E-05
IEEE500

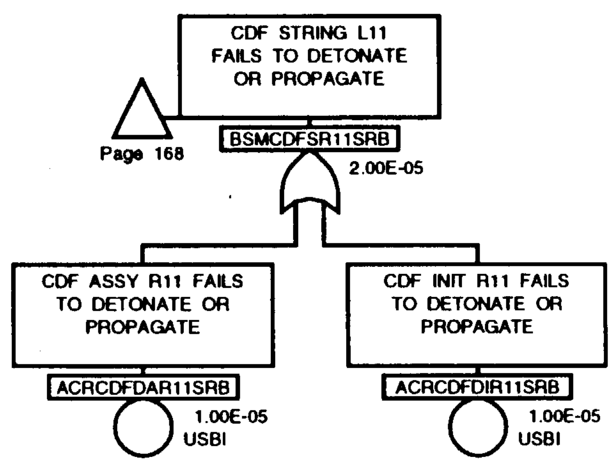

R BSMS FAIL
Page 148
RBSMFAIL
3.01E-05
FWD MAN OR BSM FAILS TO DETONATE
RFCDFMFD
2.01E-05
R BSM FAILURE TO IGNITE
RBSMFI
2.00E-16
AFT MAN OR BSM FAILS TO DETONATE
RACDFMFD
2.01E-05
Page 182
CDF R FWD MAN FAILS TO DETONATE OR PROPAGATE
ACRCDFDRFMNSRD
1.00E-05
USBI
R FWD BSM NSDS FAIL TO DETONATE
RFBSMNSDSFD
1.01E-05
FAILURE TO IGNITE 2/4 R BSM OF THE FWD SIDE
ISRM004
1.00E-16
Page 168
FAILURE TO IGNITE 2/4 R BSM OF THE AFT SIDE
ISRM005
1.00E-16
Page 175
R FWD BSM NSD A FAILS TO DETONATE
RFBSMNSDAFD
2.84E-04
Page 166
R FWD BSM NSD B FAILS TO DETONATE
RFBSMNSDBFD
2.84E-04
Page 167

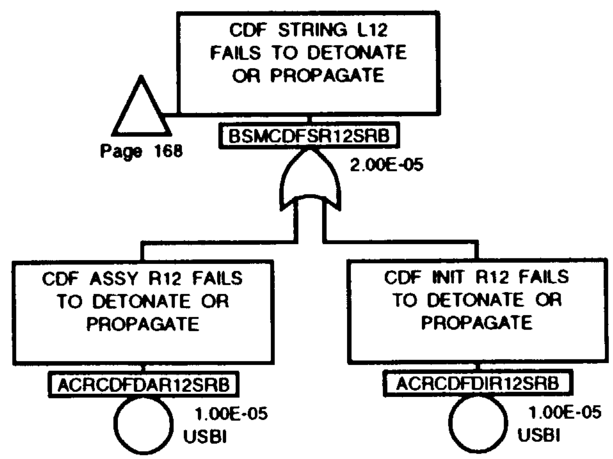

R FWD BSM NSD A FAILS TO DETONATE
RFBSMNSDAFD
2.84E-04
Page 165
NSD R FWD A FAILS TO DETONATE
ACRNDFDRFWASRB
3.00E-05
HYPOTHESIS-2
R FWD BSM PIC A FAILS
RFBSMPICA
2.54E-04
R SRB SEP ARM SIGNAL A
RSEPARMA
1.02E-04
Page 150
PIC R FWD BSM A FAILS TO ARM
ACRPCFARFBASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1 SIGNAL A
RSEPF1A
1.02E-04
Page 151
PIC R FWD BSM A FAILS TO FIRE
ACRPCFFRFBASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2 SIGNAL A
RSEPF2A
1.12E-04
Page 152

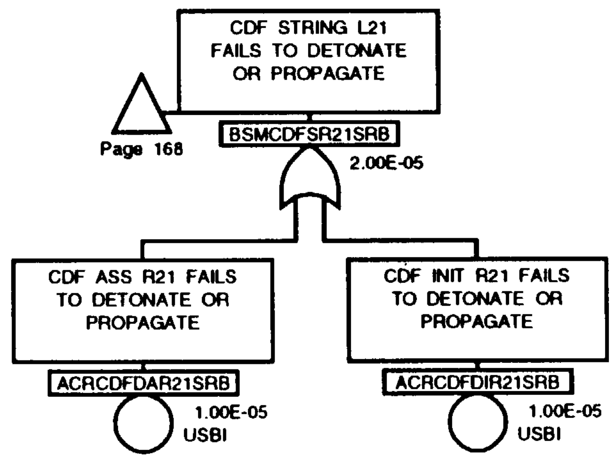

R FWD BSM NSD B FAILS TO DETONATE
Page 165
RFBSMNSDBFD
2.84E-04
NSD R FWD B FAILS TO DETONATE
ACRNDFDRFWBSRB
3.00E-05
HYPOTHESIS-2
R FWD BSM PIC B FAILS
RFBSMPICB
2.54E-04
R SRB SEP ARM SIGNAL B
RSEPARMB
1.02E-04
Page 154
PIC R FWD BSM B FAILS TO ARM
ACRPCFARFBBSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1 SIGNAL B
RSEPF1B
1.02E-04
Page 155
PIC R FWD BSM B FAILS TO FIRE
ACRPCFFRFBBSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2 SIGNAL B
RSEPF2B
1.12E-04
Page 156

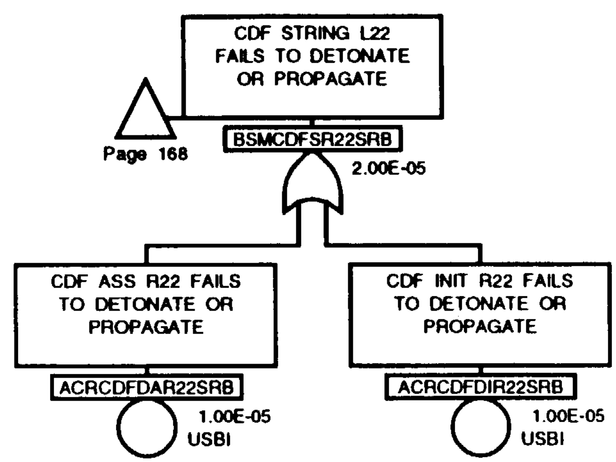


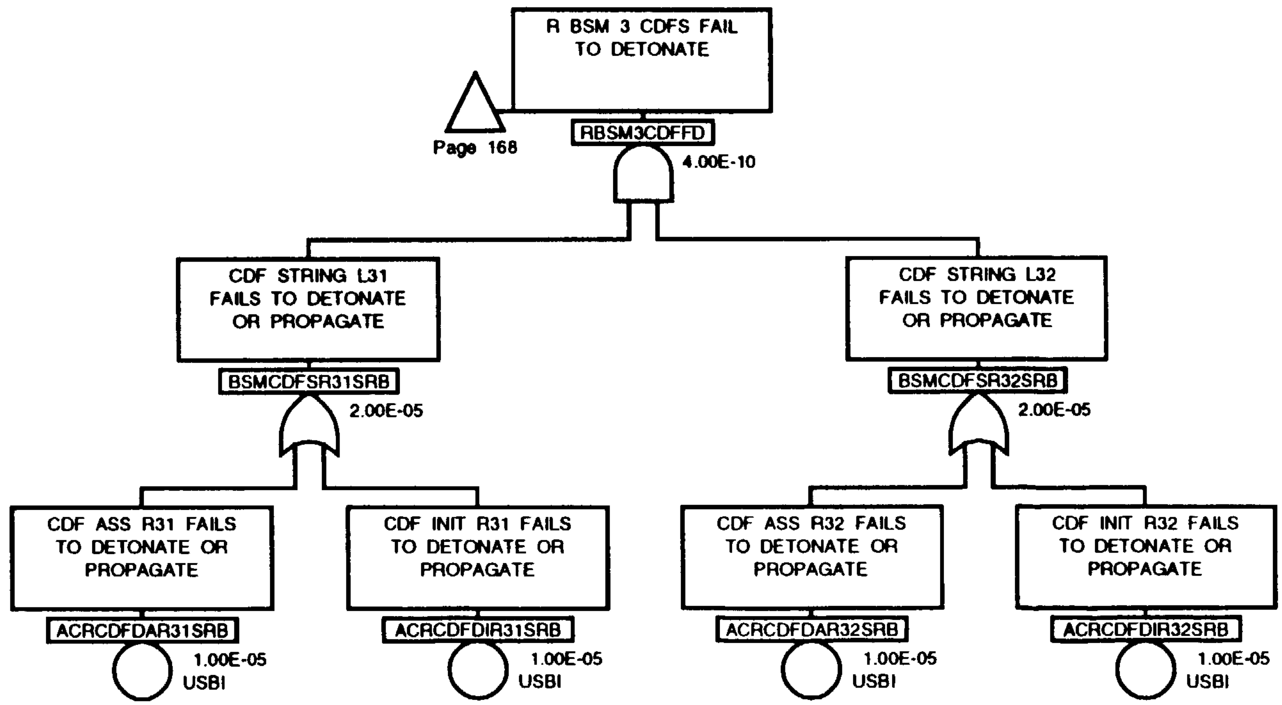
FAILURE TO IGNITE 2/4 R BSM OF THE FWD SIDE
ISRM004
1.00E-16
Page 165
R BSM 1 FAILS TO IGNITE
RBSM001FI
1.00E-04
R BSM 2 FAILS TO IGNITE
RBSM002FI
1.00E-04
R BSM 3 FAILS TO IGNITE
RBSM003FI
1.00E-04
R BSM 4 FAILS TO IGNITE
RBSM004FI
1.00E-04
Page 174
R BSM 1 CDFS FAIL TO DETONATE
RBSM1CDFFD
4.00E-10
ROCKET MOTOR R BSM 1 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPIRBS1SRB
1.00E-04
HYPOTHESIS-6
R BSM 2 CDFS FAIL TO DETONATE
RBSM2CDFFD
4.00E-10
ROCKET MOTOR RBS2 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPIRBS2SRB
1.00E-04
HYPOTHESIS-6
R BSM 3 CDFS FAIL TO DETONATE
RBSM3CDFFD
4.00E-10
Page 173
ROCKET MOTOR RBS3 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPIRBS3SRB
1.00E-04
HYPOTHESIS-6
CDF STRING L11 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR11SRB
2.00E-05
Page 169
CDF STRING L12 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR12SRB
2.00E-05
Page 170
CDF STRING L21 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR21SRB
2.00E-05
Page 171
CDF STRING L22 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR22SRB
2.00E-05
Page 172

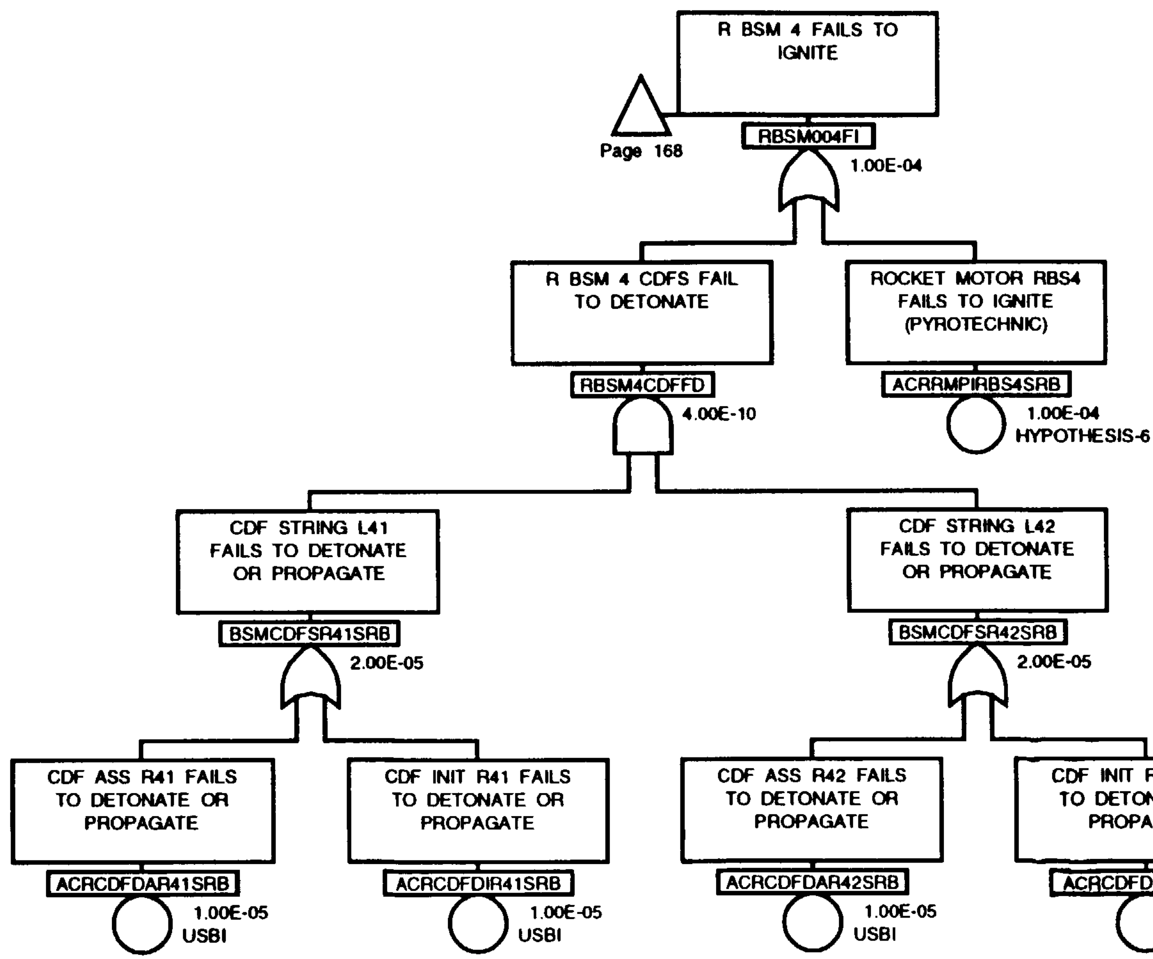

CDF STRING L11 FAILS TO DETONATE OR PROPAGATE
Page 168
BSMCDFSR11SRB
2.00E-05
CDF ASSY R11 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR11SRB
1.00E-05
USBI
CDF INIT R11 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR11SRB
1.00E-05
USBI

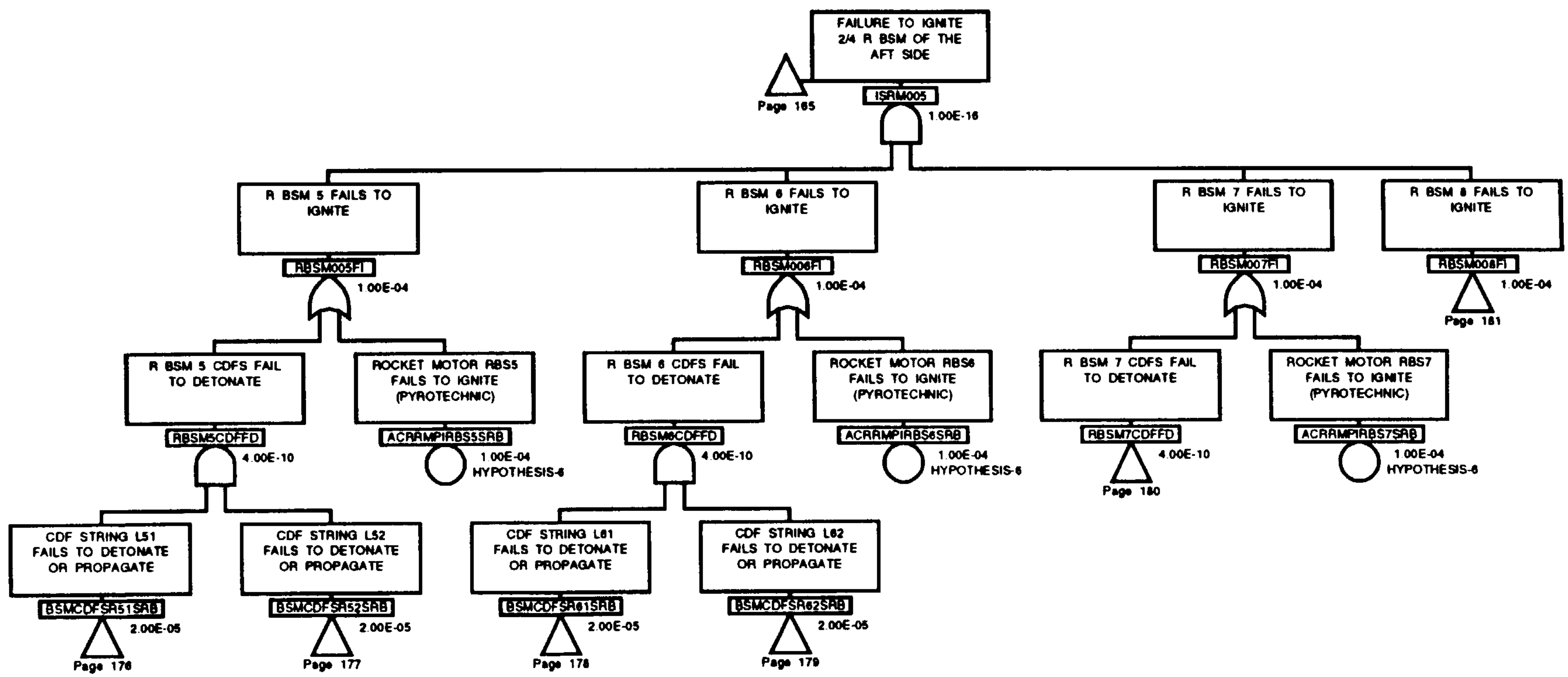

CDF STRING L12 FAILS TO DETONATE OR PROPAGATE
Page 168
BSMCDFSR12SRB
2.00E-05
CDF ASSY R12 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR12SRB
1.00E-05
USBI
CDF INIT R12 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR12SRB
1.00E-05
USBI


CDF STRING L21
FAILS TO DETONATE
OR PROPAGATE
BSMCDFSR21SRB
2.00E-05
Page 168
CDF ASS R21 FAILS
TO DETONATE OR
PROPAGATE
ACRCDFDAR21SRB
1.00E-05
USBI
CDF INIT R21 FAILS
TO DETONATE OR
PROPAGATE
ACRCDFDIR21SRB
1.00E-05
USBI

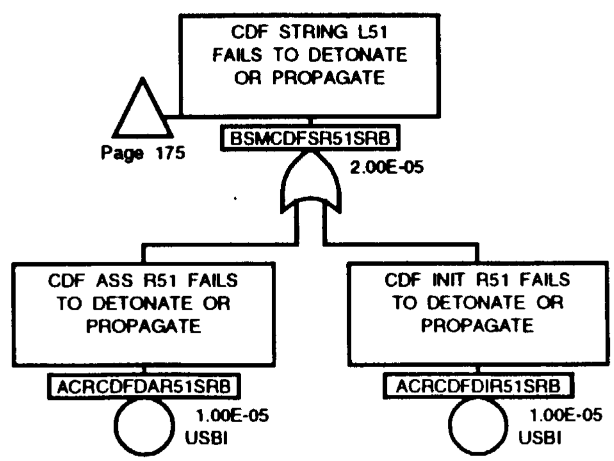

CDF STRING L22 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR22SRB
2.00E-05
Page 168
CDF ASS R22 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR22SRB
1.00E-05
USBI
CDF INIT R22 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR22SRB
1.00E-05
USBI

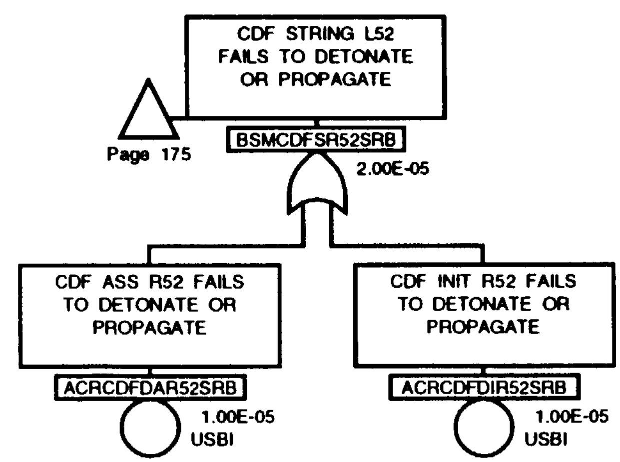

R BSM 3 CDFS FAIL TO DETONATE
Page 168
RBSM3CDFFD
4.00E-10
CDF STRING L31 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR31SRB
2.00E-05
CDF STRING L32 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR32SRB
2.00E-05
CDF ASS R31 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR31SRB
1.00E-05
USBI
CDF INIT R31 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR31SRB
1.00E-05
USBI
CDF ASS R32 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR32SRB
1.00E-05
USBI
CDF INIT R32 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR32SRB
1.00E-05
USBI

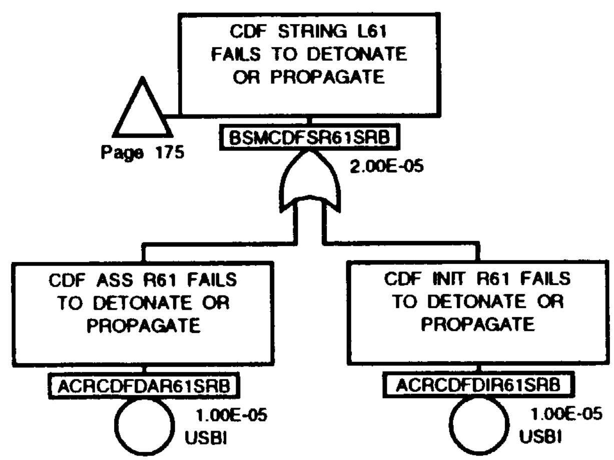

R BSM 4 FAILS TO IGNITE
Page 168
RBSM004FI
1.00E-04
R BSM 4 CDFS FAIL TO DETONATE
ROCKET MOTOR RBS4 FAILS TO IGNITE (PYROTECHNIC)
RBSM4CDFFD
4.00E-10
ACRRMPIRBS4SRB
1.00E-04
HYPOTHESIS-6
CDF STRING L41 FAILS TO DETONATE OR PROPAGATE
CDF STRING L42 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR41SRB
2.00E-05
BSMCDFSR42SRB
2.00E-05
CDF ASS R41 FAILS TO DETONATE OR PROPAGATE
CDF INIT R41 FAILS TO DETONATE OR PROPAGATE
CDF ASS R42 FAILS TO DETONATE OR PROPAGATE
CDF INIT R42 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR41SRB
1.00E-05
USBI
ACRCDFDIR41SRB
1.00E-05
USBI
ACRCDFDAR42SRB
1.00E-05
USBI
ACRCDFDIR42SRB
1.00E-05
USBI

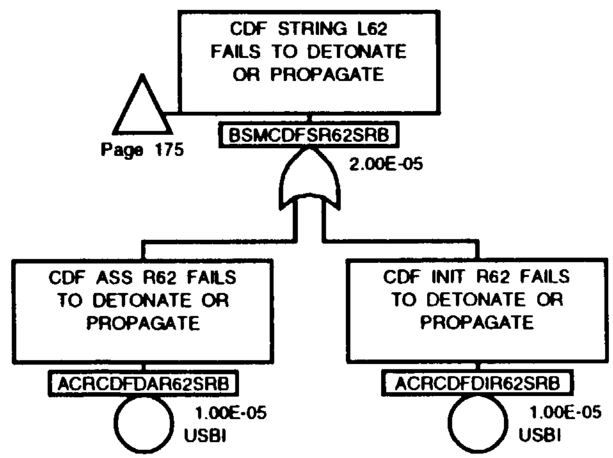


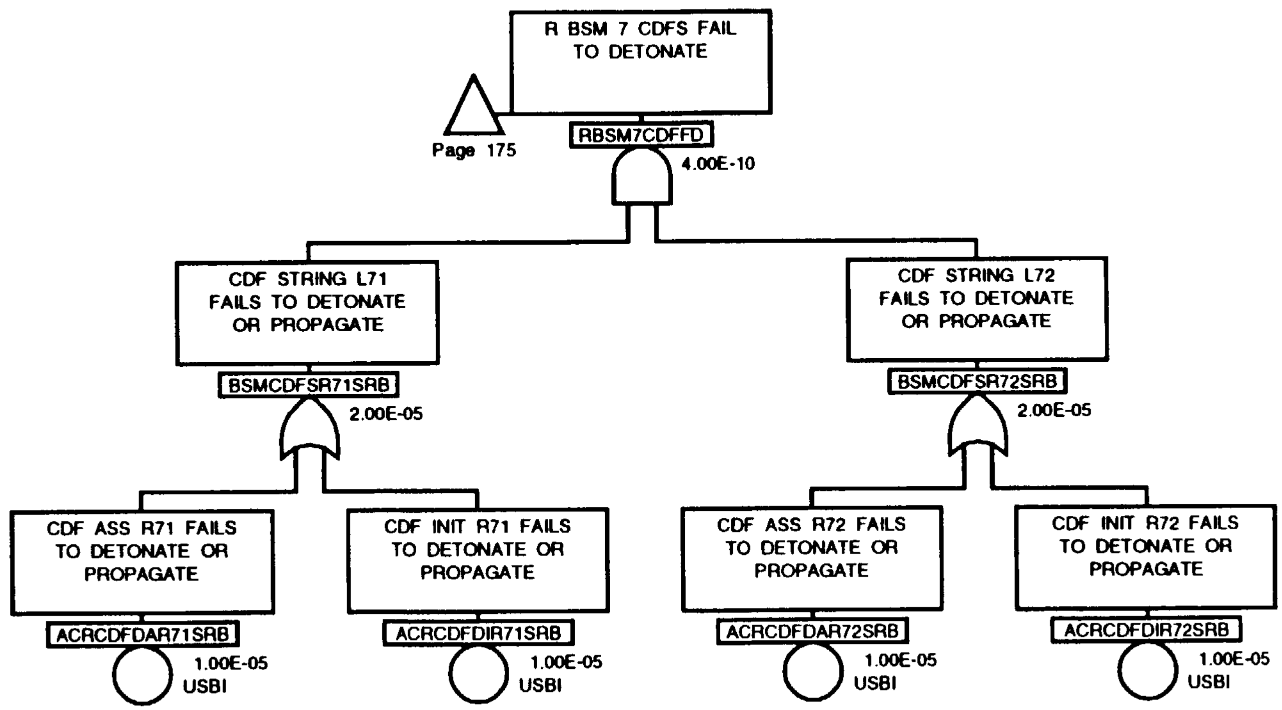
FAILURE TO IGNITE 2/4 R BSM OF THE AFT SIDE
ISRM005
1.00E-16
Page 165
R BSM 5 FAILS TO IGNITE
RBSM005FI
1.00E-04
R BSM 6 FAILS TO IGNITE
RBSM006FI
1.00E-04
R BSM 7 FAILS TO IGNITE
RBSM007FI
1.00E-04
R BSM 8 FAILS TO IGNITE
RBSM008FI
1.00E-04
Page 181
R BSM 5 CDFS FAIL TO DETONATE
RBSM5CDFFD
4.00E-10
ROCKET MOTOR RBS5 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPIRBS5SRB
1.00E-04
HYPOTHESIS-6
R BSM 6 CDFS FAIL TO DETONATE
RBSM6CDFFD
4.00E-10
ROCKET MOTOR RBS6 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPIRBS6SRB
1.00E-04
HYPOTHESIS-6
R BSM 7 CDFS FAIL TO DETONATE
RBSM7CDFFD
4.00E-10
Page 180
ROCKET MOTOR RBS7 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPIRBS7SRB
1.00E-04
HYPOTHESIS-6
CDF STRING L51 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR51SRB
2.00E-05
Page 176
CDF STRING L52 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR52SRB
2.00E-05
Page 177
CDF STRING L61 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR61SRB
2.00E-05
Page 178
CDF STRING L62 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR62SRB
2.00E-05
Page 179

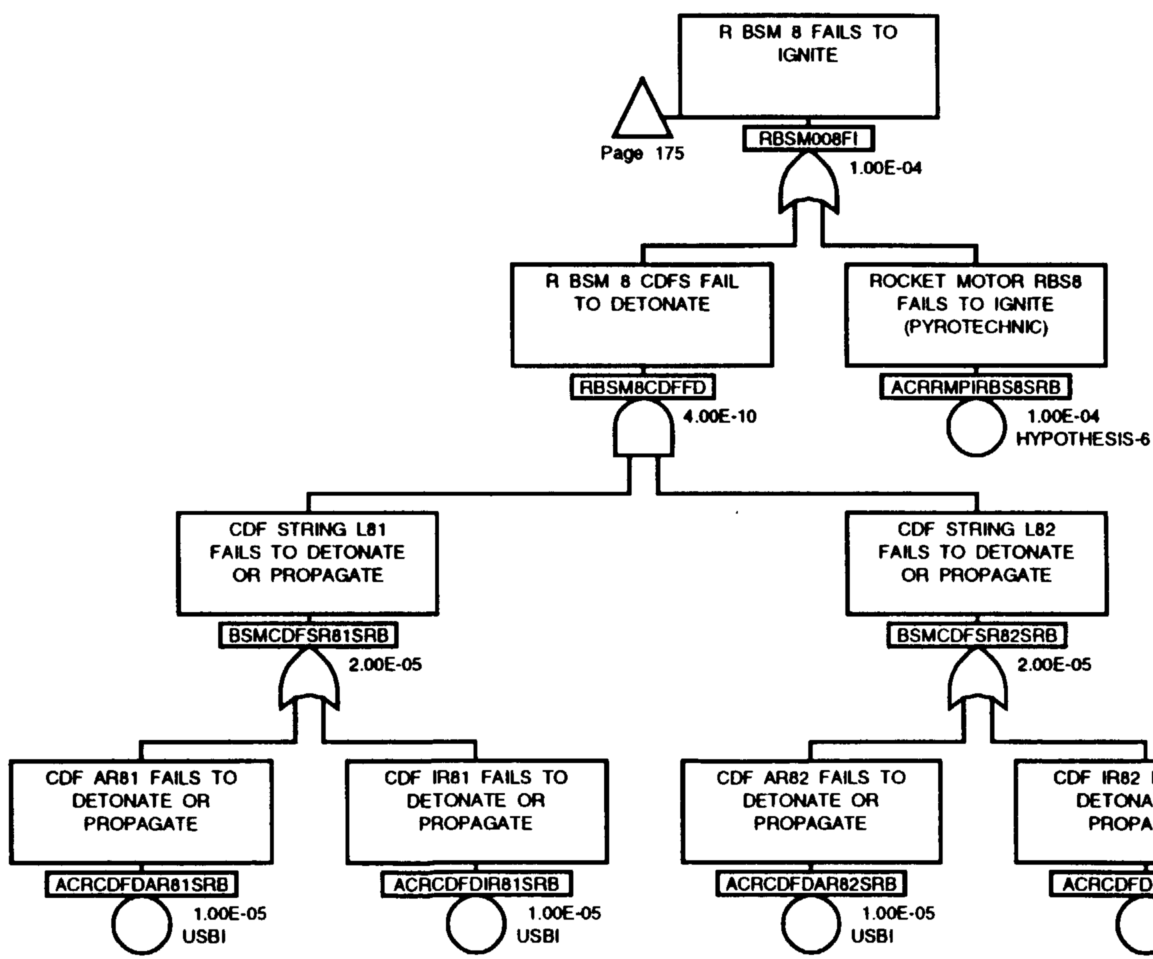

CDF STRING L51 FAILS TO DETONATE OR PROPAGATE
Page 175
BSMCDFSR51SRB
2.00E-05
CDF ASS R51 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR51SRB
1.00E-05
USBI
CDF INIT R51 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR51SRB
1.00E-05
USBI

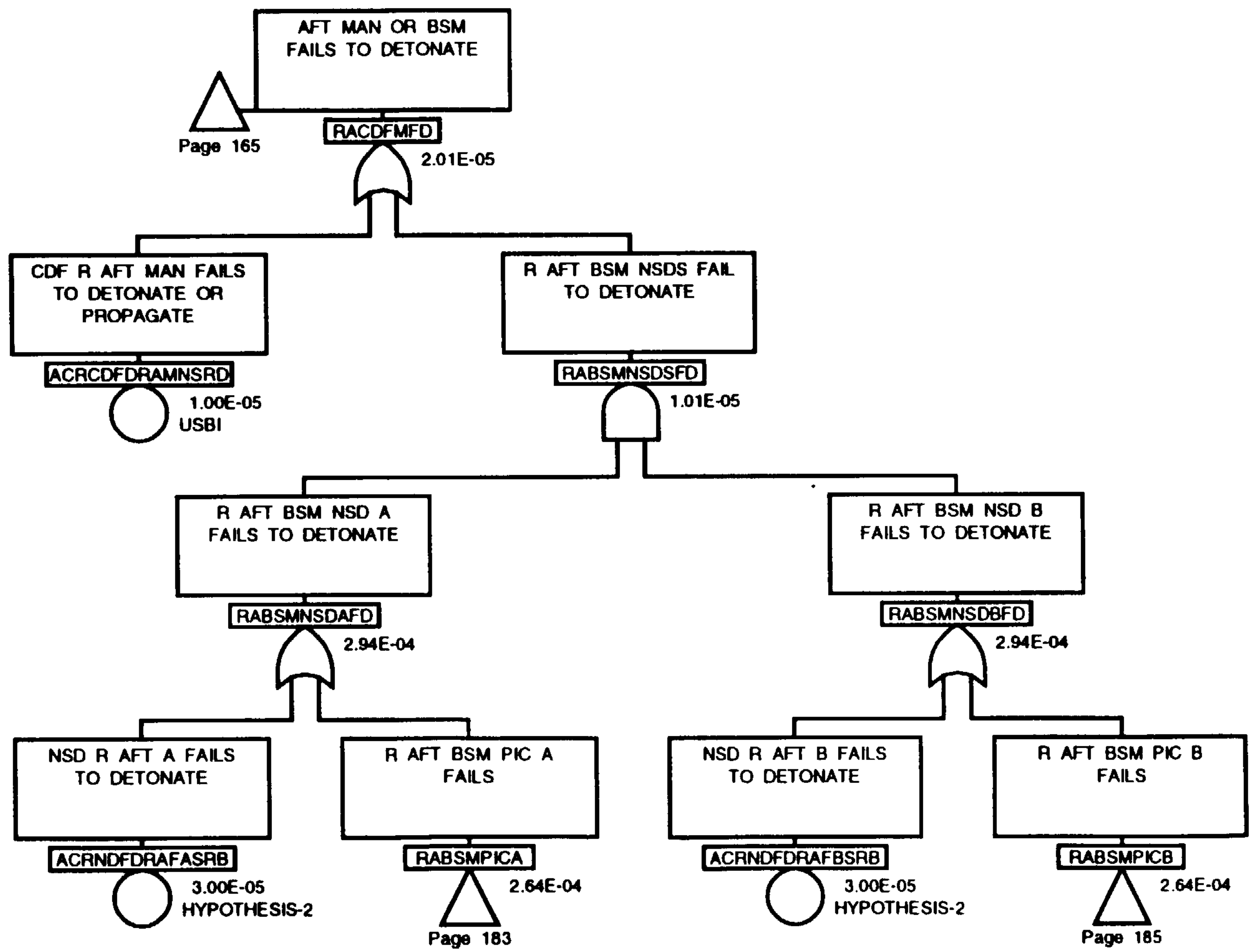

CDF STRING L52 FAILS TO DETONATE OR PROPAGATE
Page 175
BSMCDFSR52SRB
2.00E-05
CDF ASS R52 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR52SRB
1.00E-05
USBI
CDF INIT R52 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR52SRB
1.00E-05
USBI

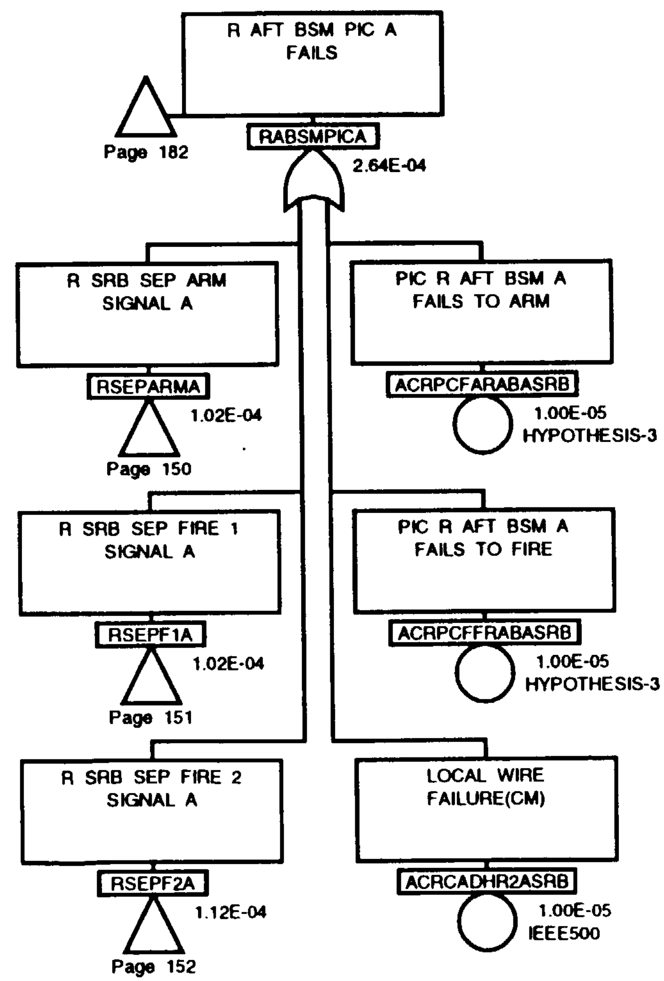

CDF STRING L61 FAILS TO DETONATE OR PROPAGATE
Page 175
BSMCDFSR61SRB
2.00E-05
CDF ASS R61 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR61SRB
1.00E-05
USBI
CDF INIT R61 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR61SRB
1.00E-05
USBI

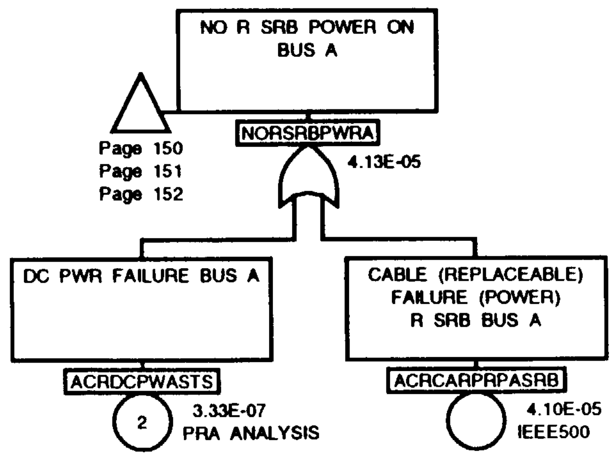

CDF STRING L62 FAILS TO DETONATE OR PROPAGATE
Page 175
BSMCDFSR62SRB
2.00E-05
CDF ASS R62 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR62SRB
1.00E-05
USBI
CDF INIT R62 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR62SRB
1.00E-05
USBI


R BSM 7 CDFS FAIL TO DETONATE
RBSM7CDFFD
4.00E-10
Page 175
CDF STRING L71 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR71SRB
2.00E-05
CDF STRING L72 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR72SRB
2.00E-05
CDF ASS R71 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR71SRB
1.00E-05
USBI
CDF INIT R71 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR71SRB
1.00E-05
USBI
CDF ASS R72 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR72SRB
1.00E-05
USBI
CDF INIT R72 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR72SRB
1.00E-05
USBI

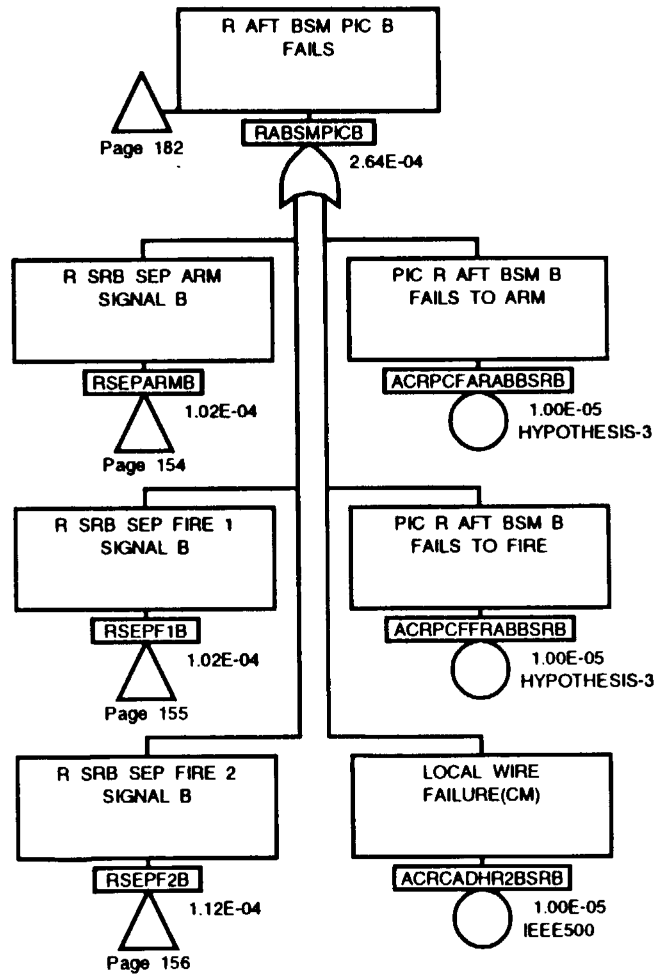

R BSM 8 FAILS TO IGNITE
Page 175
RBSM008FI
1.00E-04
R BSM 8 CDFS FAIL TO DETONATE
RBSM8CDFFD
4.00E-10
ROCKET MOTOR RBS8 FAILS TO IGNITE (PYROTECHNIC)
ACRRMPIRBS8SRB
1.00E-04
HYPOTHESIS-6
CDF STRING L81 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR81SRB
2.00E-05
CDF STRING L82 FAILS TO DETONATE OR PROPAGATE
BSMCDFSR82SRB
2.00E-05
CDF AR81 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR81SRB
1.00E-05
USBI
CDF IR81 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR81SRB
1.00E-05
USBI
CDF AR82 FAILS TO DETONATE OR PROPAGATE
ACRCDFDAR82SRB
1.00E-05
USBI
CDF IR82 FAILS TO DETONATE OR PROPAGATE
ACRCDFDIR82SRB
1.00E-05
USBI

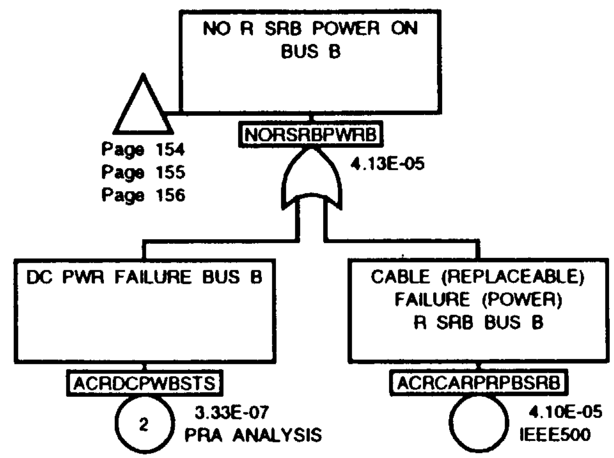

AFT MAN OR BSM FAILS TO DETONATE
Page 165
RACDFMFD
2.01E-05
CDF R AFT MAN FAILS TO DETONATE OR PROPAGATE
ACRCDFDRAMNSRD
1.00E-05
USBI
R AFT BSM NSDS FAIL TO DETONATE
RABSMNSDSFD
1.01E-05
R AFT BSM NSD A FAILS TO DETONATE
RABSMNSDAFD
2.94E-04
R AFT BSM NSD B FAILS TO DETONATE
RABSMNSDBFD
2.94E-04
NSD R AFT A FAILS TO DETONATE
ACRNDFDRAFASRB
3.00E-05
HYPOTHESIS-2
R AFT BSM PIC A FAILS
RABSMPICA
2.64E-04
Page 183
NSD R AFT B FAILS TO DETONATE
ACRNDFDRAFBSRB
3.00E-05
HYPOTHESIS-2
R AFT BSM PIC B FAILS
RABSMPICB
2.64E-04
Page 185

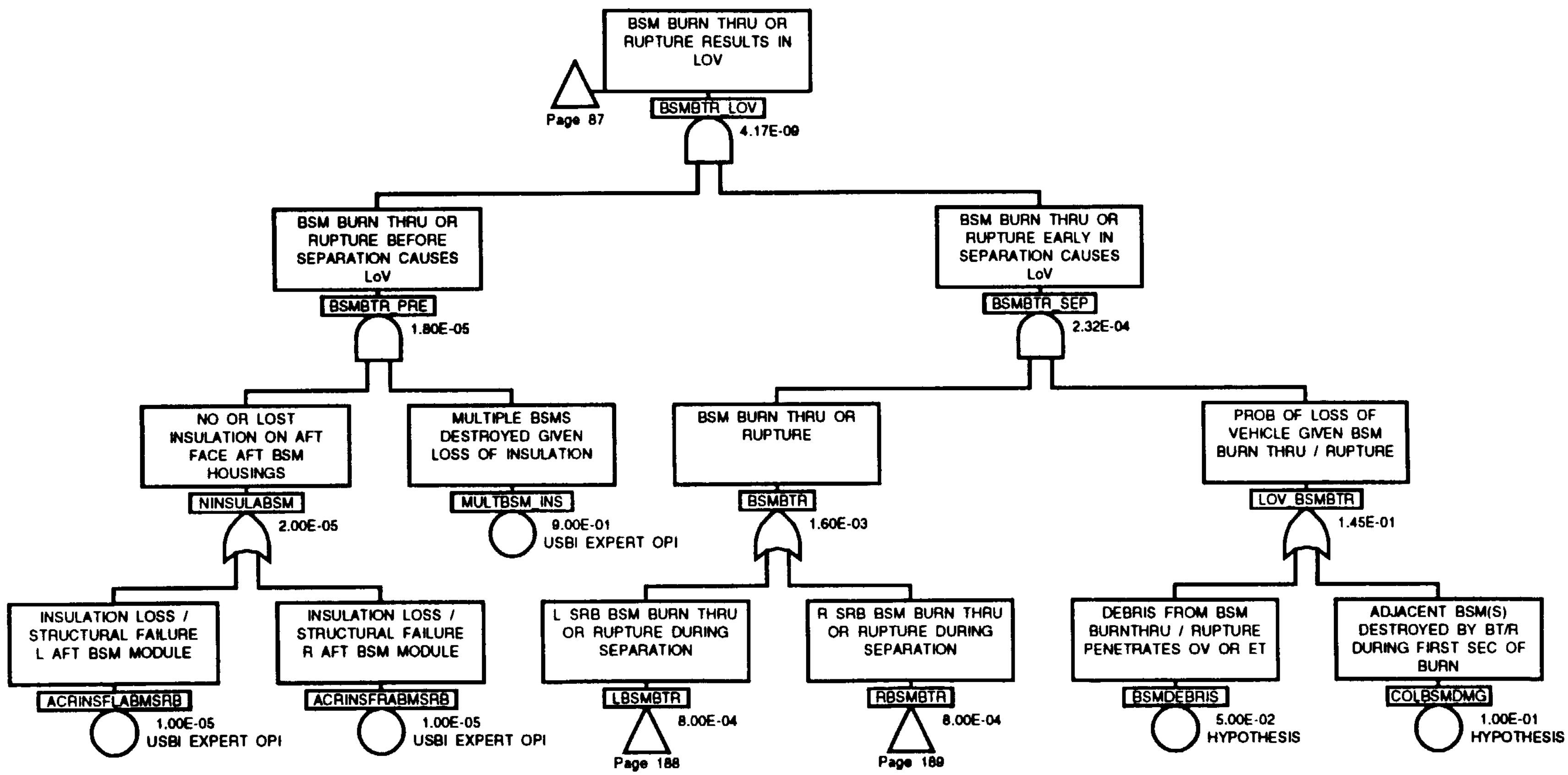

R AFT BSM PIC A FAILS
RABSMPICA
2.64E-04
Page 182
R SRB SEP ARM SIGNAL A
RSEPARMA
1.02E-04
Page 150
PIC R AFT BSM A FAILS TO ARM
ACRPCFARABASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1 SIGNAL A
RSEPF1A
1.02E-04
Page 151
PIC R AFT BSM A FAILS TO FIRE
ACRPCFFRABASRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2 SIGNAL A
RSEPF2A
1.12E-04
Page 152
LOCAL WIRE FAILURE(CM)
ACRCADHR2ASRB
1.00E-05
IEEE500

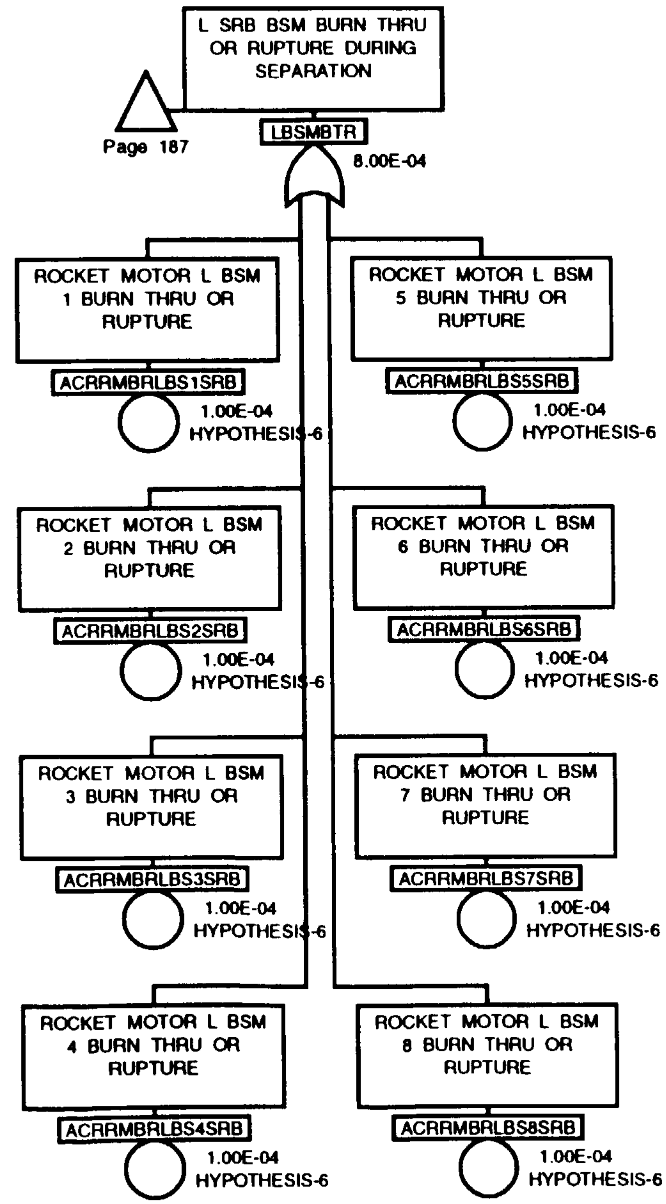


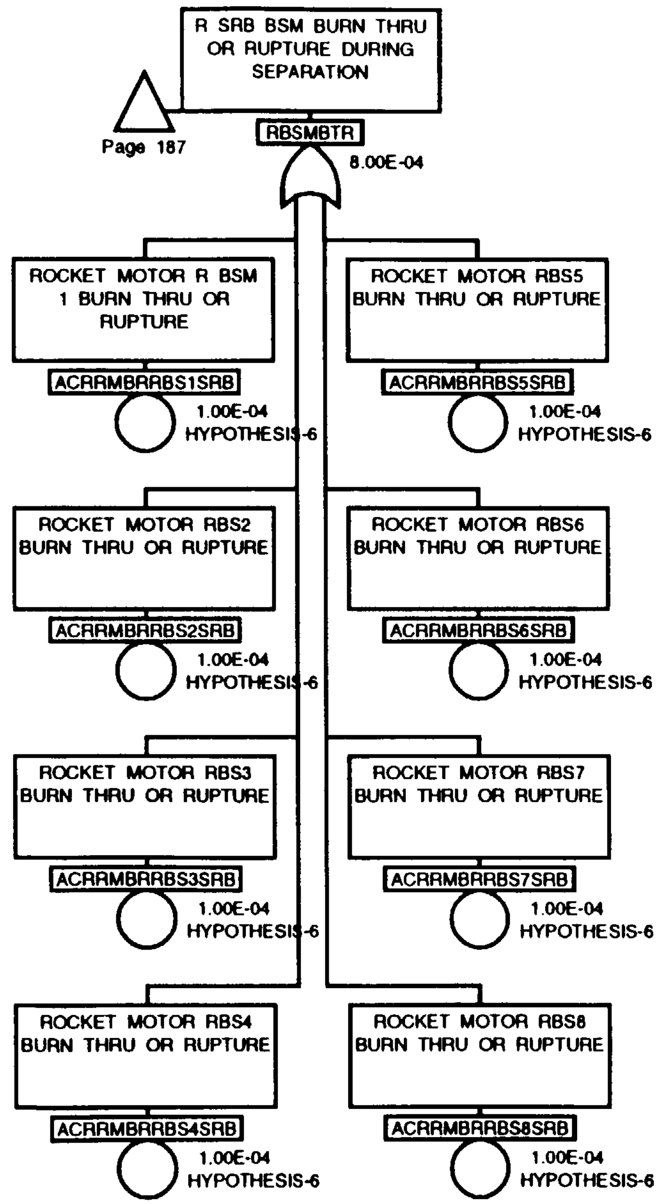
NO R SRB POWER ON BUS A
NORSRBPWRA
4.13E-05
Page 150
Page 151
Page 152
DC PWR FAILURE BUS A
ACRDCPWASTS
2
3.33E-07
PRA ANALYSIS
CABLE (REPLACEABLE) FAILURE (POWER) R SRB BUS A
ACRCARPRPASRB
4.10E-05
IEEE500

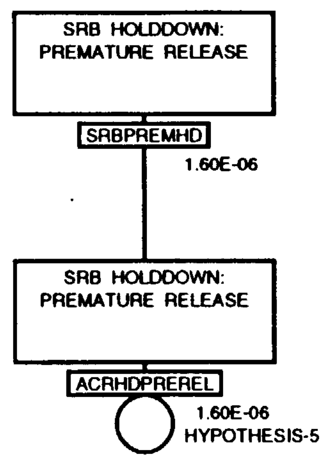

R AFT BSM PIC B FAILS
RABSMPICB
2.64E-04
Page 182
R SRB SEP ARM SIGNAL B
RSEPARMB
1.02E-04
Page 154
PIC R AFT BSM B FAILS TO ARM
ACRPCFARABBSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 1 SIGNAL B
RSEPF1B
1.02E-04
Page 155
PIC R AFT BSM B FAILS TO FIRE
ACRPCFFRABBSRB
1.00E-05
HYPOTHESIS-3
R SRB SEP FIRE 2 SIGNAL B
RSEPF2B
1.12E-04
Page 156
LOCAL WIRE FAILURE(CM)
ACRCADHR2BSRB
1.00E-05
IEEE500

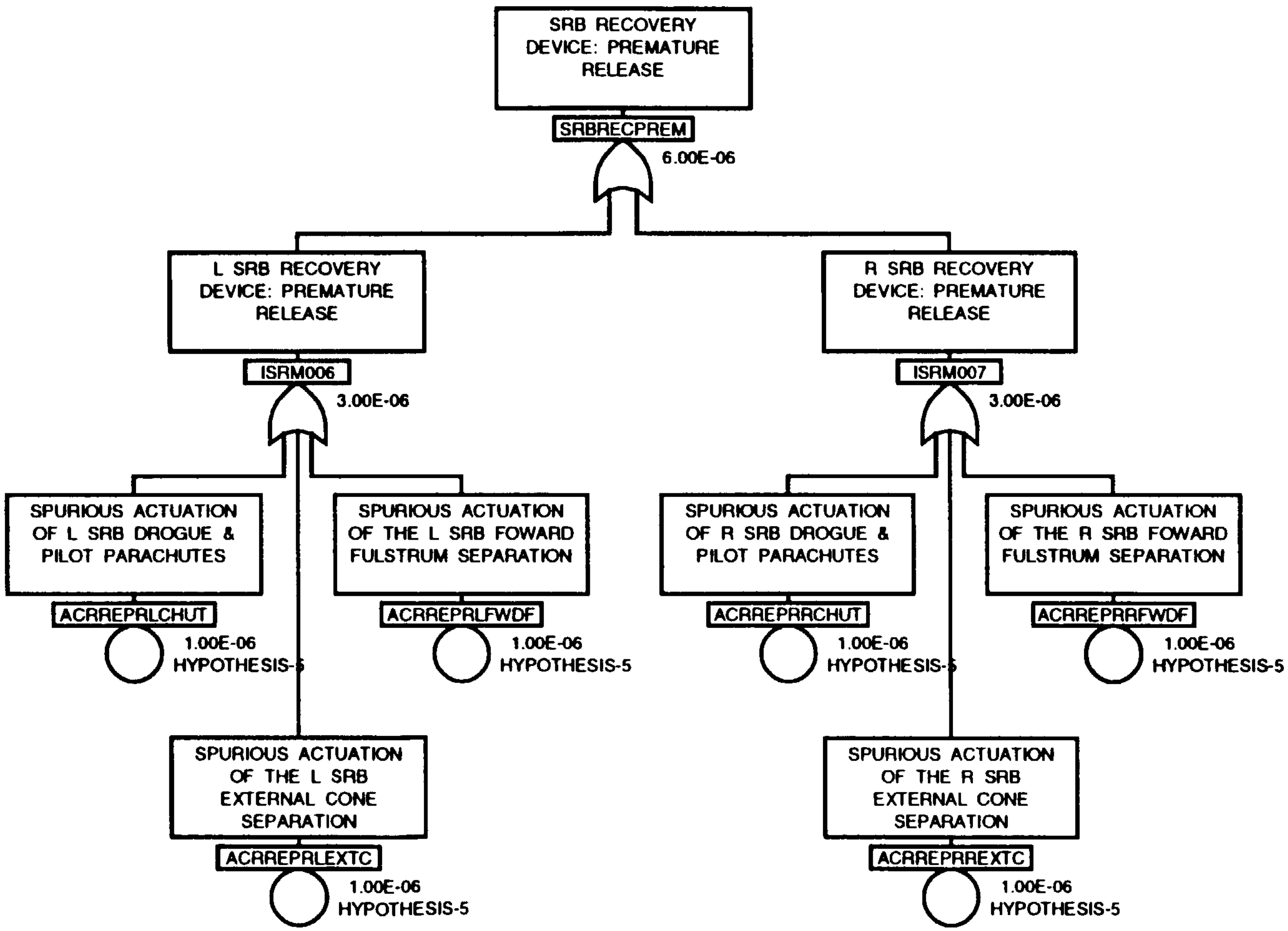

NO R SRB POWER ON BUS B
NORSRBPWRB
4.13E-05
Page 154
Page 155
Page 156
DC PWR FAILURE BUS B
ACRDCPWBSTS
2
3.33E-07
PRA ANALYSIS
CABLE (REPLACEABLE) FAILURE (POWER) R SRB BUS B
ACRCARPRPBSRB
4.10E-05
IEEE500

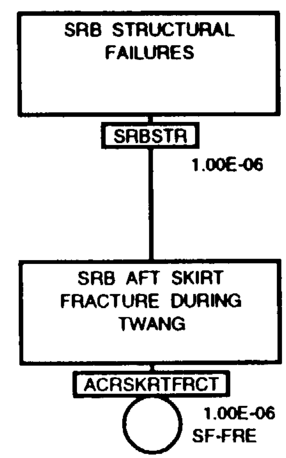

BSM BURN THRU OR RUPTURE RESULTS IN LOV
BSMBTR_LOV
4.17E-09
Page 87
BSM BURN THRU OR RUPTURE BEFORE SEPARATION CAUSES LoV
BSMBTR_PRE
1.80E-05
BSM BURN THRU OR RUPTURE EARLY IN SEPARATION CAUSES LoV
BSMBTR_SEP
2.32E-04
NO OR LOST INSULATION ON AFT FACE AFT BSM HOUSINGS
NINSULABSM
2.00E-05
MULTIPLE BSMS DESTROYED GIVEN LOSS OF INSULATION
MULTBSM_INS
9.00E-01
USBI EXPERT OPI
BSM BURN THRU OR RUPTURE
BSMBTR
1.60E-03
PROB OF LOSS OF VEHICLE GIVEN BSM BURN THRU / RUPTURE
LOV_BSMBTR
1.45E-01
INSULATION LOSS / STRUCTURAL FAILURE L AFT BSM MODULE
ACRINSFLABMSRB
1.00E-05
USBI EXPERT OPI
INSULATION LOSS / STRUCTURAL FAILURE R AFT BSM MODULE
ACRINSFRABMSRB
1.00E-05
USBI EXPERT OPI
L SRB BSM BURN THRU OR RUPTURE DURING SEPARATION
LBSMBTR
8.00E-04
Page 188
R SRB BSM BURN THRU OR RUPTURE DURING SEPARATION
RBSMBTR
8.00E-04
Page 189
DEBRIS FROM BSM BURNTHRU / RUPTURE PENETRATES OV OR ET
BSMDEBRIS
5.00E-02
HYPOTHESIS
ADJACENT BSM(S) DESTROYED BY BT/R DURING FIRST SEC OF BURN
COLBSMDMG
1.00E-01
HYPOTHESIS

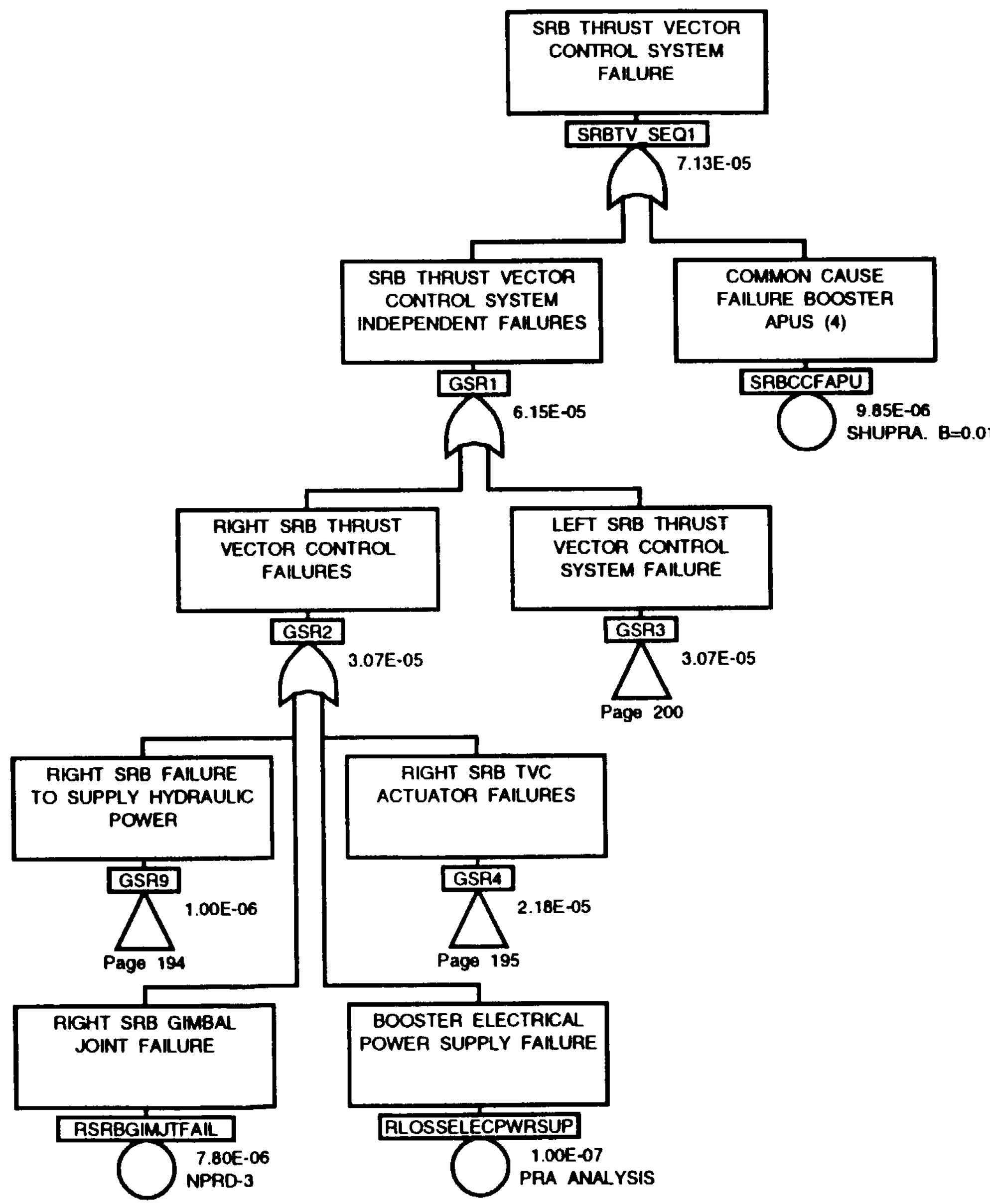

L SRB BSM BURN THRU OR RUPTURE DURING SEPARATION
LBSMBTR
8.00E-04
Page 187
ROCKET MOTOR L BSM 1 BURN THRU OR RUPTURE
ACRRMBRLBS1SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR L BSM 2 BURN THRU OR RUPTURE
ACRRMBRLBS2SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR L BSM 3 BURN THRU OR RUPTURE
ACRRMBRLBS3SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR L BSM 4 BURN THRU OR RUPTURE
ACRRMBRLBS4SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR L BSM 5 BURN THRU OR RUPTURE
ACRRMBRLBS5SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR L BSM 6 BURN THRU OR RUPTURE
ACRRMBRLBS6SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR L BSM 7 BURN THRU OR RUPTURE
ACRRMBRLBS7SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR L BSM 8 BURN THRU OR RUPTURE
ACRRMBRLBS8SRB
1.00E-04
HYPOTHESIS-6

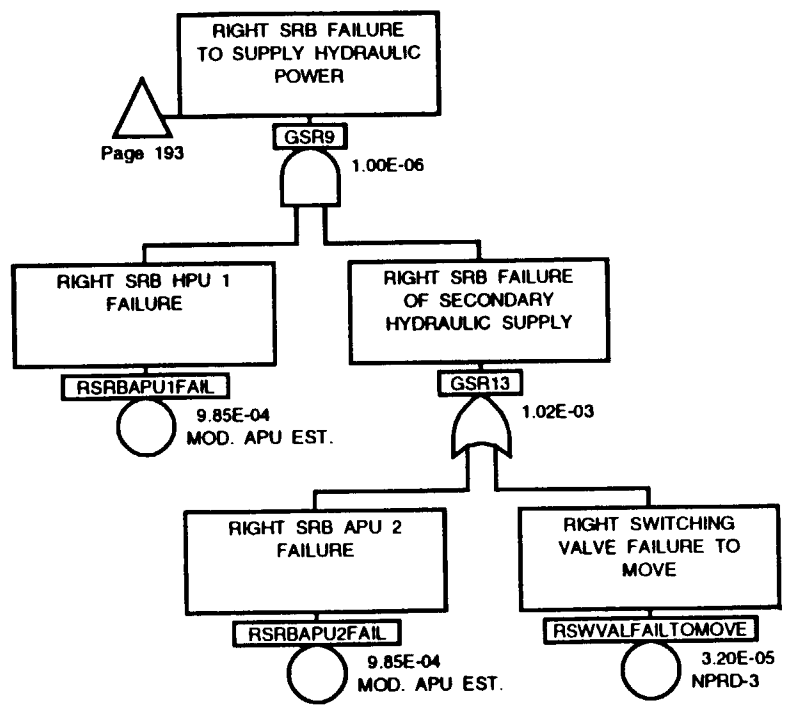

R SRB BSM BURN THRU OR RUPTURE DURING SEPARATION
Page 187
RBSMBTR
8.00E-04
ROCKET MOTOR R BSM 1 BURN THRU OR RUPTURE
ACRRMBRRBS1SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR RBS5 BURN THRU OR RUPTURE
ACRRMBRRBS5SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR RBS2 BURN THRU OR RUPTURE
ACRRMBRRBS2SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR RBS6 BURN THRU OR RUPTURE
ACRRMBRRBS6SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR RBS3 BURN THRU OR RUPTURE
ACRRMBRRBS3SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR RBS7 BURN THRU OR RUPTURE
ACRRMBRRBS7SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR RBS4 BURN THRU OR RUPTURE
ACRRMBRRBS4SRB
1.00E-04
HYPOTHESIS-6
ROCKET MOTOR RBS8 BURN THRU OR RUPTURE
ACRRMBRRBS8SRB
1.00E-04
HYPOTHESIS-6

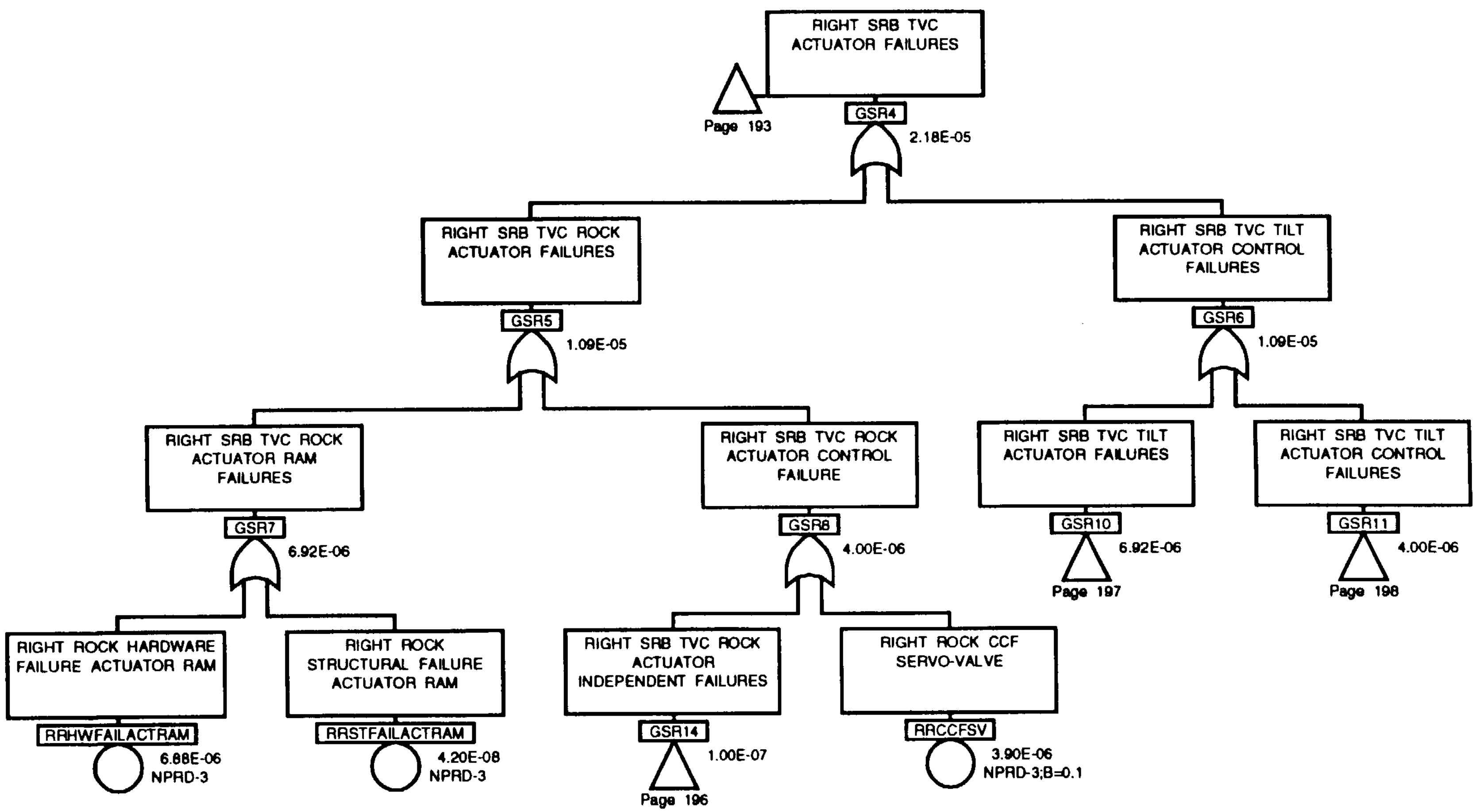

SRB HOLDDOWN:
PREMATURE RELEASE
SRBPREMHD
1.60E-06
SRB HOLDDOWN:
PREMATURE RELEASE
ACRHDPREREL
1.60E-06
HYPOTHESIS-5

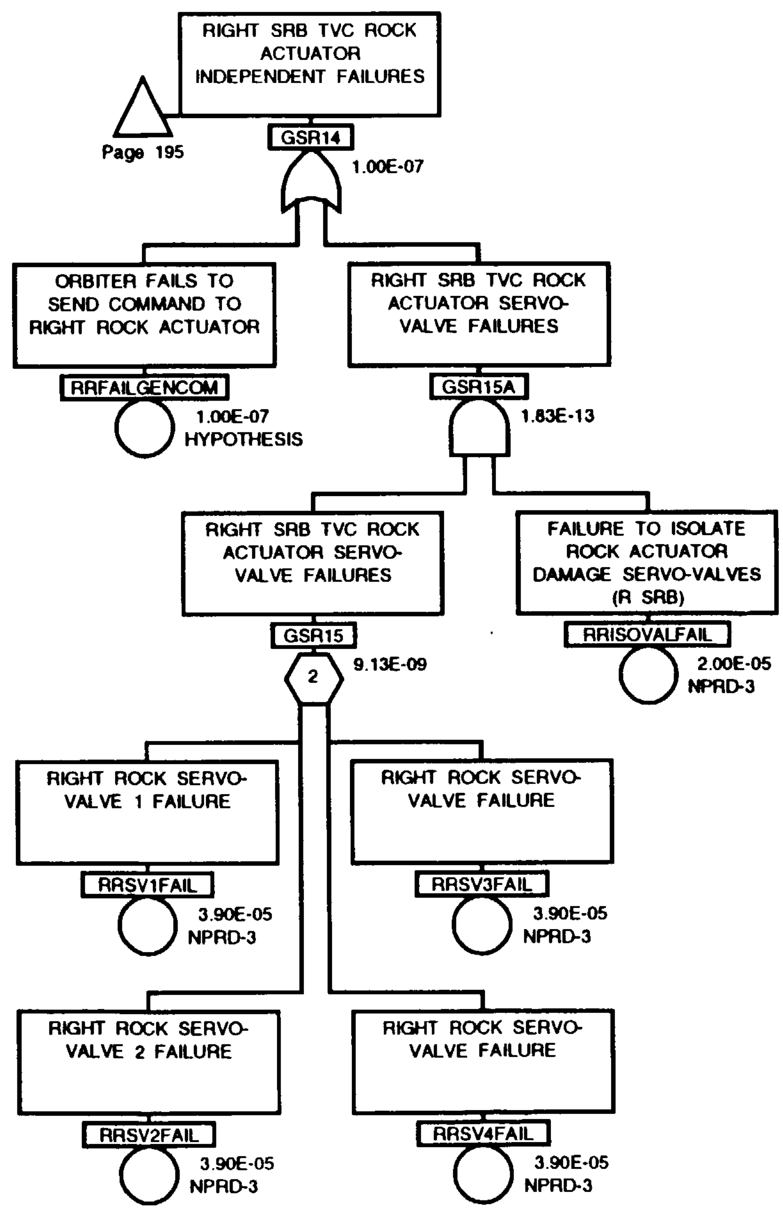

SRB RECOVERY DEVICE: PREMATURE RELEASE
SRBRECPREM
6.00E-06
L SRB RECOVERY DEVICE: PREMATURE RELEASE
ISRM006
3.00E-06
R SRB RECOVERY DEVICE: PREMATURE RELEASE
ISRM007
3.00E-06
SPURIOUS ACTUATION OF L SRB DROGUE & PILOT PARACHUTES
ACRREPRLCHUT
1.00E-06
HYPOTHESIS-5
SPURIOUS ACTUATION OF THE L SRB FOWARD FULSTRUM SEPARATION
ACRREPRLFWDF
1.00E-06
HYPOTHESIS-5
SPURIOUS ACTUATION OF R SRB DROGUE & PILOT PARACHUTES
ACRREPRRCHUT
1.00E-06
HYPOTHESIS-5
SPURIOUS ACTUATION OF THE R SRB FOWARD FULSTRUM SEPARATION
ACRREPRRFWDF
1.00E-06
HYPOTHESIS-5
SPURIOUS ACTUATION OF THE L SRB EXTERNAL CONE SEPARATION
ACRREPRLEXTC
1.00E-06
HYPOTHESIS-5
SPURIOUS ACTUATION OF THE R SRB EXTERNAL CONE SEPARATION
ACRREPRREXTC
1.00E-06
HYPOTHESIS-5

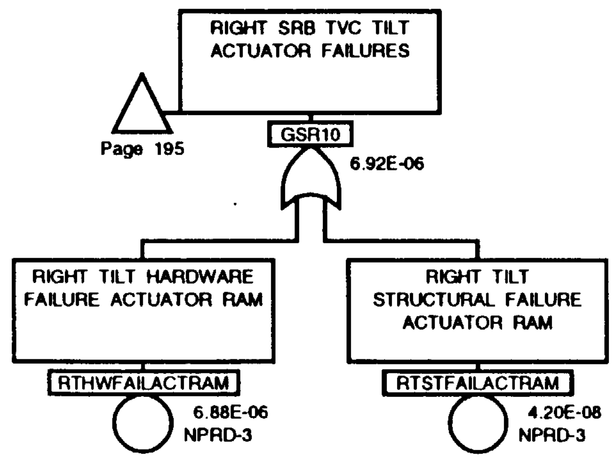

SRB STRUCTURAL FAILURES
SRBSTR
1.00E-06
SRB AFT SKIRT FRACTURE DURING TWANG
ACRSKRTFRCT
1.00E-06
SF-FRE

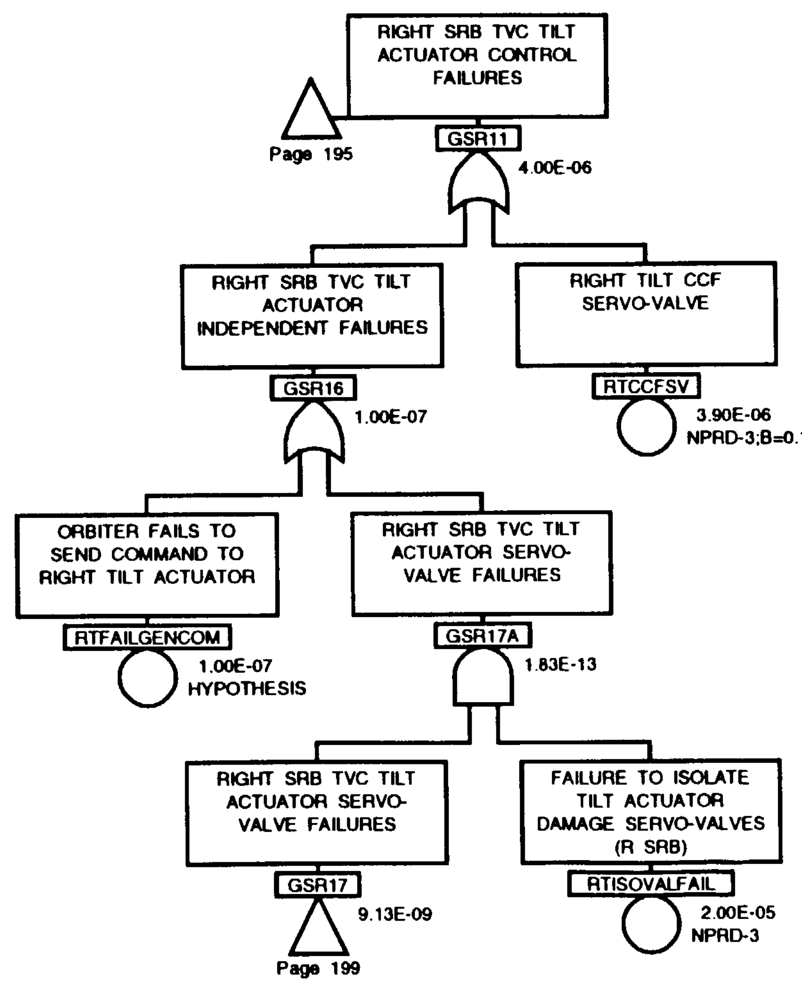

SRB THRUST VECTOR CONTROL SYSTEM FAILURE
SRBTV SEQ1
7.13E-05
SRB THRUST VECTOR CONTROL SYSTEM INDEPENDENT FAILURES
GSR1
6.15E-05
COMMON CAUSE FAILURE BOOSTER APUS (4)
SRBCCFAPU
9.85E-06
SHUPRA. B=0.01
RIGHT SRB THRUST VECTOR CONTROL FAILURES
GSR2
3.07E-05
LEFT SRB THRUST VECTOR CONTROL SYSTEM FAILURE
GSR3
3.07E-05
Page 200
RIGHT SRB FAILURE TO SUPPLY HYDRAULIC POWER
GSR9
1.00E-06
Page 194
RIGHT SRB TVC ACTUATOR FAILURES
GSR4
2.18E-05
Page 195
RIGHT SRB GIMBAL JOINT FAILURE
RSRBGIMJTFAIL
7.80E-06
NPRD-3
BOOSTER ELECTRICAL POWER SUPPLY FAILURE
RLOSSELECPWRSUP
1.00E-07
PRA ANALYSIS

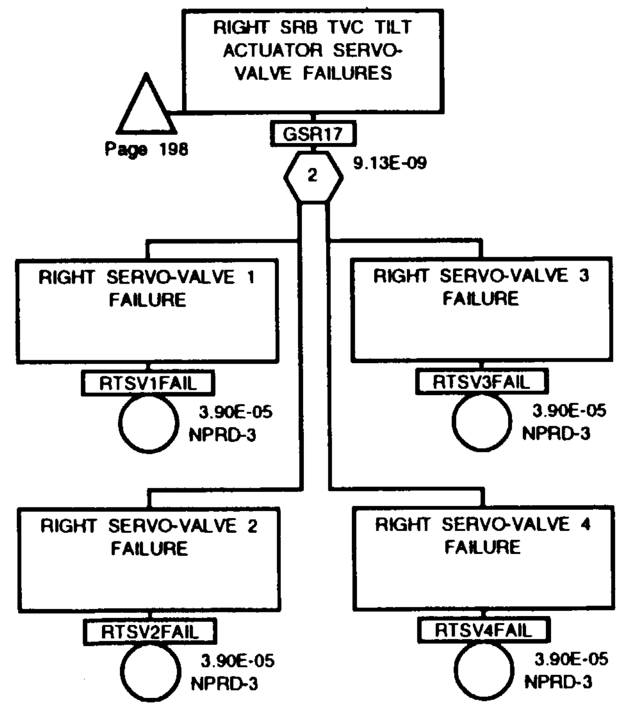

RIGHT SRB FAILURE TO SUPPLY HYDRAULIC POWER
Page 193
GSR9
1.00E-06
RIGHT SRB HPU 1 FAILURE
RSRBAPU1FAIL
9.85E-04
MOD. APU EST.
RIGHT SRB FAILURE OF SECONDARY HYDRAULIC SUPPLY
GSR13
1.02E-03
RIGHT SRB APU 2 FAILURE
RSRBAPU2FAIL
9.85E-04
MOD. APU EST.
RIGHT SWITCHING VALVE FAILURE TO MOVE
RSWVALFAILTOMOVE
3.20E-05
NPRD-3

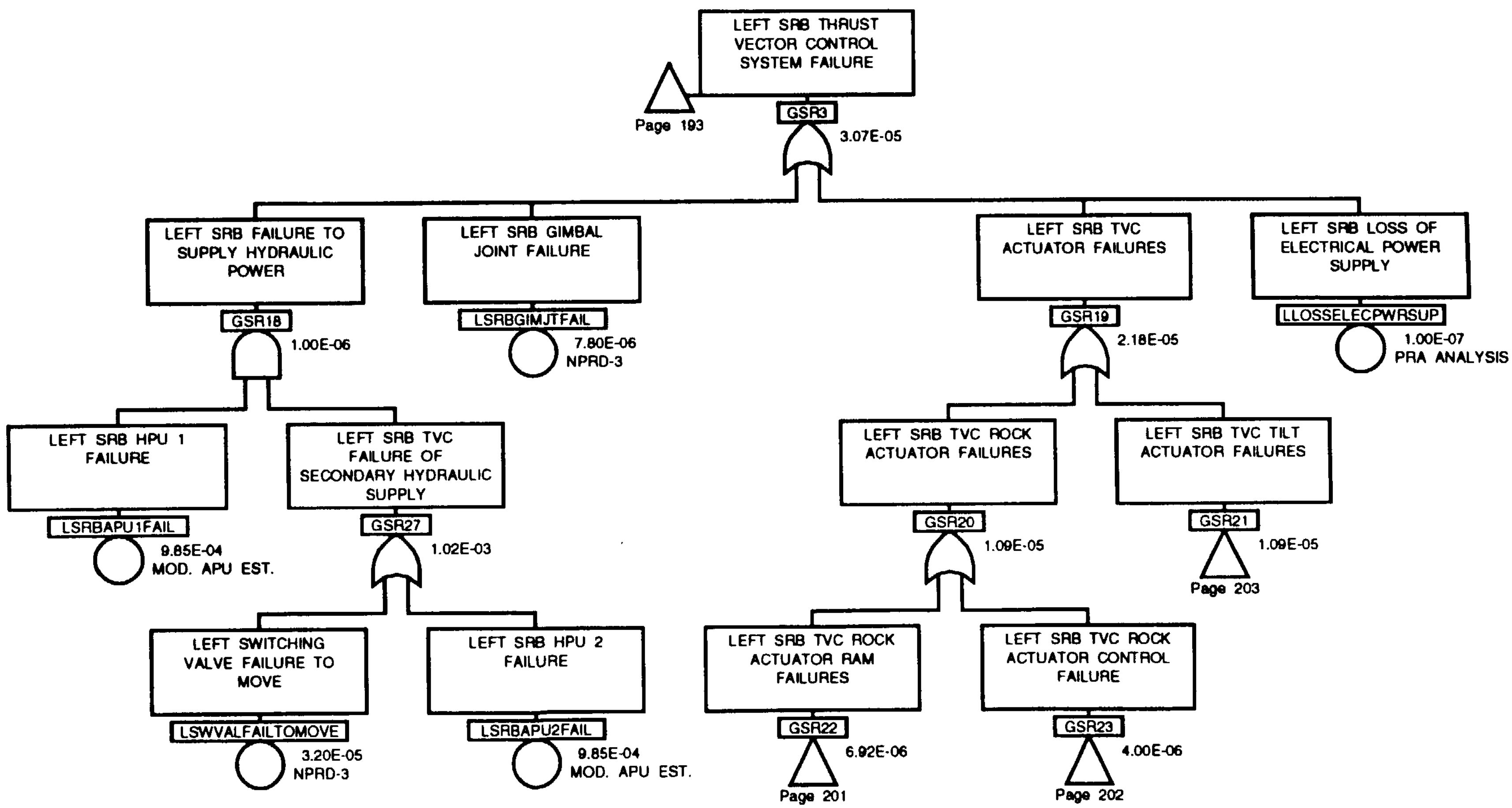

RIGHT SRB TVC ACTUATOR FAILURES
Page 193
GSR4
2.18E-05
RIGHT SRB TVC ROCK ACTUATOR FAILURES
GSR5
1.09E-05
RIGHT SRB TVC TILT ACTUATOR CONTROL FAILURES
GSR6
1.09E-05
RIGHT SRB TVC ROCK ACTUATOR RAM FAILURES
GSR7
6.92E-06
RIGHT SRB TVC ROCK ACTUATOR CONTROL FAILURE
GSR8
4.00E-06
RIGHT SRB TVC TILT ACTUATOR FAILURES
GSR10
6.92E-06
Page 197
RIGHT SRB TVC TILT ACTUATOR CONTROL FAILURES
GSR11
4.00E-06
Page 198
RIGHT ROCK HARDWARE FAILURE ACTUATOR RAM
RRHWFAILACTRAM
6.88E-06
NPRD-3
RIGHT ROCK STRUCTURAL FAILURE ACTUATOR RAM
RRSTFAILACTRAM
4.20E-08
NPRD-3
RIGHT SRB TVC ROCK ACTUATOR INDEPENDENT FAILURES
GSR14
1.00E-07
Page 196
RIGHT ROCK CCF SERVO-VALVE
RRCCFSV
3.90E-06
NPRD-3;B=0.1

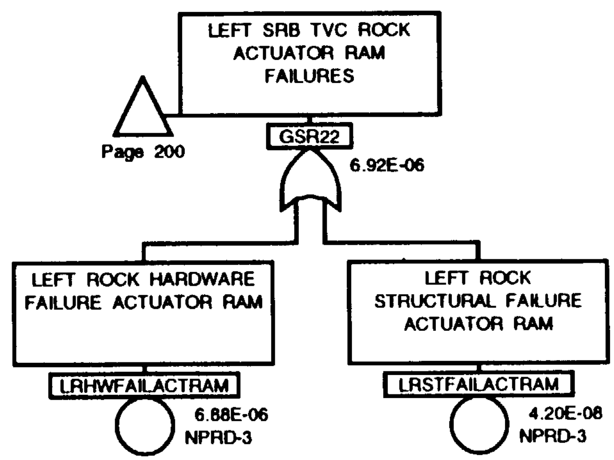

RIGHT SRB TVC ROCK ACTUATOR INDEPENDENT FAILURES
Page 195
GSR14
1.00E-07
ORBITER FAILS TO SEND COMMAND TO RIGHT ROCK ACTUATOR
RRFAILGENCOM
1.00E-07
HYPOTHESIS
RIGHT SRB TVC ROCK ACTUATOR SERVO-VALVE FAILURES
GSR15A
1.83E-13
RIGHT SRB TVC ROCK ACTUATOR SERVO-VALVE FAILURES
GSR15
2
9.13E-09
FAILURE TO ISOLATE ROCK ACTUATOR DAMAGE SERVO-VALVES (R SRB)
RRISOVALFAIL
2.00E-05
NPRD-3
RIGHT ROCK SERVO-VALVE 1 FAILURE
RRSV1FAIL
3.90E-05
NPRD-3
RIGHT ROCK SERVO-VALVE FAILURE
RRSV3FAIL
3.90E-05
NPRD-3
RIGHT ROCK SERVO-VALVE 2 FAILURE
RRSV2FAIL
3.90E-05
NPRD-3
RIGHT ROCK SERVO-VALVE FAILURE
RRSV4FAIL
3.90E-05
NPRD-3

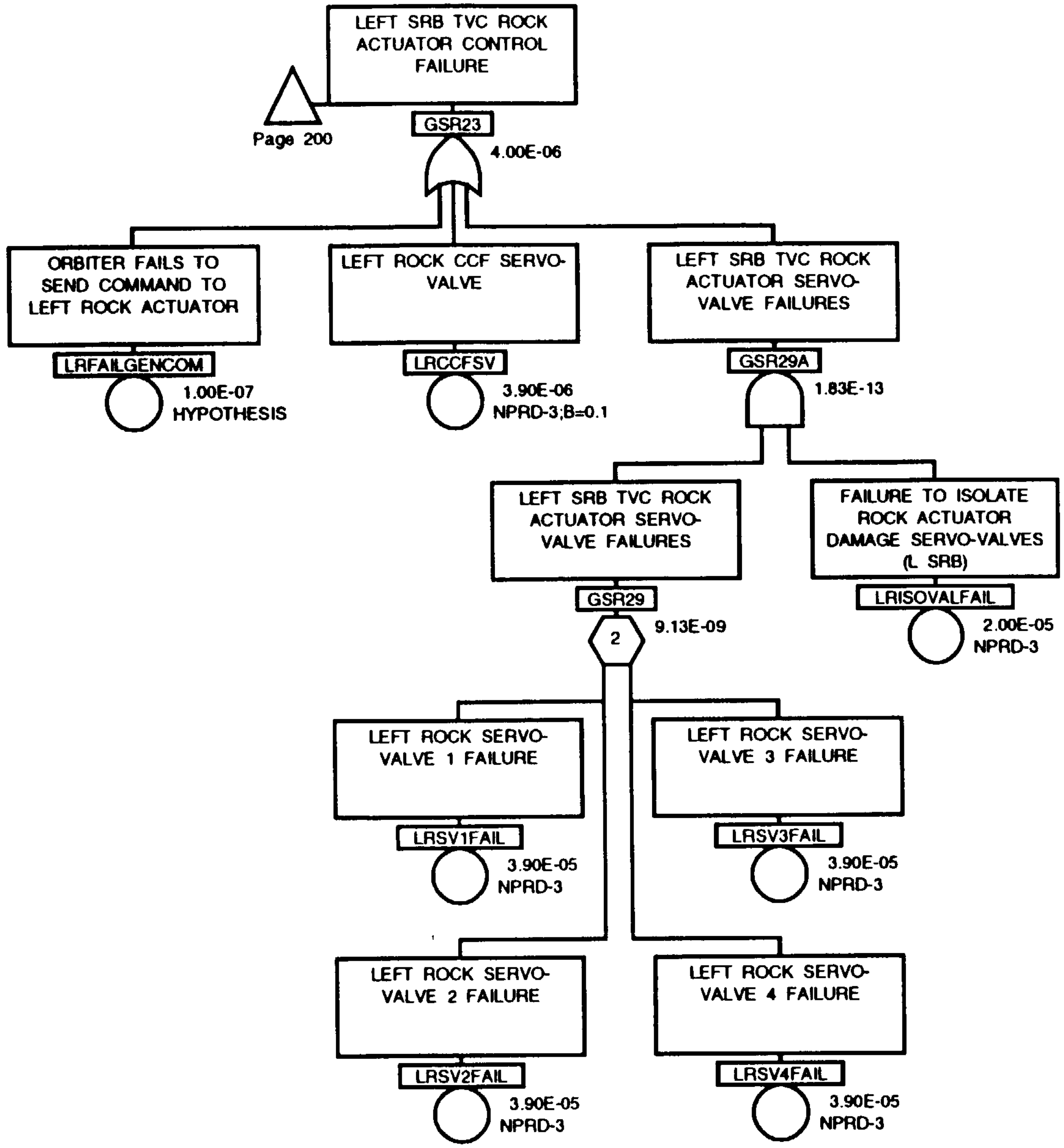

RIGHT SRB TVC TILT ACTUATOR FAILURES
Page 195
GSR10
6.92E-06
RIGHT TILT HARDWARE FAILURE ACTUATOR RAM
RTHWFAILACTRAM
6.88E-06
NPRD-3
RIGHT TILT STRUCTURAL FAILURE ACTUATOR RAM
RTSTFAILACTRAM
4.20E-08
NPRD-3

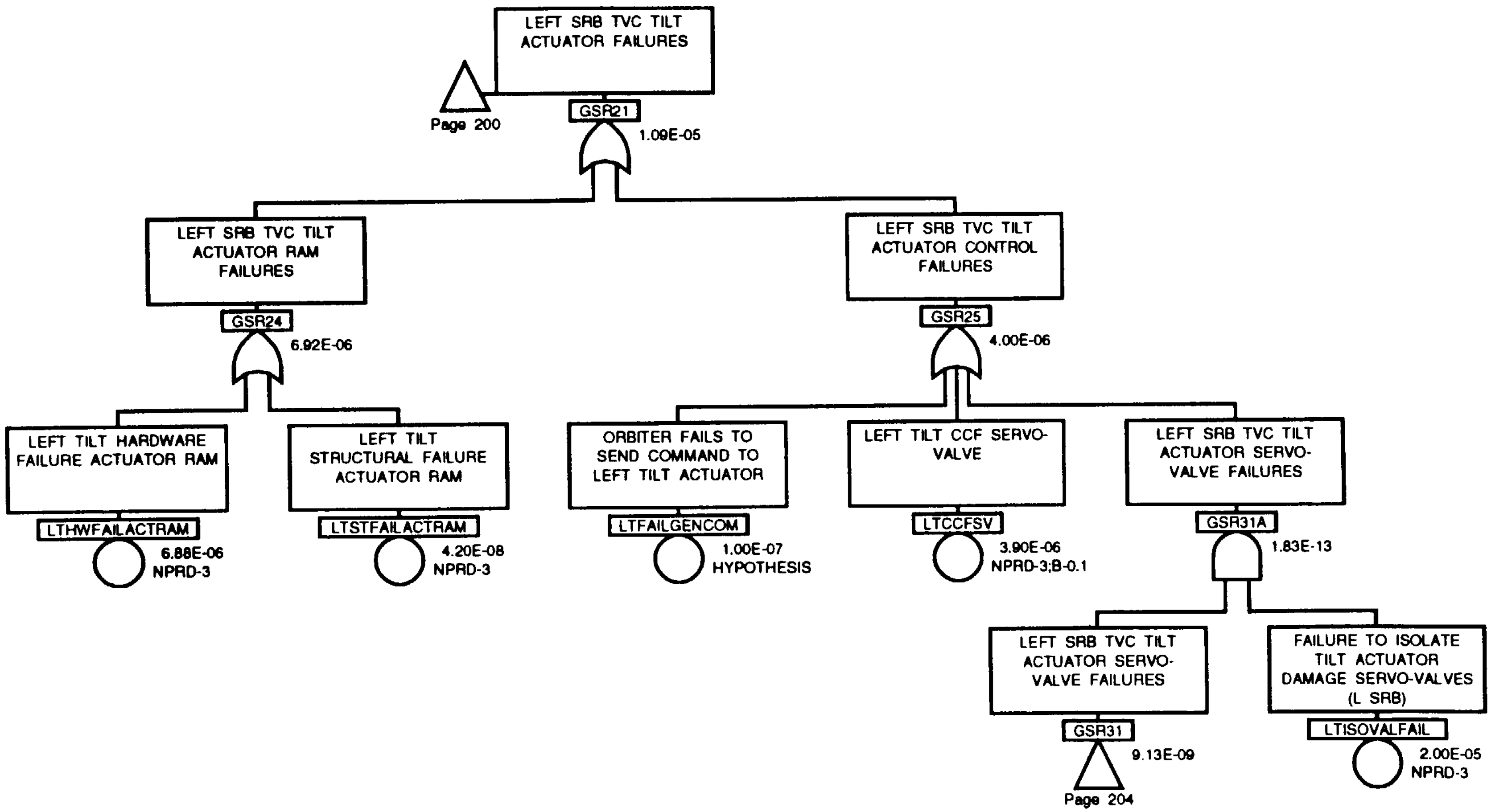

RIGHT SRB TVC TILT ACTUATOR CONTROL FAILURES
Page 195
GSR11
4.00E-06
RIGHT SRB TVC TILT ACTUATOR INDEPENDENT FAILURES
RIGHT TILT CCF SERVO-VALVE
GSR16
1.00E-07
RTCCFSV
3.90E-06
NPRD-3;B=0.1
ORBITER FAILS TO SEND COMMAND TO RIGHT TILT ACTUATOR
RIGHT SRB TVC TILT ACTUATOR SERVO-VALVE FAILURES
RTFAILGENCOM
1.00E-07
HYPOTHESIS
GSR17A
1.83E-13
RIGHT SRB TVC TILT ACTUATOR SERVO-VALVE FAILURES
FAILURE TO ISOLATE TILT ACTUATOR DAMAGE SERVO-VALVES (R SRB)
GSR17
9.13E-09
Page 199
RTISOVALFAIL
2.00E-05
NPRD-3

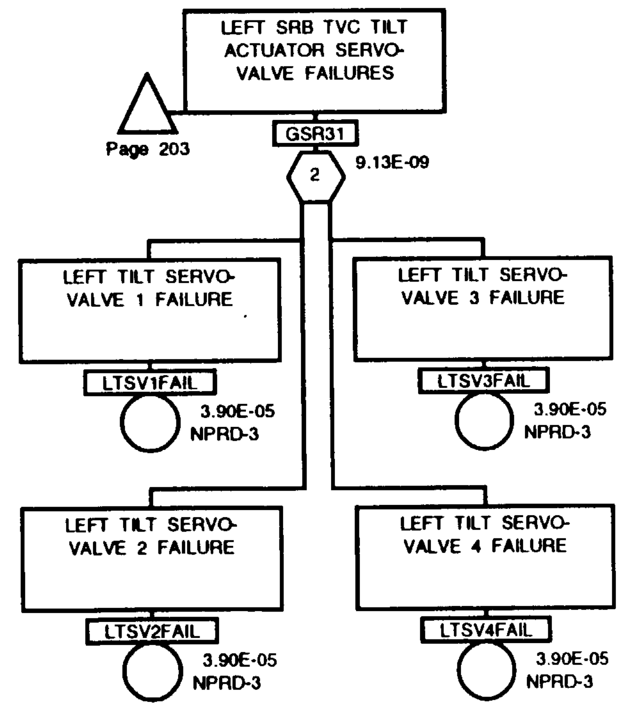

RIGHT SRB TVC TILT ACTUATOR SERVO-VALVE FAILURES
Page 198
GSR17
2
9.13E-09
RIGHT SERVO-VALVE 1 FAILURE
RTSV1FAIL
3.90E-05
NPRD-3
RIGHT SERVO-VALVE 3 FAILURE
RTSV3FAIL
3.90E-05
NPRD-3
RIGHT SERVO-VALVE 2 FAILURE
RTSV2FAIL
3.90E-05
NPRD-3
RIGHT SERVO-VALVE 4 FAILURE
RTSV4FAIL
3.90E-05
NPRD-3


LEFT SRB THRUST VECTOR CONTROL SYSTEM FAILURE
Page 193
GSR3
3.07E-05
LEFT SRB FAILURE TO SUPPLY HYDRAULIC POWER
GSR18
1.00E-06
LEFT SRB GIMBAL JOINT FAILURE
LSRBGIMJTFAIL
7.80E-06
NPRD-3
LEFT SRB TVC ACTUATOR FAILURES
GSR19
2.18E-05
LEFT SRB LOSS OF ELECTRICAL POWER SUPPLY
LLOSSELECPWRSUP
1.00E-07
PRA ANALYSIS
LEFT SRB HPU 1 FAILURE
LSRBAPU1FAIL
9.85E-04
MOD. APU EST.
LEFT SRB TVC FAILURE OF SECONDARY HYDRAULIC SUPPLY
GSR27
1.02E-03
LEFT SRB TVC ROCK ACTUATOR FAILURES
GSR20
1.09E-05
LEFT SRB TVC TILT ACTUATOR FAILURES
GSR21
1.09E-05
Page 203
LEFT SWITCHING VALVE FAILURE TO MOVE
LSWVALFAILTOMOVE
3.20E-05
NPRD-3
LEFT SRB HPU 2 FAILURE
LSRBAPU2FAIL
9.85E-04
MOD. APU EST.
LEFT SRB TVC ROCK ACTUATOR RAM FAILURES
GSR22
6.92E-06
Page 201
LEFT SRB TVC ROCK ACTUATOR CONTROL FAILURE
GSR23
4.00E-06
Page 202


LEFT SRB TVC ROCK ACTUATOR RAM FAILURES
Page 200
GSR22
6.92E-06
LEFT ROCK HARDWARE FAILURE ACTUATOR RAM
LRHWFAILACTRAM
6.88E-06
NPRD-3
LEFT ROCK STRUCTURAL FAILURE ACTUATOR RAM
LRSTFAILACTRAM
4.20E-08
NPRD-3


LEFT SRB TVC ROCK ACTUATOR CONTROL FAILURE
Page 200
GSR23
4.00E-06
ORBITER FAILS TO SEND COMMAND TO LEFT ROCK ACTUATOR
LRFAILGENCOM
1.00E-07
HYPOTHESIS
LEFT ROCK CCF SERVO-VALVE
LRCCFSV
3.90E-06
NPRD-3;B=0.1
LEFT SRB TVC ROCK ACTUATOR SERVO-VALVE FAILURES
GSR29A
1.83E-13
LEFT SRB TVC ROCK ACTUATOR SERVO-VALVE FAILURES
GSR29
2
9.13E-09
FAILURE TO ISOLATE ROCK ACTUATOR DAMAGE SERVO-VALVES (L SRB)
LRISOVALFAIL
2.00E-05
NPRD-3
LEFT ROCK SERVO-VALVE 1 FAILURE
LRSV1FAIL
3.90E-05
NPRD-3
LEFT ROCK SERVO-VALVE 3 FAILURE
LRSV3FAIL
3.90E-05
NPRD-3
LEFT ROCK SERVO-VALVE 2 FAILURE
LRSV2FAIL
3.90E-05
NPRD-3
LEFT ROCK SERVO-VALVE 4 FAILURE
LRSV4FAIL
3.90E-05
NPRD-3


LEFT SRB TVC TILT ACTUATOR FAILURES
Page 200
GSR21
1.09E-05
LEFT SRB TVC TILT ACTUATOR RAM FAILURES
GSR24
6.92E-06
LEFT SRB TVC TILT ACTUATOR CONTROL FAILURES
GSR25
4.00E-06
LEFT TILT HARDWARE FAILURE ACTUATOR RAM
LTHWFAILACTRAM
6.88E-06
NPRD-3
LEFT TILT STRUCTURAL FAILURE ACTUATOR RAM
LTSTFAILACTRAM
4.20E-08
NPRD-3
ORBITER FAILS TO SEND COMMAND TO LEFT TILT ACTUATOR
LTFAILGENCOM
1.00E-07
HYPOTHESIS
LEFT TILT CCF SERVO-VALVE
LTCCFSV
3.90E-06
NPRD-3;B-0.1
LEFT SRB TVC TILT ACTUATOR SERVO-VALVE FAILURES
GSR31A
1.83E-13
LEFT SRB TVC TILT ACTUATOR SERVO-VALVE FAILURES
GSR31
9.13E-09
Page 204
FAILURE TO ISOLATE TILT ACTUATOR DAMAGE SERVO-VALVES (L SRB)
LTISOVALFAIL
2.00E-05
NPRD-3


LEFT SRB TVC TILT ACTUATOR SERVO-VALVE FAILURES
Page 203
GSR31
2
9.13E-09
LEFT TILT SERVO-VALVE 1 FAILURE
LTSV1FAIL
3.90E-05
NPRD-3
LEFT TILT SERVO-VALVE 3 FAILURE
LTSV3FAIL
3.90E-05
NPRD-3
LEFT TILT SERVO-VALVE 2 FAILURE
LTSV2FAIL
3.90E-05
NPRD-3
LEFT TILT SERVO-VALVE 4 FAILURE
LTSV4FAIL
3.90E-05
NPRD-3

SRB Component Data

COMPONENT	QTY/FLIGHT	# OF FLIGHTS	GROUND TESTS	TOTAL	FAILURES*
Frangible Nut	8	62	141	637	0
Booster Ctdg (Frangible Nut)	16	62	189	1181	0
NSI Pressure Cartridge	20	62	271	1511	0
CDF Manifold	18	62	292	1408	0
CDF Assembly**	56	62	838	4310	0
CDF Initiator	32	62	409	2393	***1
Booster Separation Bolt	16	62	104	1096	0
Forward Separation Bolt	2	62	77	201	0
Aft Separation Bolt	8	62	141	637	0

* Only failures which could lead to loss of vehicle are included.

** Similar designs (at E.T., Inc.) have had over 75,000 successful firings with no failures

*** Failure successfully screened by LAT, lot rejected at vendors's facility (not counted as flight failure)

Additional CDF related information obtained from Explosive Technologies: 19,460 test firings with no failures

CDF Failure Probability Estimate>1/(3*(19460+2*(4310)+1408+2393))=1.05E-5

RSRM Joint Leak Data

NOZZLE-TO-CASE JOINTS

Joint Component	Source	Hot Firings	Leak Checks	Leak Potentiality Factor	Failures
Polysulfide	Flights 1-37,39,41	78			5
	Static Tests	9			1
	Totals:	87			6
Wiper O-Ring	Flights 1-37,39,41	6	78		
	Static Tests	1	9		
	NUES/TPTA,QM6	1			
	Totals:	8	87	0.2	1
Vent Port Plug Primary O-Ring	Flights 1-37,39,41		234		
(nozzle and case combined)	Static Tests		30		
	TPTA 1.3,2.1,2.2	7			
	NUES/JES 3C	4			1
(47 motors counted as 23 tests)	SPC (70lb Motor)	23	23		
	Totals:	34	287	0.9	1
Vent Port Plug Second O-Ring	Flights 1-37,39,41		312		
(nozzle and case combined)	Static Tests		40		
	TPTA 1.3,2.1,2.2	3			
	NUES/JES 3C	3			
	Totals:	6	352	0.9	0
Closure Vent Port Plug	Flights 1-37,39,41		312		
(nozzle and case combined)	Static Tests		40		
	TPTA 1.3,2.1	2			
	NUES/JES 3C	2			
	Totals:	4	352	0.6	0
Primary O-Ring	Flights 1-37,39,41		78		
	Static Tests		9		
	TPTA 1.2,2.1	2			
	NUES 3A,PVM1	2			
	Totals:	4	87	0.6	0
Leak Check Port Plug	Flights 1-37,39,41		780		
(case/nozzle/igniter combined)	Static Tests		100		
	SRM01-51L (fld)	4			
	SRM01-51L (noz)	7			
	Totals:	11	880	0.6	0
Stat-O-Seal	Case	100	9000		
	Igniter		5040		
	Nozzle	100	6776		
	Totals:	200	20816	0.9	0
Secondary O-Ring	Flights 1-37,39,41		78		
	Static Tests		10		
	TPTA 1.3	1			
	NUES 3B	1			
	Totals:	2	88	0.9	0

RSRM Joint Leak Data

IGNITER INTERNAL JOINTS

Joint Component	Source	Hot Firings	Leak Checks	Leak Potentiality Factor	Failures
S&A Primary Gasket	Static Tests	12	12		
	SRM, HPM, RSRM	128	128		
	Totals:	140	140	0.6	0
S&A Secondary Gasket	Static Test		12		
	SRM, HPM, RSRM		128		
	Totals:		140	0.9	0
COMMON CAUSE					
Leak Check Port Plug	Flights 1-37,39,41		780		
(case/nozzle/igniter)	Static Tests		100		
	SRM01-51L (fld)	4			
	SRM01-51L (noz)	7			
	Totals:	11	880	0.6	0
OPT Primary O-Ring	Static Tests	36			
(3/igniter)	SRM,HPM,RSRM	384			
	Minuteman	3300			
	Totals:	3720			0
OPT Secondary O-Ring	TPTA-2.2	3	0		
(3/igniter)	JES-3C	3	24		
	TPTA-1.3	3	256		
	Totals:	9	280	0.9	0
COMMON CAUSE	Static Tests	12	12		
Rotor Primary O-Rings	SRM,HPM,RSRM	128	128		
	Totals:	140	140	0.6	0
Rotor Secondary O-Rings	Static Tests	2	12		
	SRM,HPM,RSRM		128		
	Totals:	2	140	0.9	0
COMMON CAUSE					
SII Primary O-Ring	Static Tests	24	24		
	SRM,HPM,RSRM	256	256		
	Totals:	280	280	0.9	0
SII Secondary O-Ring	Static Tests	2	24		
	SRM,HPM,RSRM		256		
	Totals:	2	280	0.9	0

RSRM Joint Leak Data

IGNITER-TO-CASE JOINT

Joint Component	Source	Hot Firings	Leak Checks	Leak Potentiality Factor	Failures
INNER J-LEG	FSM-3	1			
	RSRM 23,35-37,39,41	12			
	Totals:	13			0
Special Bolt O-Ring	Static Test	48	48		
	SRM,HPM,RSRM	512	512		
(4/igniter)	Totals:	560	560	0.6	0
Outer J-Leg	FSM-3	1			
	RSRM 23,35-37,39,41	12			
	Totals:	13			0
Inner Gasket/Inner Seal	blow-holes (RSRM)	60			
	Static Tests		12		
	SRM,HPM,RSRM		128		
	Totals:	60	140	0.6	0
Inner Gasket/Outer Seal	blow-hole (RSRM)	60			
	Static Tests		12		
	SRM,HPM,RSRM		128		
	Totals:	60	140	0.9	0
Outer Gasket/Inner Seal	blow-holes (RSRM)	60			
	Static Tests		12		
	SRM,HPM,RSRM		128		
	Totals:	60	140	0.6	0
Outer Gasket/Outer Seal	Static Tests				
	SRM,HPM,RSRM		12		
	Totals:		128		
Stat-O-Seals	Case	100	9000		
(36/igniter)	Igniter		5040		
	Nozzle	100	6776		
	Totals:	200	20816	0.9	0
Leak Check Port Plug	Flights 1-37,39,41		780		
(case/nozzle/igniter)	Static Tests		100		
	SRM01-51L (fld)	4			
	SRM01-51L (noz)	7			
	Totals:	11	880	0.6	0

RSRM Joint Leak Data

CASE FIELD JOINT

Joint Component	Source	Hot Firings	Leak Checks	Leak Potentiality Factor	Failures
J-Seal	Flights 1-37,39,41	234			
	Static Tests	15			
	JES 3A	2			
	TPTA 1.1, 2.1	3			
	Totals:	254			0
Capture Feature O-Ring	Flights 1-37,39,41		234		
	Static Tests		24		
	JES 3B	1	0		
	QM-6	1	2		
	PVM-1	1	1		
	Totals:	3	261	0.6	0
Vent Port Plug Primary O-Ring (nozzle and case combined)	Flights 1-37,39,41				
	Static Tests				
	TPTA 1.3,2.1,2.2	7			
	NUES/JES 3C	4			1
(47 motors counted as 23 tests)	SPC(70lb Motor)	23	23		
	Totals:	34	287	0.9	1
Vent Port Plug Second O-Ring (nozzle and case combined)	Flights 1-37,39,41		312		
	Static Tests		40		
	TPTA 1.3,2.1,2.2	3			
	NUES/JES 3C	3			
	Totals:	6	352	0.9	0
Closure Vent Port Plug (nozzle and case combined)	Flights 1-37,39,41		312		
	Static Tests		40		
	TPTA 1.3,2.1	2			
	NUES/JES 3C	2			
	Totals:	4	352	0.5	0
Primary O-Ring	Flights 1-37,39,41		234		
	Static Tests	1	27		
	TPTA 1.3,2.1,2.2	5			
	JES3B/3C	2			
	Totals:	8	261	0.9	0
Outer Gasket/Outer Seal	Static Tests				
	SRM,HPM,RSRM		12		
	Totals:		128		
Leak Check Prot Plug (case/nozzle/igniter combinded)	Flights 1-37,39,41		780		
	static Tests		100		
	SRM01-51L (fld)	4			
	SRM01-51L (noz)	7			
	Totals:	11	880	0.5	0
Secondary O-Ring	Flights 1-37,39,41		234		
	Static Tests		27		
	TPTA 2.2	2			
	JES 3C	1			
	Totals:	3	261	0.9	0

RSRM Joint Leak Data

NOZZLE JOINT

Joint Component	Source	Hot Firings	Leak Checks	Leak Potentiality Factor	Failures
RTV Backfill	Joint 1	90			5
	Joint 2	18			7
	Joint 3	88			10
	Joint 4	88			10
	Joint 5	88			6
	Totals:	372			38
Primary O-Ring	Flight	24	390		
	Static Tests	14	50		
	Totals:	38	440	0.6	0
Secondary O-Ring	Flight		390		
	Static Tests		50		
	Totals:	0	440	0.9	0
Stat-O-Seals	Case	100	9000		
	Igniter		5040		
	Nozzle	100	6776		
	Totals:	200	20816	0.9	0
Leak Check Port Plug	Flights 1-37,39,41		780		
	Static Tests		100		
	SRM01-51L (fld)	4			
	SRM01-51L (noz)	7			
	Totals:	11	880	0.6	0

B.3. Orbiter Auxiliary Power Unit/Hydraulics

9.0 DEVELOPMENT OF PROBABILITY DISTRIBUTIONS FOR FAULT TREES

The development of probability distributions for the fault trees is done using Bayesian updating methods. Prior probability distributions for failure rates are taken from the 1987 APU/HPU study, NPRD-95, IREP, IEEE Std. 500, WASH 1400, Shuttle experience and expert judgment. System level priors for the entire APU/HYD/WSB system (failure to start and failure to run distributions) are developed using component data mostly from the 1987 study. Bayesian updating was done at the system level using data found in the in-flight anomaly list (IFAS), PRACA reports, and Post Flight Mission Safety Evaluation Reports.

Data obtained shows that there have been four APU shutdowns on ascent due to the water spray boiler failing to provide adequate cooling, and a near hydraulic system failure due to a massive hydraulic leak during descent.

Due to the fact that the APU/HYD/WSB systems have redundancy, i.e., they are a two-out-of-three or better system, common cause failures become a concern. The fault trees are evaluated using the Multiple Greek Letter (MGL) method to determine the common cause and independent failure rates.

Section 9.1 describes how the MGL method is used to determine the independent failure rates and common cause failure rates from the generic failure rate for each sequence.

Section 9.2 describes the prior distributions used in the study. Fault trees are included in this section to show how prior distributions are calculated for APU/HYD/WSB failure to start, APU/HYD/WSB failure to run, and APU turbine wheel runaway.

<u>9.1 Models/Equations for Fault Tree Basic Events</u>

9.1.1 List of Basic Events

Table 9.1-1 is a complete list of the basic events found in the fault trees, and their two letter identification code used throughout the model.

9.1.2 Assumptions

Several assumptions have been made concerning data input probability distributions. The first is that given a common cause leak, all three APU units leak. The second assumption pertains to the detection/confirmtion of the leaks. If all three units leak, and a leak is detected in one unit, then the leaks in all units are assumed to be found. A third assumption concerns the restarts of APU units. All units will have to go through a restart process sometime during the reentry process. Some scenarios have APU hydrazine leaks detected, in which case an APU unit is shutdown during the entry sequence. After an APU unit is shutdown, if another unit fails, then the shutdown unit is restarted. However, in the sequence, only one restart of the shutdown APU is considered. There are several reasons for this simplistic modeling. First, the reentry sequence will not begin until an APU unit is working to perform the flight controls check. Second, leaking APUs are shutdown only when a leak is detected and confirmed, and the probability of a leak being detected is only about one in twenty, so these scenario simplifications will not have a significant impact on the total risk.

Identification	Basic Event
CE	Flight critical equipment damaged given LL or TU
CF	Common cause failure to run
CL	Common cause leak
CO	No containment given turbine overspeed
CS	Common cause failure to start or run
HB	Hub breakup given turbine overspeed
ID	Independent/dependent failure to run (ascent)
IF	Independent failure to run (ascent)
IS	Independent failure to start or run (descent)
LA	Leak detected/confirmed given all three APU units leak
LD	Leak detected/confirmed given that one APU unit leaks
LF	Own leakage induced failure (ascent)
LK	Leak in one APU unit
LL	Large exhaust gas or hydrazine leak
LO	Leakage from another unit induced failure (ascent)
LS	Leakage from other unit induced failure to start or run (descent)
LU	Leak undetected given that one APU unit leaks
LZ	Leak undetected given that all three APU units leak
O1	APU unit okay given that one other APU unit leaks
O3	APU unit okay given that all three APU units leak
OK	APU unit okay
OL	APU unit okay given that it leaks
OS	Own leakage induced failure to start or run (descent)
SI	Structural integrity of aft compartment fails given LL or TU
SR	Successful restart of shutdown APU unit
TU	Turbine overspeed or hub failure at normal speed
UL	Unsuccessful single APU/HYD unit reentry, TAEM and landing

Table 9.1-1: List of Basic Events and Descriptions

9.1.3 Derivation of Common Cause Failure Equations

As components fail, it is not always entirely clear which failures are truly independent and which are common cause. In order to estimate the frequency of common cause failures from the total estimated frequency, several methods, such as the Multiple Greek Letter (MGL) or beta factor methods, are used. In this analysis, the MGL method was used. The labeling of the APU units is as follows: if a single APU unit is leaking hydrazine, then that unit is labeled as unit 1, or if all three APU units are leaking hydrazine, then the unit that is shutdown (if the leaks are detected/confirmed) is labeled as unit 1.

9.1.3.1 One APU Unit Leaks Hydrazine During Reentry, TAEM and Landing (L0 State)[1]

Sequence 4

In this sequence, APU units 1 and 2, or 1 and 3, fail. This is basically a 1 out of 3 system, denoted Q(1/3). There are two ways in which independent failures of this type can occur: Q_1Q_2 and Q_1Q_3. For the common cause failures, there are also two ways that those may occur: Q_{12} and Q_{13}. Rewriting those terms in the MGL format using Q_1 for independent failures and Q_2 for common cause failure of two components yields the following equation for system failures:

$$Q(1/3) = 2Q_2 + 2Q_1^2$$

In this form of the MGL method where we are dealing both with common cause failures for two systems and common cause failures for three systems. The MGL method defines two parameters: β and γ. Beta is the ratio of two and three unit common cause failures of each unit to all failures for each unit. Gamma is the ratio of three unit common cause failures to two and three unit common cause failures. For each unit, beta is thus:

$$\beta = \frac{2Q_2+Q_3}{Q_1+2Q_2+Q_3}$$

and gamma is:

$$\gamma = \frac{Q_3}{2Q_2+Q_3}$$

Omitting the algebra, the single system and common cause for two system failures can be written as:

$$Q_1 = (1-\beta)Q$$

$$Q_2 = \frac{1}{2}(1-\gamma)\beta Q$$

Since Q represents the failures due to start or run failures, it should be rewritten as:

$$Q = q_s + \lambda t$$

[1] The LO descent initiating event state is equivalent to the IL0 ascent end state.

where q_s is the failure to start probability, and λt is the probability of a failure during the run time.[2,3] If we substitute into Q(1/3) for Q_1, Q_2 and Q, then the equation for failures becomes:

$$Q(1/3) = [(1-\gamma_s)\beta_s q_s + (1-\gamma_r)\beta_r \lambda t] + 2[(1-\beta_s)q_s + (1-\beta_r)\lambda t]^2$$

This is the total failure rate. We now need to relate the above equation to the fault tree basic events. The first term in the above equation is the common cause term, and does not need to be changed. The second term in the above equation needs to represent the independent failures as depicted in the fault tree. For example, if we examine the fault tree for the sequence 4 LOV with the initiating L0 state (one APU unit is leaking), then by analysis at the basic event level, the probability of the component failures in the sequence can be expressed as:

$$P(1,2\ or\ 1,3) = P(1\ IF)P(2\ IF) + P(1\ IF)P(3\ IF) + P(CCF) + P(1\ IF)P(3\ LO) + \cdots$$

where IF, CCF and LO where defined previously as independent failures, common cause failure, and own leak induced failure. Since we are only concerned about independent and common cause failures, we will ignore the fourth and remaining terms as being inapplicable to the determination of the common cause failure rate and the independent failure rate. If the independent failure rates are the same for all APU units, then the previous two expressions can be combined as:

$$P(CCF) = [(1-\gamma_s)\beta_s q_s + (1-\gamma_r)\beta_r \lambda t]$$

$$2P(IF)^2 = 2[(1-\beta_s)q_s + (1-\beta_r)\lambda t]^2$$

If we reduce the independent failure rate probability, we get:

$$P(IF) = \sqrt{[(1-\beta_s)q_s + (1-\beta_r)\lambda t]^2}$$

which reduces to:

$$P(IF) = [(1-\beta_s)q_s + (1-\beta_r)\lambda t]$$

Sequence 6

In this sequence, both APU units 2 and 3 have failed. This is basically a 1 out of 3 system, denoted Q(1/3). There is one way in which independent failures of this type can occur: Q_2Q_3. For the common cause failures, there is also only one way that this may occur: Q_{23}. Rewriting those terms in the MGL format using Q_1 for independent failures and Q_2 for common cause failure of two components yields the following equation for system failures:

$$Q(1/3) = Q_1^2 + Q_2$$

As before, the single and common cause (for two systems) factors are defined as:

$$Q_1 = (1-\beta)Q$$

$$Q_2 = \tfrac{1}{2}(1-\gamma)\beta Q$$

(2) In this analysis the β_s and β_r are given the same numerical value, and γ_s and γ_r are given the same numerical value.

(3) For ascent sequences, λt is the probability of basic event ID (or IF) in Table 9.3.1. For descent sequences $q_s + \lambda t$ is the probability of a basic event IS in Table 9.3-1.

Since Q represents the failures due to start or run failures, it should be rewritten as:

$$Q = q_s + \lambda t$$

where q_s is the failure to start probability, and λt is the probability of a failure during the run time. If we substitute into Q(1/3) for Q_1, Q_2 and Q_3 then the equation for failures becomes:

$$Q(1/3) = \tfrac{1}{2}[(1-\gamma_s)\beta_s q_s + (1-\gamma_r)\beta_r \lambda t] + [(1-\beta_s)q_s + (1-\beta_r)\lambda t]^2$$

As before, we can see that the first term represents the common cause failure rate, and the second tern represents the independent failure rate. If we examine the fault tree for the sequence 6 LOV with the initiating L0 state, then by analysis at the basic event level, the probability of the component failures in the sequence can be expressed as:

$$P(2,3) = P(2\ IF)P(3\ IF) + P(CCF) + P(2\ IF)P(3\ LO) + \cdots$$

where IF, CCF and LO where defined previously as independent failures, common cause failure, and own leak induced failure. Since we are only concerned about independent and common cause failures, we will ignore the third and remaining terms as being inapplicable to the determination of the common cause failure rate and the independent failure rate. If the independent failure rates are the same for all APU units, then the previous two expressions can be combined as:

$$P(CCF) = \tfrac{1}{2}[(1-\gamma_s)\beta_s q_s + (1-\gamma_r)\beta_r \lambda t]$$

$$P(IF)^2 = [(1-\beta_s)q_s + (1-\beta_r)\lambda t]^2$$

If we reduce the independent failure rate probability, we get:

$$P(IF) = \sqrt{[(1-\beta_s)q_s + (1-\beta_r)\lambda t]^2}$$

which reduces to:

$$P(IF) = [(1-\beta_s)q_s + (1-\beta_r)\lambda t]$$

This is the same expressions as determined in the Sequence 4 LOV.

Sequence 7

In this sequence, since there is no leak detection, no distinction is made between which units fail and which do not. All three units fail, even though 1 out of 3 is needed for survival, so this is denoted Q(1/3). There is one way in which independent failures of this type can occur: $Q_1Q_2Q_3$. For the common cause failures, there is also only one common cause for all three, Q_{123}. There are three combinations of pairs of common cause failures for two systems, i.e., Q_{12} and Q_{23} is one pair, and three combinations of an independent failure and a common cause failure for two systems, i.e., Q_1 and Q_{23} and one pair. Rewriting those terms in the MGL format using Q_1 for independent failures, Q_2 for common cause failures of two components and Q_3 for common cause failures of three components yields the following equation for system failures:

$$Q(1/3) = Q_3 + 3Q_1Q_2 + 3Q_2^2 + Q_1^3$$

Omitting the algebra, the failures can be written as:

$Q_1 = (1-\beta)Q$

$Q_2 = \frac{1}{2}(1-\gamma)\beta Q$

$Q_3 = \gamma\beta Q$

Substituting for Q_1, Q_2 and Q_3 into Q(1/3) yields:

$$Q(1/3) = \gamma\beta Q + \tfrac{3}{2}(1-\beta)\beta(1-\gamma)Q^2 + \tfrac{1}{2}\tfrac{(1-\gamma)}{(1-\beta)}\beta\left[\tfrac{3}{2}(1-\beta)\beta(1-\gamma)Q^2\right] + (1-\beta)^3 Q^3$$

If we examine the above expression, we see that there are four terms, which from left to right we'll call one, two, three and four. The third term is negligible because

$$\tfrac{1}{2}\tfrac{(1-\gamma)}{(1-\beta)}\beta << 1$$

and is, furthermore, much less than the second term. As before:

$$Q = q_s + \lambda t$$

where q_s is the failure to start probability, and λt is the probability of a failure during the run time. Substitute Q into Q(1/3) with the simplifying assumption yields:

$$Q(1/3) = (\gamma_s\beta_s q_s + \gamma_r\beta_r\lambda t) + \tfrac{3}{2}\{[(1-\beta_s)\beta_s(1-\gamma_s)q_s^2] + [(1-\beta_s)\beta_r(1-\gamma_r)q_s\lambda t] + [(1-\beta_r)\beta_s(1-\gamma_s)q_s\lambda t] + [(1-\beta_r)\beta_r(1-\gamma_r)\lambda^2 t^2]\} + [(1-\beta_s)q_s + (1-\beta_r)\lambda t]^3$$

As before, we can see that the first term represents the common cause failure rate, and the second tem represents the independent failure rate. If we examine the fault tree for the sequence 7 LOV with the initiating L0 state, then by analysis at the basic event level, the probability of the component failures in the sequence can be expressed as:

$$P(1,2,3) = P(1\ IF)P(2\ IF)P(3\ IF) + P(CCF) + P(1\ LO)P(2\ IF)P(3\ IF) + \cdots$$

where IF, CCF and LO where defined previously as independent failures, common cause failure, and own leak induced failure. Since we are only concerned about independent and common cause failures, we will ignore the third and remaining terms as being inapplicable to the determination of the common cause failure rate and the independent failure rate. If the independent failure rates are the same for all APU units, then the previous two expressions can be combined as:

$$P(CCF) = \gamma_s\beta_s q_s + \gamma_r\beta_r\lambda t + \tfrac{3}{2}\{[(1-\beta_s)\beta_s(1-\gamma_s)q_s^2] + [(1-\beta_s)\beta_r(1-\gamma_r)q_s\lambda t] + [(1-\beta_r)\beta_s(1-\gamma_s)q_s\lambda t] + [(1-\beta_r)\beta_r(1-\gamma_r)\lambda^2 t^2]\}$$

$$P(IF) = [(1-\beta_s)q_s + (1-\beta_r)\lambda t]$$

Sequence 11

In this sequence, two APU units fail, and since the event is undetected, no distinction is made as to which two have failed. System failures are thus defined as:

$$Q(1/3) = 3Q_2 + 3Q_1^2$$

As before, the failures are defined as:

$Q_1 = (1-\beta)Q$

$Q_2 = \frac{1}{2}(1-\gamma)\beta Q$

Since Q represents the failures due to start and run failures, it should be rewritten as:

$Q = q_s + \lambda t$

where q_s is the failure to start probability, and λt is the probability of a failure during the run time. If we substitute into Q(1/3) for Q_1, Q_2 and Q, then the equation for failures becomes:

$$Q(1/3) = \tfrac{3}{2}[(1-\gamma_s)\beta_s q_s + (1-\gamma_r)\beta_r \lambda t] + 3[(1-\beta_s)q_s + (1-\beta_r)\lambda t]^2$$

As before, we can see that the first term represents the common cause failure rate, and the second tern represents the independent failure rate. If we examine the fault tree for the sequence 11 LOV with the initiating L0 state, then by analysis at the basic event level, the probability of the component failures in the sequence can be expressed as:

$$P(2\,fail) = P(1\,IF)P(2\,IF) + P(1\,IF)P(3\,IF) + P(2\,IF)P(3\,IF) + P(CCF) + P(2\,IF)P(3\,LO) + \cdots$$

where IF, CCF and LO where defined previously as independent failures, common cause failure, and own leak induced failure. Since we are only concerned about independent and common cause failures, we will ignore the fifth and remaining terms as being inapplicable to the determination of the common cause failure rate and the independent failure rate. If the independent failure rates are the same for all APU units, then the previous two expressions can be combined as:

$$P(CCF) = \tfrac{3}{2}[(1-\gamma_s)\beta_s q_s + (1-\gamma_r)\beta_r \lambda t]$$

$$3P(IF)^2 = 3[(1-\beta_s)q_s + (1-\beta_r)\lambda t]^2$$

If we reduce the independent failure rate probability, we get:

$$P(IF) = [(1-\beta_s)q_s + (1-\beta_r)\lambda t]$$

Sequence 12

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for IL0 sequence 7.

Sequence 16

This sequence occurs when APU/HYD systems 1 and 2 or 1 and 3 fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 4.

This sequence also models the remaining two APU units developing a common cause leak, given the initial leak in one unit.[1] As described for OK sequence 21, the formula for common cause leakage is given by:

$$P(CCF) = \gamma_L \beta_L \lambda_L t + \tfrac{3}{2}(1-\beta_L)\beta_L(1-\gamma_L)\lambda_L^2 t^2$$

Here, $\lambda_L t$ is the probability of the initial state, L0. So, since the conditional probability of developing the common cause leak is multiplied against the initial state probability, and given that the first term in the equation is by far the dominant factor, the common cause conditional probability should be entered as:

$$P(CCF) = \gamma_L \beta_L$$

Sequence 18

This sequence occurs when APU/HYD systems 2 and 3 fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 6. The equation for a common cause leak is the same as that described for L0 sequence 16.

Sequence 19

This sequence occurs when all APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 7. The equation for a common cause leak is the same as that described for L0 sequence 16.

Sequence 23

This sequence occurs when any two out of the three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 11. The equation for a common cause leak is the same as that described for L0 sequence 16.

Sequence 24

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 7. The equation for a common cause leak is the same as that described for L0 sequence 16.

9.1.3.2 All Three APU Units Leak Hydrazine During Reentry, TAEM and Landing (LT State)

Sequence 4

This sequence occurs when APU/HYD systems 1 and 2 or 1 and 3 fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 4.

[1] λ_L is the frequency of event LK in Table 9.3-1.

Sequence 6

This sequence occurs when APU/HYD systems 2 and 3 fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 6.

Sequence 7

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 7.

Sequence 11

This sequence occurs when any two out of the three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 11.

Sequence 12

This sequence occurs when any two out of the three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 12.

9.1.3.3 All Three APU Units are OK During Reentry, TAEM and Landing (OK State)

Sequence 4

This sequence occurs when any two out of the three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 11.

Sequence 5

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 7.

Sequence 9

This sequence occurs when APU/HYD systems 1 and 2 or 1 and 3 fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 4.

This sequence also involves a common cause treatment of APU leaks. Here, we are modeling any one of the three APUs develops a leak, which is basically a 1 out of 3 system, denoted as Q(1/3). There are three ways in which independent failures of this type can occur: Q_1, Q_2 or Q_3. Rewriting those terms in the MGL format using Q_1 for the independent failures yields the following equation for system failures:

$$Q(1/3) = 3Q_1$$

As before, the failures are identified as:

$$Q_1 = (1 - \beta)Q$$

Since Q in this case represents leakage failures over the exposure time, Q is replaced by:

$$Q = \lambda_L t$$

where λ_L is the leakage failure rate and t is the exposure time of the system. If we substitute into Q(1/3) for Q1, then the equation for failures becomes:

$$Q(1/3) = 3(1-\beta_L)\lambda_L t$$

Since independent failures are the only contributors in this equation, we get:

$$P(IF) = 3(1-\beta_L)\lambda_L t$$

Sequence 11

This sequence occurs when APU/HYD systems 2 and 3 fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 6. The equation for independent leaks is the same as that described for OK sequence 9.

Sequence 12

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 7. The equation for independent leaks is the same as that described for OK sequence 9.

Sequence 16

This sequence occurs when any two out of the three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 11. The equation for independent leaks is the same as that described for OK sequence 9.

Sequence 17

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 7. The equation for independent leaks is the same as that described for OK sequence 9.

Sequence 21

This sequence occurs when APU/HYD systems 1 and 2 or 1 and 3 fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 4.

This sequence also involves a common cause treatment of APU leaks. Here, we are modeling all three APUs develop leaks. The equations for independent and common cause failures are similar to those described for L0 sequence 7, but with Q defined differently as in OK sequence 9. Omitting the algebra, the new independent and common cause failure rates can be determined by the following equations:

$$P(CCF) = \gamma_L \beta_L \lambda_L t + \tfrac{3}{2}(1-\beta_L)\beta_L(1-\gamma_L)\lambda_L^2 t^2$$

$$P(IF) = (1-\beta_L)\lambda_L t$$

Sequence 23

This sequence occurs when APU/HYD systems 2 and 3 fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 6. The equations for independent and common cause leaks are the same as those described for OK sequence 21.

Sequence 24

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 7. The equations for independent and common cause leaks are the same as those described for OK sequence 21.

Sequence 28

This sequence occurs when any two out of the three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 11. The equations for independent and common cause leaks are the same as those described for OK sequence 21.

Sequence 29

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for L0 sequence 7. The equations for independent and common cause leaks are the same as those described for OK sequence 21.

9.1.3.4 All Three APU Units are OK During Ascent (OK State)

For the ascent phase, it is assumed that all APU units are already started, otherwise the launch sequence would not have been completed. Hence, Q is now defined as:

$$Q = \lambda t$$

Sequence 4

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are similar to those described for L0 sequence 7, but with Q defined differently. Omitting the algebra, the new independent and common cause failure rates can be determined by the following equations:

$$P(IF) = (1 - \beta_r)\lambda t$$

$$P(CCF) = \gamma_r \beta_r \lambda t + \tfrac{3}{2}(1 - \beta_r)\beta_r(1 - \gamma_r)\lambda^2 t^2$$

9.1.3.5 At Least One APU Unit is Leaking Hydrazine During Ascent (LK State)

Sequence 6

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for OK sequence 4. The equation for independent leaks is the same as that described for OK sequence 9.

Sequence 7

This sequence occurs when one APU unit has an undetected leaks. The equation for independent leaks is the same as that described for OK sequence 9.

Sequence 12

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for OK sequence 4. The equation for independent leaks is the same as that described for OK sequence 9.

Sequence 16

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for OK sequence 4. The equations for independent and common cause leaks are the same as those described for OK sequence 21.

Sequence 17

This sequence occurs when all three APU units have undetected leaks. The equations for independent and common cause leaks are the same as those described for OK sequence 21.

Sequence 20

This sequence occurs when all three APU/HYD systems fail. The equations for independent system failures and common cause failures are the same as those described for OK sequence 4. The equations for independent and common cause leaks are the same as those described for OK sequence 21.

9.1.3.6 MGL Parameters

The following point estimates are generic over all components and all failure modes. They were developed as part of a recent effort funded by EPRI to completely automate the process of analyzing common cause failures in PRAs. The software is available through Boyer Chu at EPRI. This recent effort was based on previous data development and MGL method development found in EPRI INP 3967 (1985), NUREG/CR-4780 (1988), and NUREG/CR-5801 (1993).

For information on methods and procedures for common cause failure you can refer to NUREG/CR-4780 (1988) and NUREG/CR-5801 (1993).

APU component failure rates are generally within the variability range of the generic database from which the Beta and Gamma factors are derived. We believe, therefore, that these are an indication of future failure rates of the APU, and the generic factors apply to the APUs.

We also used the generic data for common cause hydrazine leakage. We have found six leaks (see Section 9.2.2.6). Two of the leaks happened in the same mission (STS-9) for a common cause (carbonization and stress cracking of the injector). The Beta factor could be estimated as 1/3 (3 of 6). However, we know that the manufacturing process has been altered to reduce the likelihood of this cause. There has also been an effort to reduce the exposure of the nozzles to hydrazine between missions. We have used, therefore, a generic Beta factor of 0.1 instead of the data driven Beta factor of 1/3. We see no justification to apply a Beta factor less than indicated by the generic level.

9.1.4 Equations Graphed in Fault Tree for Illustration

As an example of how the independent failure rate and common cause failure rate equations developed in the previous section are applied, see Figure 9.1-1. In the figure is a simple fault tree that shows the sequence 4 LOV for the ascent phase in which no hydrazine leaks have occurred.

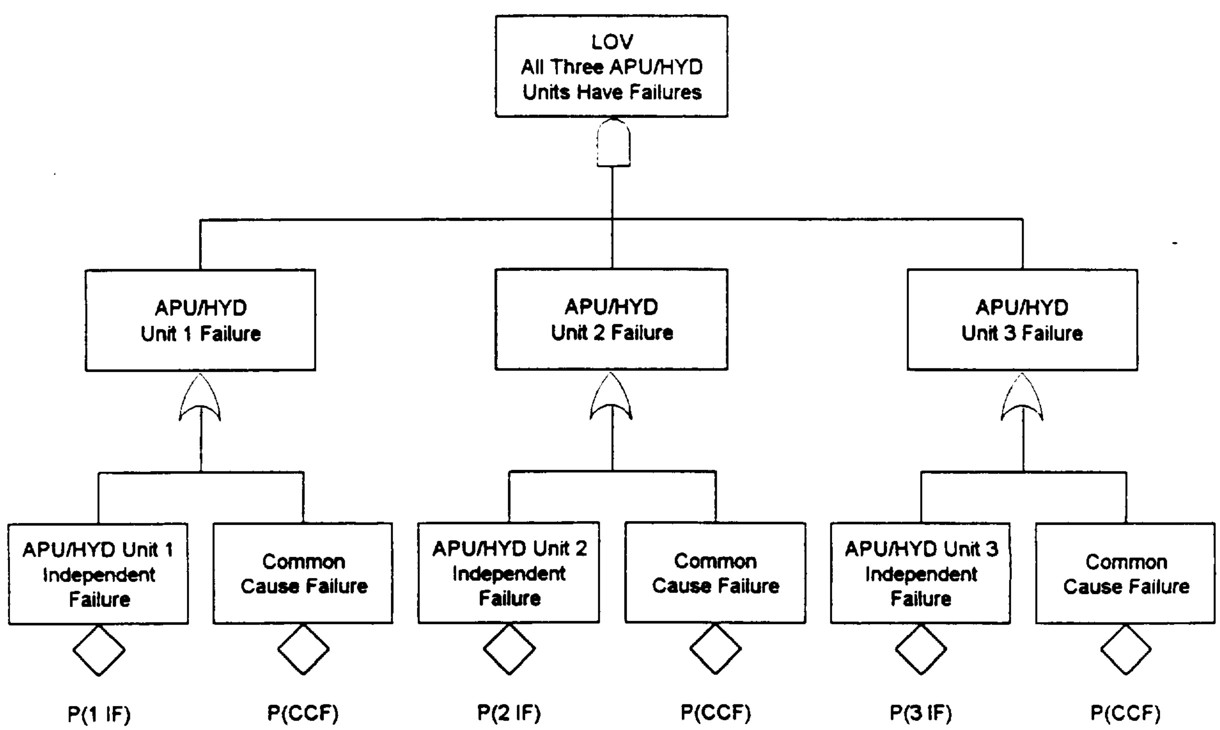


Figure 9.1-1: Fault Tree for LOV Sequence 4 for an OK State During Ascent

For the LOV to occur, all three APU/HYD systems must fail. System failures can occur independently, or as common cause failures. These failure rates were determined from the total failure rate using the Multiple Greek Letter method previously described, and are shown under the basic events to which they pertain.

From before, we defined P(CCF) and P(IF) as:

$$P(IF) = (1 - \beta_r)\lambda t$$

$$P(CCF) = \gamma_r \beta_r \lambda t + \tfrac{3}{2}(1 - \beta_r)\beta_r(1 - \gamma_r)\lambda^2 t^2$$

9.2 Prior Distribution for Model

The priors used in the assessment of P(IF) came from a previous study (McDonnell Douglas Astronautics Company Engineering Services, Space Shuttle Probabilistic Risk Assessment Proof-of-Concept Study Volume III: Auxiliary Power Unit and Hydraulic Power Unit Analysis Report, paper WP-VA88004-03, 1987). As described previously, the priors were updated at the system level with observed Shuttle in flight failures.

9.2.1 Inputs Needed to Develop Priors

The study performed in 1987 was done at a component level; i.e., the failure rates of the components in the system were calculated, and no quantification was done on the system level. This study has defined basic events on the system level in order to have such information for future decision-making. Two prior distributions, the failure to start on demand and the run failure rate, were estimated using the component level data.

The fault tree in Figure 9.2-1 depicts the component failures that most contribute to a system failure to run. These components failure rates were agglomerated to obtain a prior distribution for APU system failure to run (events, ID, IF and IS).

Similarly, Figure 9.2-2 depicts a fault tree in which any of the component failures may cause a failure to start condition. These component failure rates were agglomerated for the start contribution of event IS.

The 1987 study performed a detailed fault tree for turbine overspeed. Quantification of that tree showed that four events dominated the failure probability. These are shown in a simplified fault tree in Figure 9.2-3.

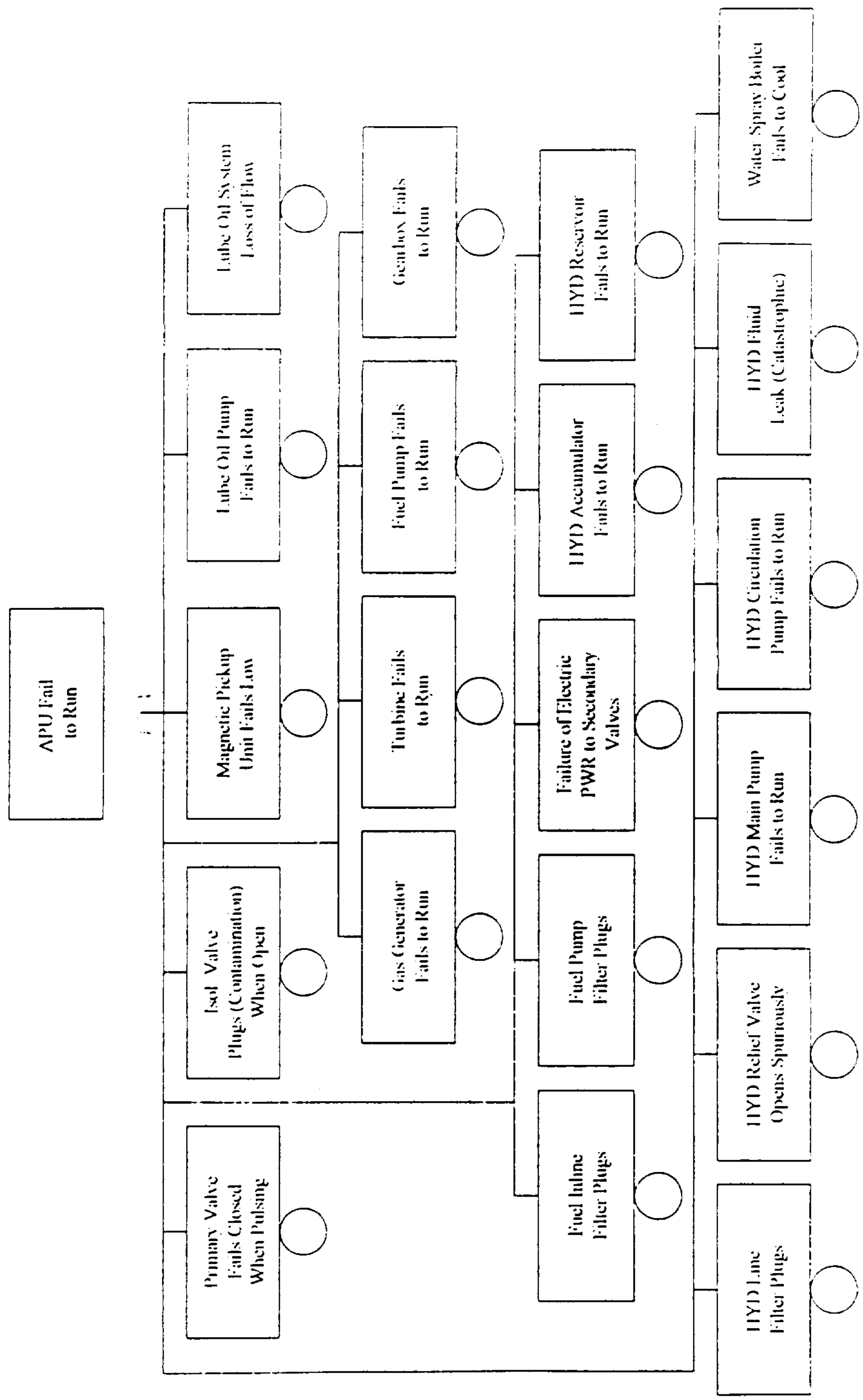


Figure 9.2-1: Fault Tree for APU/HYD/WSB Run Failures

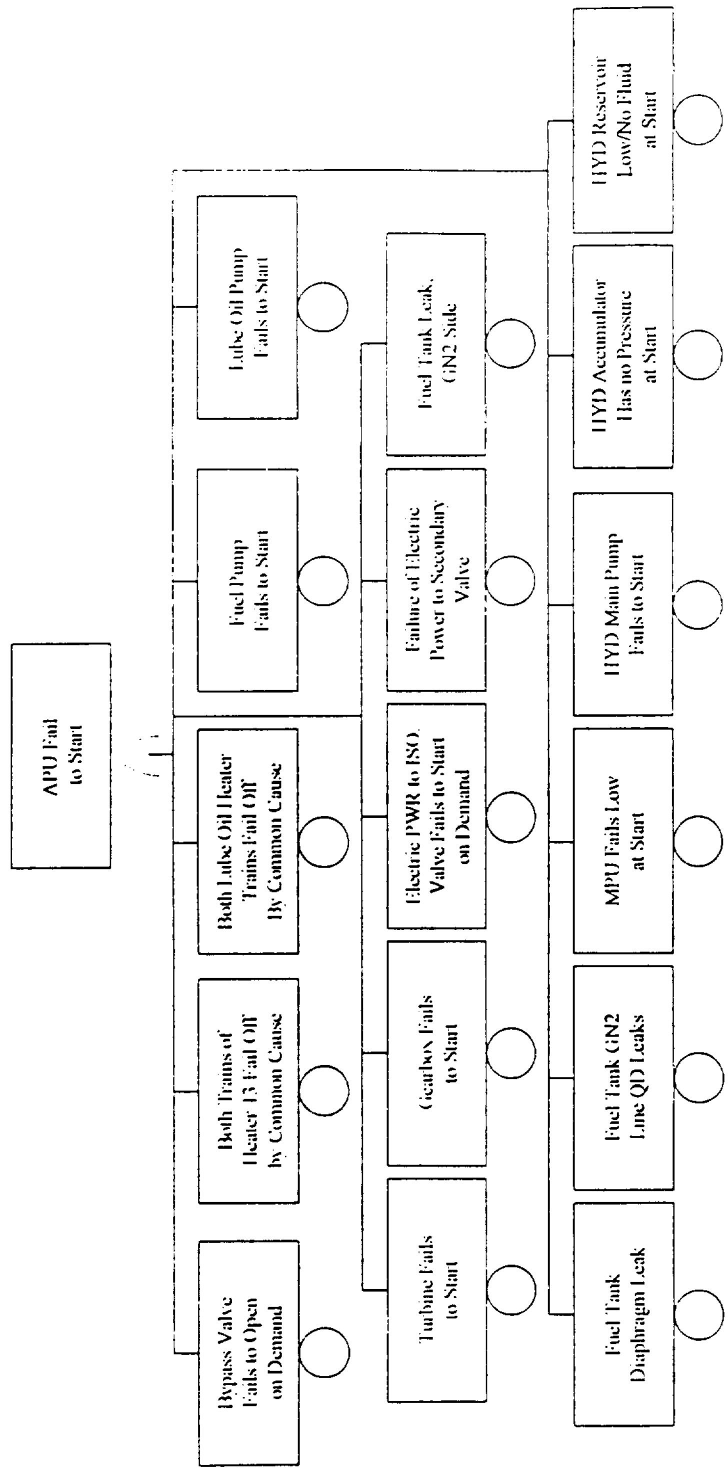


Figure 9.2-2: Fault Tree for APU/HYD/WSB Start Failures

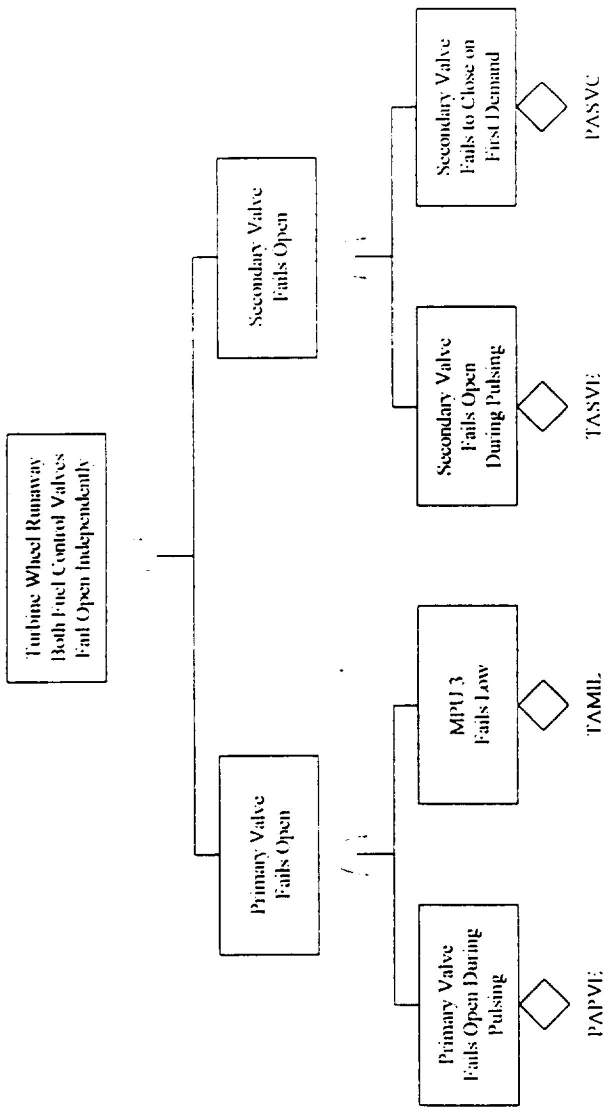


Figure 9.2-3: Fault Tree for Turbine Overspeed Failures

9.2.2 Output Distributions for Priors

9.2.2.1 APU Failure to Run

The first prior calculated is that for an APU to fail to run. Table 9.2-1 lists the component failures frequency distributions that were in the model for APU subsystem run failures.

Failure	Mean-Dist	5th percentile	Median	95th percentile	Ref. (1)
Primary Valve Fails Closed When Pulsing	4.481E-03	3.494E-04	2.404E-03	1.225E-02	1
Isol. Valve Plugs (Contamination) When Open	1.086E-06	4.681E-08	4.343E-07	3.875E-06	1
Magnetic Pickup Unit Fails Low	2.240E-03	1.747E-04	1.202E-03	6.127E-03	1
Fuel Pump Fails To Run	7.685E-05	2.791E-06	2.887E-05	2.797E-04	1
Lube Oil Pump Fails To Run	7.685E-05	2.791E-06	2.887E-05	2.797E-04	1
Lube Oil System Loss Of Flow	2.664E-03	9.334E-05	9.698E-04	9.681E-03	1
Gas Generator Fails To Run	1.436E-04	9.020E-07	2.467E-05	4.429E-04	1
Turbine Fails To Run	6.041E-04	2.722E-05	2.350E-04	1.837E-03	1
Gearbox Fails To Run	2.628E-05	9.323E-07	9.672E-06	9.651E-05	1
Fuel Inline Filter Plugs	7.959E-06	2.799E-07	2.907E-06	2.894E-05	1
Fuel Pump Filter Plugs	2.040E-04	2.722E-06	5.002E-05	6.507E-04	1
Failure Of Electric Pwr To Secondary Valves	4.926E-05	9.231E-07	1.357E-05	1.866E-04	1
HYD Accumulator Fails To Run	2.664E-05	1.0E-06	1.0E-05	1.0E-04	2
HYD Reservoir Fails To Run	2.664E-05	1.0E-06	1.0E-05	1.0E-04	2
HYD Line Filter Plugs	7.840E-06	6.0E-06	7.746E-06	1.0E-05	3
HYD Relief Valve Opens Spuriously	1.212E-05	3.0E-06	9.487E-06	3.0E-05	5
HYD Main Pump Fails To Run	4.040E-05	1.0E-05	3.162E-05	1.0E-04	2.5
HYD Circulation Pump Fails To Run	1.127E-04	7.0E-06	5.292E-05	4.0E-04	2,3
HYD Fluid Leak (Catastrophic)	4.332E-04	5.0E-06	5.0E-05	5.0E-04	1,3,4
Water Spray Boiler Fails To Cool	3.385E-05	1.0E-04	2.236E-05	5.0E-06	2.5
Total Fail To Run/Hr	9.150E-03	3.059E-03	6.956E-03	2.174E-02	

(1)

1. 1987 APU Study
2. NPRD-95
3. IEEE-STD-500
4. OREDA
5. WASH-1400
6. Shuttle history of 0 failures is 882 demands in a maximum entropy log normal: 882 = (6 APU Starts/Missions + 4 HPU starts + 4 HPU Hot Fire Tests) x 63

Table 9.2-1: Component Failures Leading to APU System Run Failure (Failures/hour)

In order to calculate the distribution of the sum of these failures, an @Risk Monte Carlo simulation (20,000 trials) in a Lotus 1-2-3 spreadsheet was used. A graphical representation of this distribution can be seen in Figure 9.2-4.

9.2.2.2 APU Failure to Start

In Table 9.2-2, various component failures are listed that will lead to a failed-start condition. Once again, to calculate the failed-start distribution based on the sum of the various component failures, an @Risk Monte Carlo simulation (20,000 trials) in a Lotus 1-2-3 spreadsheet was used.

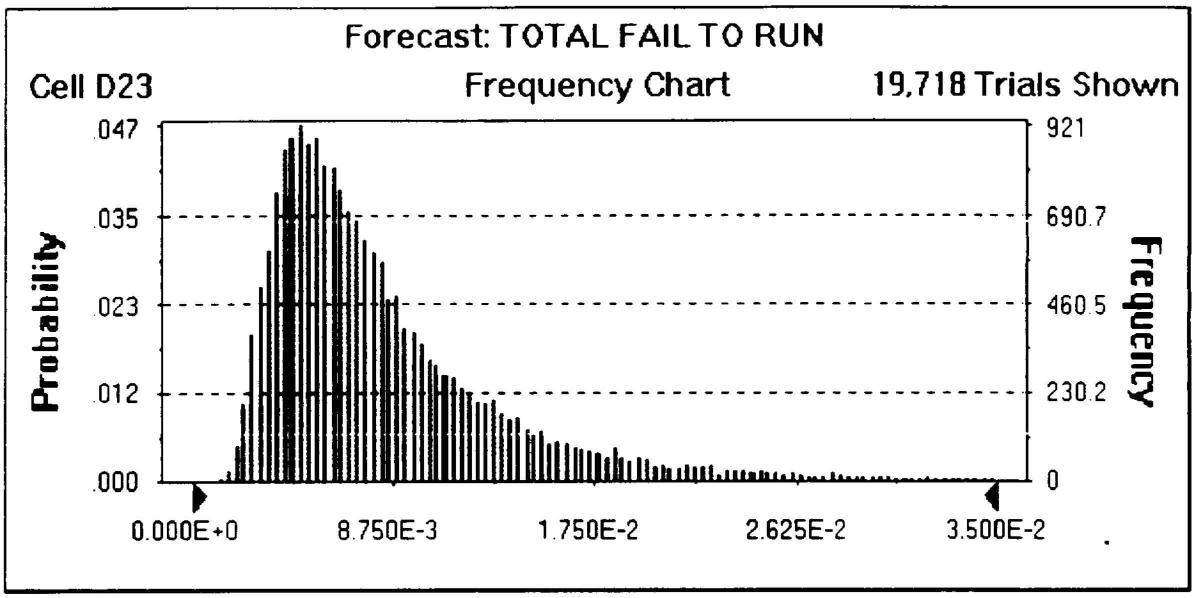


Figure 9.2-4: @Risk Simulation Results for Failure to Run Frequency

Failure	Mean-Dist	5th percentile	Median	95th percentile	Reference
Bypass Valve Fails To Open On Demand	4.689E-04	1.690E-05	1.730E-04	1.276E-03	1
Common Cause Heater Train 13 Failure	6.5E-05	4.6E-006	3.6E-05	1.5E-04	1
Common Cause Lube Oil Heater Train Failure	2.1E-05	5.3E-07	7.8E-06	5.7E-05	1
Fuel Pump Fails To Start	1.278E-05	9.139E-08	2.138E-06	4.702E-05	1
Lube Oil Pump Fails To Start	1.278E-05	9.139E-08	2.138E-06	4.702E-05	1
Turbine Fails To Start	1.278E-05	9.139E-08	2.138E-06	4.702E-05	1
Gearbox Fails To Start	1.278E-05	9.139E-08	2.138E-06	4.702E-05	1
Electric Pwr To Primary Valve Fails	6.2E-04	1.3E-05	2.0E-04	1.9E-03	1
Electric Power To Secondary Valve Fails	6.207E-04	1.329E-05	2.045E-04	1.879E-03	1
MPU Fails Low	7.409E-04	3.447E-05	3.260E-04	2.032E-03	1
HYD Main Pump Fails To Start	4.0E-04	4.683E-05	2.426E-04	1.257E-05	6
HYD Accumulator Has No Pressure At Start	4.475E-03	1.68E-04	1.680E-03	1.68E-02	2[1]
HYD Reservoir Low/No Fluid At Start	4.475E-03	1.68E-04	1.680E-03	1.68E-02	2[1]
Total Failures To Start	1.205E-02	3.322E-03	7.949E-03	3.342E-02	

[1] Converted hourly failure rate to a start failure by multiplication by exposure time (168 hours)

1. 1987 APU Study
2. NPRD-95
3. IEEE-STD-500
4. OREDA
5. WASH-1400
6. Shuttle history of 0 failures is 882 demands in a maximum entropy log normal: 882 = (6 APU Starts/Missions + 4 HPU Starts + HPU Hot Fire Tests) x 63

Table 9.2-2: Component Failures Leading to APU System Start Failure (Failures/Demand to Start)

The @Risk Monte Carlo simulation (20,000 trials) for the failure to start probability distribution can be seen in Figure 9.2-5.

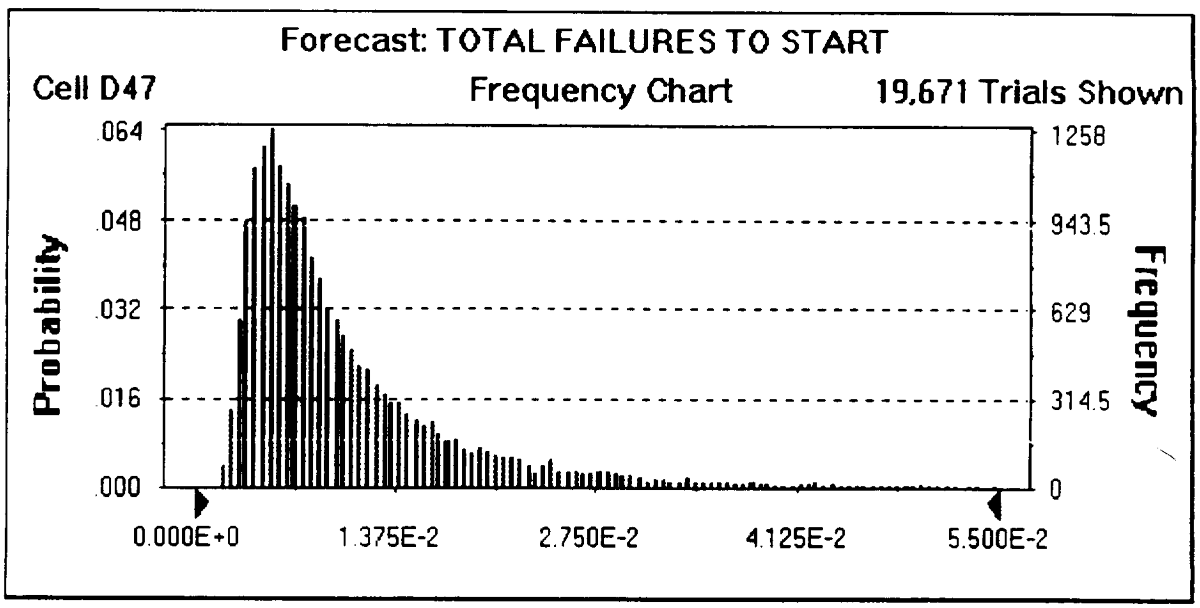


Figure 9.2-5: @Risk Simulation Results for Failure to Start Frequency

9.2.2.3 Turbine Overspeed and Hub Failure at Normal Speed

Figure 9.2-3 depicted the fault tree for a turbine overspeed condition which is an initiating event (TU). Prior distributions were obtained from the 1987 APU study. The following Table 9.2-3 provides the priors and the in-flight shuttle data used for the likelihood function. The posterior failure rates of these various components are listed in Table 9.2-5. To calculate the turbine over-speed frequency distribution based on fault tree logic, @Risk Monte Carlo simulation (20,000 trials) in a Lotus 1-2-3 spreadsheet was used.

Event	Prior (Log Normal) 5 Percentile	Prior (Log Normal) 95 Percentile	Shuttle Specific Data
PASVC	8x10 -5/D	7x10 -3/D	1/378 Demands [1]
TASVE	1x10 -4/hr	1x10 -2/hr	0/0 [2]
TAMIL	5x10 -5/hr	5x10 -3/hr	1/796 hrs [3]
PAPVE	1x10 -4/hr	1x10 -2/hr	1/292 hrs [4]

[1] 2 Demand/APU x 63 millions x 3 APUs/Missons = 378 Demands

[2] Failure of primary valve in mission SB-31 generated a demand on the secondary valve for a few minutes before the launch was scrubbed. The secondary valve did not fail.

[3] 1.33 hours/APU x 3 APUs/Missions x 3 HPUs/APUs x 63 Missions = 796 hours

[4] 1.33 hours/APU x 3 APUs/Missions x 63 Missions = 292

Table 9.2-3: Priors and In-Flight Shuttle Data Used for the Likelihood Function

Shuttle in-flight failures used in the above table are described below in Table 9.2-4:

Car No.	Date	Flight No.	APU No.	Basic Event	Description
AC8511-01	08/06/84	41B	3	PASVC	GGVM Shut off valve leaking at a rate of 248 scim due to a broken poppet valve seat
AC0055-01	07/24/81	1	2	TAMIL	MPU #2 was inopr.; MPU resistance measured open
IFA STS-31-01	04/24/91	STS-31	1	PAPVE	Primary pulse control valve chipped (valve sent failure) allowing hydrazine to continue flowing. Secondary valve took over. Launch scrubbed.

Table 9.2-4: APU Turbine Component Failure Descriptions

The @Risk Monte Carlo simulation (20,000 trials) for the failure to start probability distribution can be seen in Figure 9.2-6

Failure	Mean-Dist	5th percentile	Median	95th percentile
Primary Valve Fails Open During Pulsing	1.477E-03	6.852E-05	6.500E-04	4.054E-03
Magnetic Pickup Unit Fails Low	2.240E-03	1.747E-04	1.202E-03	6.127E-03
Secondary Valve Fails Open During Pulsing	9.602E-04	5.032E-05	4.484E-04	2.685E-03
Secondary Valve Fails To Close On Demand	2.631E-03	2.305E-04	1.504E-03	7.500E-03
Total Probability For Turbine Overspeed/Flight(1)	2.518E-04	6.733E-06	7.530E-05	9.403E-04

(1) All APUs included

Table 9.2-5: Posterior Failure Rate Data for Component Failures Leading to Turbine Overspeed

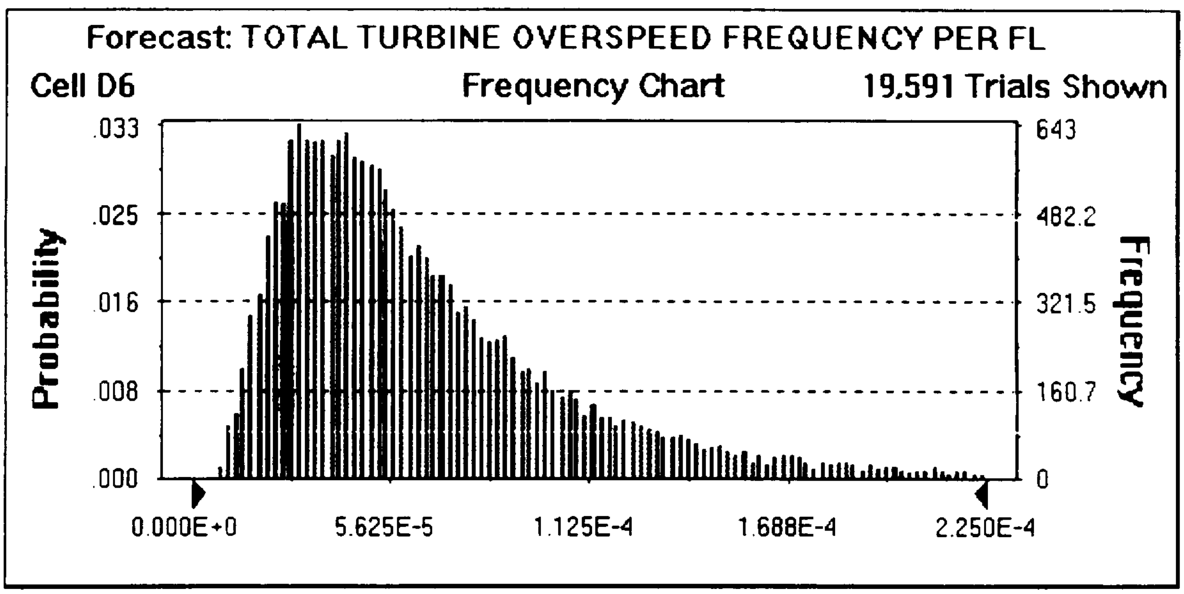


Figure 9.2-6: @Risk Simulation Results for Turbine Overspeed Frequency

Turbine hub failure at normal speed is not a significant contributor to the probability of this event. APU hub cracking is mapped and it has been shown by analysis (at JSC) that the likelihood of blade cracking propagating to a hub crack is very small. Furthermore, experiments on hub breakup show that even a notched or drilled hub requires a speed significantly above nominal to induce hub failure. NPRD-95 has a value of turbine failure of about 10 -5/hr. for all modes combined, not just hub failure. Therefore, hub failure at normal speed is at least an order of magnitude less in probability then turbine overspeed.

9.2.2.4 Other Prior Distributions

The remaining prior distributions were taken directly from the 1987 study, were defined by MGL analysis, or were a result of our assessment. All of the prior distributions are in Table 9.2-8. The two letter descriptions were discussed previously in Table 9.1-1.

Some events, such as an APU OK state, are not in this table since they are not incorporated into the quantification of the scenarios. For some inputs only a mean value was estimated.

9.2.2.5 Large Exhaust Gas or Hydrazine Leak (LL)

This prior distribution was generated by breaking the event down into its three major contributors: tank/pipe rupture; hot gas leak; and isolation valve leak/rupture. For both the tank/pipe rupture and hot gas leak modes, a failure rate range based on variability was defined from Nonelectronic Parts Reliability Data 1995 (NPRD-95). The median value from this range was multiplied by the 1.5 hour total APU run time for ascent and descent, and times 3 for the number of APUs, to get a point estimate failure probability for the system per flight.

A failure rate range was also defined for the isolation valve leak from NPRD-95. In this case, the range was treated as defining the 5th and 95th percentiles of a lognormal distribution which was used as the prior in a Bayesian update. The evidence data consisted of two incidents in which cracks were found in APU and HPU isolation valves which did not propagate to a through crack of the valve casing that separates the flow path from the solenoid cavity. The concern here is that when hydrazine comes in contract with the solenoid it could decompose and rupture the isolation valve causing an unisolatable leak. These were not "hard" failures, but are valid evidence of failure potential. They were treated, therefore, by a near miss methodology as follows.

The solution was to treat the data according to the probability that these incidents might propagate into "hard" failures on other flights, where the circumstances might be different. This is a matter of judgment on the part of the analyst. In this case, since these incidents were determined to have a low probability of propagating to "hard" failures, the evidence was treated as having a 5% probability of representing 1 failure in 72000 hours (a lower bounding estimate of the total exposure time for APU and HPU isolation valves), and a 95% chance of representing zero failures in 72000 hours. The overall posterior distribution was then generated by taking a weighted average (according to the previously determined weights) of the two possible posterior distributions.

The following Table 9.2-6 shows the prior distributions.

	5 Percentile	95 Percentile	Exposure Time
Tank/Pipe Replace (prior only)	10 -9/hr.	10 -7/hr.	63 x 3 x 1.5 hrs.
Hot Gas Leak (prior only)	same	same	same
Isolation Valve (prior)	1 x 10 -7/hr.	10 -7/hr.	72000 hrs.
Isolation Valve (updated)	1.2 x 10 -9/hr.	8 x 10 -8/hr.	

Table 9.2-6: Distributions for Large Hydrazine or Exhaust Gas Leak

The data used in the isolation valve analysis is anecdotal. We are aware of a crack discovered in an APU isolation valve before STS-1. We are also aware of a recent crack found in an HPU, that when tested post-flight, leaked hydrazine into the solenoid cavity.

9.2.2.6 Leak in One APU Unit (LK)

A Bayesian analysis was not performed for hydrazine leaks. Shuttle in-flight experience was used to generate a point estimate of the rate at which hydrazine leaks develop. This rate was based on the data in Table 9.2-7, showing 6 leaks in 31752 hours of exposure time (63 flights x 3 APUs x assumed average flight duration of 7 days x 24 hours/day). To generate a probability distribution, the point estimate was assumed to be the mean value of a maximum entropy (σ = 1.0) lognormal distribution.

This assessment was based on a number of assumptions. We assume that the APUs are leak checked and only launched if found acceptable. Hydrazine leaks may occur at any time during the mission. Exposure to hydrazine may cause leaks even without the system operating. However, the leaks may only be revealed when the system is operating.

CAR	IFAS	Flight	Date	APU #	Description
**		1CR	04/12/81	1	Hyd. leak from fuel pump cover
**		1CR	04/12/81	2	Hyd. leak at fuel pump inlet fitting
09F012-01		STS-9	11/28/83	1	Hyd. leak from cracked fuel injector tube *
09F013-01		STS-9	11/28/83	2	Hyd. leak from cracked fuel injector tube *
	X	STS-51F	07/29/85	1	Hyd. leak into gearbox ***
	X	STS-45	03/24/92	1	Hyd. leak into gearbox ****

* APU failed due to the hydrazine leak

** Data from APU subsystem manager database

*** This leak was detected by increased pressure in the gearbox and the start of APU2 was delayed until Vrel=10k

**** On this same mission APU2 leaked oil / GN2 from the gearbox to the aft compartment

	X	STS-45	03/24/92	2	Lube oil / GN2 leak from gearbox through turbine seal

Table 9.2-7: Hydrazine Leakage History on STS

The APUs contain many potential leakage sites. The data simply indicates that some have already occurred. Others have yet to become active. Because of this, we do not necessarily view corrective actions to individual leakage sites as reducing the predicted frequency of leaks. Rather, we treat past leaks as indicative of future rates.

9.2.2.7 Leak Detected Confirmed (LD and LA)

The first four leaks above were not detected during the mission. The last two leaks were detected by increased pressure in the gearbox. We assess the probability of leak detection, and APU delayed start, as 1 in 6 based on this data. Since no action has ever been taken on leaks during ascent, this indicated zero probability of leak detection on ascent. The use of zero detected and confirmed leaks during ascent avoids the paradox associated with a groundrule of this study. The groundrule is that aborts are assumed to be successful. Therefore, a failure that leads to an APU induced abort actually reduces the calculated risk. Flight rules call for an APU shutdown and an MDF abort if a single hydrazine leak is detected and confirmed. Two such leaks lead to a PLS abort. To avoid having to treat leaks as successes, we assume no detection on ascent.

9.2.2.8 Own Leakage/Other Leakage Induced Failures (LF and LO)

These prior distributions were defined through a data based assessment utilizing the 1987 study, PRACA records, hazards analyses and an understanding of the phenomenology of the failure modes. Specifically, the mean value for own leakage induced failure during descent was defined from the data shown in Table 9.2-7, indicating 2 APU failures in 6 leaks. The mean values for the other three conditional probabilities were then derived by maintaining the ratios between the values from the 1987 study and scaling them to the 0.3 defined for LF (des). This produced values of 0.2 for LO (des), 0.1 for LF (asc) and 0.008 for LO (asc).

An assessment of the applicable distributions was then made for the four probabilities. In the case of LF (des), an upper 4σ bound of 0.5 was defined for the distribution, assuming a normal distribution. For LF (asc), an upper 4σ bound of 0.2 was defined, again assuming a normal distribution. And for LO (asc), given the small value of the mean (0.008), a lognormal distribution was judged to be more applicable, as greater uncertainty is expected for small defined values. For this distribution, an Error Factor of 5 was assumed. For the normal distributions, values below zero should be truncated when using the defined distributions.

In the case of LO (des), data is available for a Bayesian update of the assessed value, so the distribution needs to be defined much broader than for the other cases (where the posterior was being defined directly), in order to overlap the likelihood function of the evidence. The prior distribution was defined using 0.2 as the mean value for a maximum entropy (σ = 1.0) lognormal distribution. This was updated with evidence of 0 APU failures in 12 APUs exposed to other units leaking. Note the following for each leak: There are 2 opportunities for another APU to fail owing to the leak and 1 opportunity for itself to fail. For 6 leaks, there are 6 x 2 = 12 opportunities for failure of another APU owing to the leak. None has occurred. The mean value of LO (des) drops to 0.07 given this evidence. The result of the Bayesian analysis is shown graphically in Figure 9.2-7.

9.2.2.8.1 Sensitivity Treatment of APU 3 Failures

The previous section described the baseline treatment of these conditional probabilities. In the case of APU failure due to another units leakage (LO), it could be argued that APU 3 needs to be treated differently. APU 3 is physically located about 6' (on the starboard side) from the other two units, which are only a few inches apart. Thus, we believe that there is a lesser chance of APU 3 failing due to leakage in unit 1 than an APU 2 failure.

Our fault tree treatment is conservative in that each APU is considered "identical". It does not capture "full credit" for cases in which the actual APU 3 is leaking, which would lead to reduced LO conditional probabilities for both of the other units.

One way of capturing this logic would be to drop the LO conditional probability to a lower value for all of the APU 3 terms. In order to illustrate the affect this would have on the results, two of the most significant leakage fault trees have been quantified, at the mean value, for these two cases. For the baseline case:

- OK Initial State on Entry, Seq. 16 4.159E-04
- OK Initial State on Entry, Seq. 17 1.700E-04

For the sensitivity case, using as an example 0.01 as the unit 3 LO (des) probability:

- OK Initial State on Entry, Seq. 16 2.479E-04
- OK Initial State on Entry, Seq. 17 6.214E-05

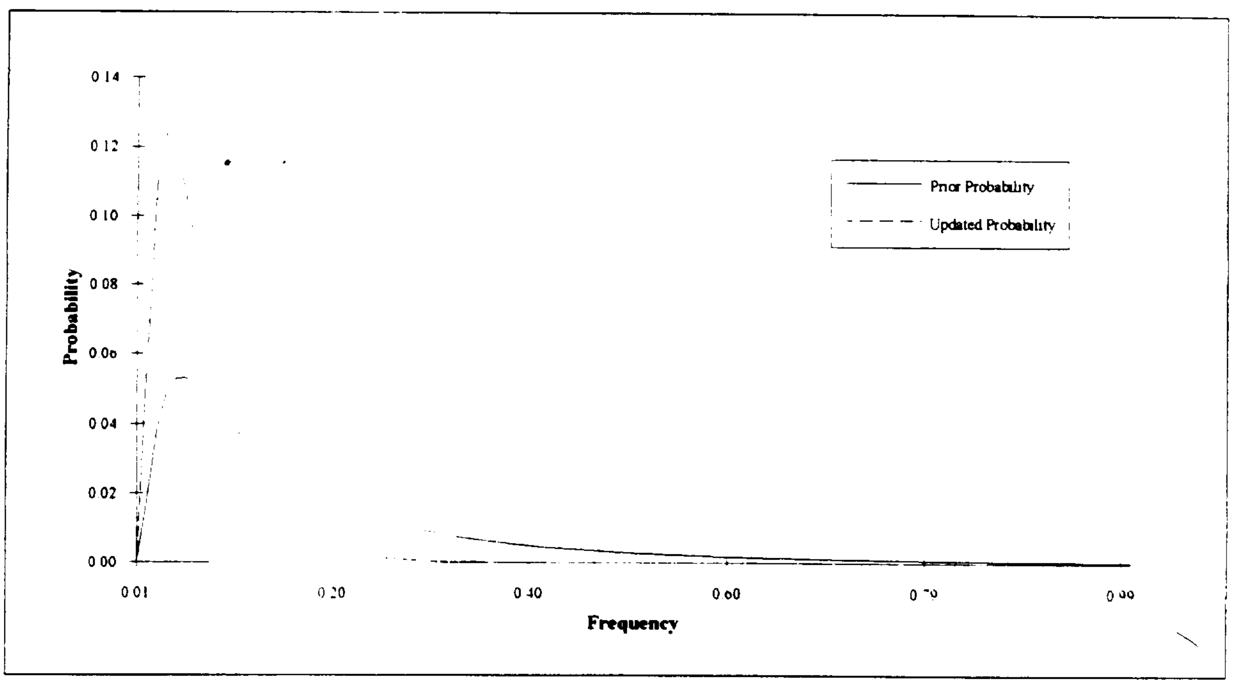


Figure 9.2-7: Bayesian Analysis Result for LO (Des)

9.2.2.9 Unsuccessful Single APU/HYD Unit Reentry, TAEM and Landing (UL)

This prior distribution was generated according to judgment weighted by several factors. First, such landings are regularly simulated successfully in training. To the extent that the simulator is successful in characterizing the vehicle response given a single APU/HYD unit, this gives credence to a very high probability of success. However, this is tempered by the fact that a single APU/HYD unit landing is not certified by the program. Unfavorable weather conditions coupled with slower control rates could potentially indicate a much higher probability of a failed landing. The assessment team has translated this into a range of 80% to 100% for a successful landing. It was also determined that the lack of a strong conviction for any values within this range warranted a uniform distribution for this range.

ID	βδ-factor	PRIOR (/hr or /demand)			
		Mean	Median	5th	95th
CE	N/A	0.5 (LL) 0.88 (TU)			
CF	Calculated	using applicable	MGL method	formulas	
CL	Calculated	using applicable	MGL method	formulas	
CO	N/A	1			
CS	Calculated	using applicable	MGL method	formulas	
HB	N/A	0.9			
ID	N/A	9.150E-03/hr	6.956E-03/hr	3.059E-03/hr	2.174E-02/hr
IF	N/A	9.150E-03/hr	6.956E-03/hr	3.059E-03/hr	2.174E-02/hr
IS	N/A	1.205E-02/start 9.150E-03/hr	7.949E-03/start 6.956E-03/hr	3.322E-03/start 3.059E-03/hr	3.342E-02/start 2.174E-02/hr
LA	N/A	0.0 (asc) 0.1667 (des)			
LD	N/A	0.0 (asc) 0.1667 (des)			
LF OS	N/A see posterior	1.0E-01 (asc)	1.0E-01 (asc)	6.0E-02 (asc)	1.4E-01 (asc)
LK	N/A	1.890E-04/hr	1.152E-04/hr	2.224E-05/hr	5.971E-04/hr
LL	N/A	2.8E-05			
LO LS	N/A	8.0E-03 (asc) 2.0E-1 (des)	5.0E-03 (asc) 1.2E -01	9.9E-04 (asc) 2.3E-02	2.5E-02 (asc) 6.36-01
LU	N/A	1.0 (asc) 0.8333 (des)			
LZ	N/A	1.0 (asc) 0.8333 (des)			
SI	N/A	1.0 (LL) 0.88 (TU)			
SR	N/A	0.98795/start	0.99205/start	0.99668/start	.96658/start
TU	N/A	2.518E-04	7.530E-05	6.733E-06	9.403E-04
UL	N/A	0.1	0.1	0.01	0.19

Table 9.2-8: Prior Probability Distributions

9.3 Posterior Distributions for APU/HYD/WSB Failure to Run and Start (Ascent and Descent

Posterior distributions were determined by updating the prior distributions with available data using Bayes' Theorem. Data points not only include failures of the APU and HYD systems, but also the Water Spray Boiler (WSB). WSB failures, which lead to an APU shutdown and subsequent hydraulic loss, were not examined in the previous 1987 study, so data was extracted for these failures from all Shuttle flights. Other data points pertaining to these failures were taken from post-Challenger flights (1988) to STS-65 (flight 63, 7/8/94).

9.3.1 Water Spray Boiler Failures Used in the Analysis

9.3.1.1 03-23-1982 STS-3

WSB 3 freeze-up during ascent. APU temperature message at lift-off plus 4 minutes 23 seconds reported lube oil temperature climbing. Controller B was then selected, but the temperature continued to rise. APU 3 shutdown at liftoff plus 8 minutes, and the right main engine went into hydraulic lock-up. After ascent, at lift-off plus one hour, controller A was then selected; both controllers appeared to be working properly. The maximum APU 3 lube oil temperature was 330°F, and the maximum bearing temperature was between 355 and 360°F. FCS checkout tested both controllers, and both were 100% nominal. This situation was also seen on STS-1 and 2.

9.3.1.2 08-02-1991 STS-43

WSB 2 failed to provide cooling to the auxiliary power unit 2 lube oil throughout the mission. APU 2 (serial number 208) has been involved in lube oil over temperatures during seven of its eight flights. The WSB did not cool the lube oil on controller A following ascent. The crew switched to controller B when the lube oil return temperature reached approximately 297°F. The APU was operated an additional 1.5 minutes on the B controller, and still no cooling was observed. The APU was shutdown when the lube oil return temperature reached 323°F. The WSB is designed to control the lube oil temperature to 250±2°F.

An extended flight control system check-out using APU 2 was performed and the WSB was not cooling on either controller. The APU ran for 11 minutes during check-out, then was shutdown and declared lost. During descent, APU 2 was activated at terminal area energy management due to the lack of cooling. The lube oil reached 259°F before shutdown after wheel stop with no evidence of cooling. The spray boiler may not have had the chance to function, however, as this temperature is close to the 250°F control limit.

9.3.1.3 09-12-1992 STS-47

During ascent, WSB 3 (serial number 15) exhibited no cooling until just prior to the early shutdown of APU 3. The lube oil temperature reached approximately 292°F when the controller was switched from A to B. The lube oil temperature continued to rise to 311°F when the decision was made to shut down APU 3 early. Prior to APU 3 deactivation, the WSB GN2 regulator outlet pressure indicated that spraying had begun. WSB 3 continued to spray until the spray logic was turned off (1 minute 43 seconds). Steady-state cooling was never achieved on either controller since the lube oil temperature was not allowed to drop to 250°F prior to boiler spray logic shutdown.

APU 3 was selected to perform FCS checkout. The checkout time frame was extended to verify WSB 3 cooling performance. The extended run time demonstrated satisfactory cooling on both controllers (3 minutes 42 seconds for B, then 1 minute 47 seconds for A). WSB lube oil and hydraulic cooling performance during entry was nominal.

Spray bar freeze up remains the most likely cause of the WSB failure, although it could have resulted from spray valve or controller failures.

<u>**9.3.1.4 01-13-1993 STS-54**</u>

During ascent, WSB 3 (serial number 15) exhibited no cooling until just after the early shutdown of APU 3. The lube oil return temperature reached approximately 295°F when the WSB was switched from controller A to B. The lube oil return temperature reached 315°F when the decision was made to shut down APU 3 early. After deactivation, the WSB 3 GN2 regulator pressure indicated that spraying had started. WSB 3 continued to spray until the spray logic was turned off (approximately 35 seconds). Steady-state cooling was never achieved on controller A or B.

APU 3 was selected to perform the FCS check-out. The FCS checkout time frame was extended to verify WSB cooling performance. The extended APU 3 run-time demonstrated satisfactory cooling on both controllers, with a minor overcool observed on controller A. APU performance using controller B during entry was nominal.

Spray bar freeze-up remains the most probable cause of this cooling problem. However, data analysis also indicated that the local pressure at the vent nozzle of system 3 during ascent was somewhat higher than the other two systems. This high pressure is due to the location of the system 3 vent nozzle outlet (it is farther forward than the system 1 and 2 vent nozzle outlets). System 3's pressure remains higher than the other systems for the first 80 seconds of ascent, which is believed to be a contributing factor toward the repeated freeze-up anomalies observed in system 3.

Spray bar freeze-up conditions occur when the water triple point condition is met inside the heat exchanger. In the worst case freeze-ups, it is postulated the water triple point was reached prior to MECO. By increasing the water preload, the duration of heat exchanger tube bundle/water preload contact can be increased, which will reduce the likelihood/severity of spray bar freeze-up by maintaining pressure above the water triple point past MECO. The ongoing spray bar freeze-up test analysis indicates that the severity of the bar freeze-up at water triple point conditions may inversely correlate to the amount of water in the boiler. Therefore, KSC has been requested to preload WSB 3 to 5 +/-0.1 lbs. of water (normal is 3.75 +/-0.24 lbs.).

9.3.2 Possible Water Spray Boiler Failure

It is unknown whether or not this reported problem is an actual failure or not. For this analysis, it has not been considered as an actual data point.

<u>**9.3.2.1 04-29-1985 STS-51B**</u>

Shortly after MECO, the backup flight system indicated an APU 3 lube oil over temperature condition. The crew switched from controller A to B at a lube oil temperature of 320°F. The temperature continued to rise for an additional 20 seconds and reached a peak of 337°F. The crew was instructed to shutdown APU 3 to avoid reaching the lube oil temperature limit of 355°F. The

APU 3 lube oil temperature had decreased to approximately 320°F at shutdown, indicating that water spray boiler controller 3B was properly controlling lube oil cooling. Post flight testing has been unsuccessful in duplicating this problem. The A controller was replaced.

9.3.3 Possible Hydraulic System Failure

9.3.3.1 02-28-1990 STS-36

Appendix C contains descriptions from PRACA records and hazards analyses of a "near-miss" failure involving a flex hose rupture in the hydraulic system.

9.3.4 Updated Posterior Distribution

The four WSB failures in Section 9.3.1 were counted as APU shutdowns. All three of these failures occurred during the ascent phase. One of these failures was permanent and caused a late restart of the APU during the entry phase, but was not counted as a failure during the reentry phase because it successfully completed its mission. For reentry, the hydraulic system rupture is counted as a possible APU/HYD unit failure in the update. The methodology for this type of update is described in section 9.2.2.5, where in this case the weighting uses 50% for 1 failure and 50% for zero failures. In the data column, if no data is available (i.e., no "trials"), an N/A for not applicable is placed in the box.

The common cause failure calculations for the MGL formulas used the ID and IS values, assuming 20 minutes for ascent and 1 hour for descent. The MGL calculations also used generic β and γ values of 0.1 and 0.27, respectively.

Table 9.3-1 lists the data and corresponding posterior probability distributions for the basic events. The means from these data distributions are used as basic event probability distribution inputs for use in SAIC's CAFTA model.

ID	Data	POSTERIOR (/hr or /demand)			
		Mean	Median	5th	95th
CE	N/A	0.5 (LL) 0.88 (TU)			
CF	Calculated	using applicable	MGL method	formulas	
CL	Calculated	using applicable	MGL method	formulas	
CO	N/A	1			
CS	Calculated	using applicable	MGL method	formulas	
HB	N/A	0.9			
ID	4/63 hrs	2.078E-02/hr	1.931E-02/hr	1.030E-02/hr	3.622E-02/hr
IF	4/63 hrs	2.078E-02/hr	1.931E-02/hr	1.030E-02/hr	3.622E-02/hr
IS	0/189 starts 0 to 1/252 hrs	5.677E-03/start 6.479E-03/hr	4.448E-03/start 5.614E-03/hr	1.433E-03/start 2.369E-03/hr	1.194E-02/start 1.219E-02/hr
LA	N/A	0.0 (asc) 0.1667 (des)			
LD	N/A	0.0 (asc) 0.1667 (des)			
LF	N/A	1.0E-01 (asc)	1.0E-01 (asc)	6.0E-02 (asc)	1.4E-01 (asc)
OS	2/6 Leaks	3.0E-01 (des)	3.0E-01 (des)	2.2E-01 (des)	3.8E-01 (des)
LK	N/A	1.890E-04/hr	1.152E-04/hr	2.224E-05/hr	5.971E-04/hr
LL	N/A	2.8E-05			
LO	N/A	8.0E-03 (asc)	5.0E-03 (asc)	9.9E-04 (asc)	2.5E-02 (asc)
LS	0/12 Leaks	7.0E-02 (des)	5.3E-02 (des)	1.4E-02 (des)	1.6E-01 (des)
LU	N/A	1.0 (asc) 0.8333 (des)			
LZ	N/A	1.0 (asc) 0.8333 (des)			
SI	N/A	1.0 (LL) 0.88 (TU)			
SR	N/A	0.99432/start	0.99555/start	0.99857/start	0.98806/start
TU	N/A	6.962E-05	5.501E-05	1.974E-05	1.672E-04
UL	N/A	0.1	0.1	0.01	0.19

Table 9.3-1: Posterior Probability Distributions

9.4 APU/HYD/WSB ANALYSIS FOR SSME MODEL

The APU failure probability assessment for the SSME model being produced at SAIC is somewhat different than that for this APU model. First, the exposure time is at most 520 seconds instead of 20 minutes. Second, only 1 of the WSB failures is relevant (STS-3) for purposes of calculating engine hydraulic lockup probability.

We started with the prior distribution for IF, given in Table 9.2-6, multiplied against the 520 second time period to produce a probability of failure (POF). We updated with 1 failure in 63 missions to produce a posterior. This represents the case in which the WSB failure and APU shutdown continues to be representative of how MCC and crew will react to a WSB failure. Since STS-3, other WSB failures have not resulted in a call for APU shutdown before MECO. Flight Rules indicate that APU shutdowns should occur post-MECO.

We also updated the same prior distribution for IF with 0 failures in 63 missions. This is like saying that STS-3 never happened and gives an overly optimistic assessment. An accurate assessment lies somewhere in between. We used a weighted average of each posterior where each update was given equal probability of being the correct one.

The Bayesian calculation is shown in Figure 9.4.1.

The MGL method was used to calculate the probability of loss of hydraulics for a single engine and for two engines as follows:

1 Engine Goes into Hydraulic Lockup via Hydraulic Failure During Ascent

$Q = 3(1-\beta)q_{APU} = 3\ (1\text{-}0.1)\ 1.5\text{E-}04 =$ ***4E-04***

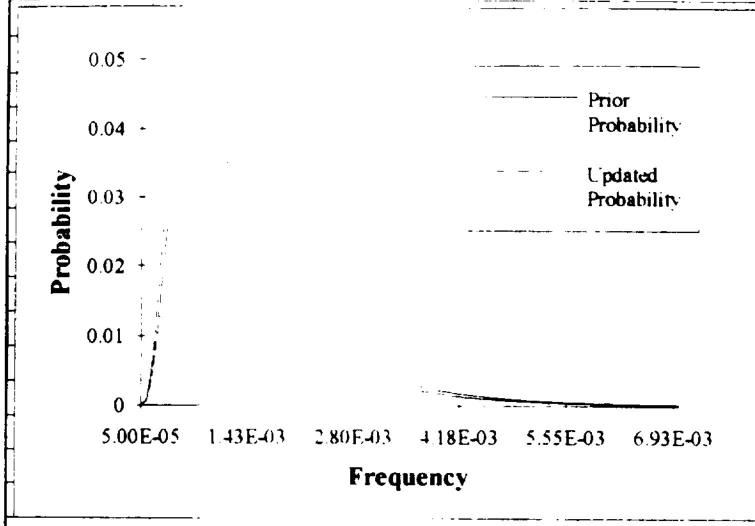
2 Engines Go into Hydraulic Lockup via Hydraulic Failure During Ascent (First 5.6 minutes)

$Q = 3/2\ (1-\gamma)\beta(336/520)q_{APU} + 3(1-\beta)^2(336/520)^2\ q^2_{APU} =$

$3/2(1\text{-}0.27)0.1(336/520)1.5\text{E-}04+3(1\text{-}0.1)^2(336/520)^2\ 1.5\text{E-}04 =$ ***1E-04***

BAYESIAN UPDATE: Easy Template

Safety Factor Associates, Inc.

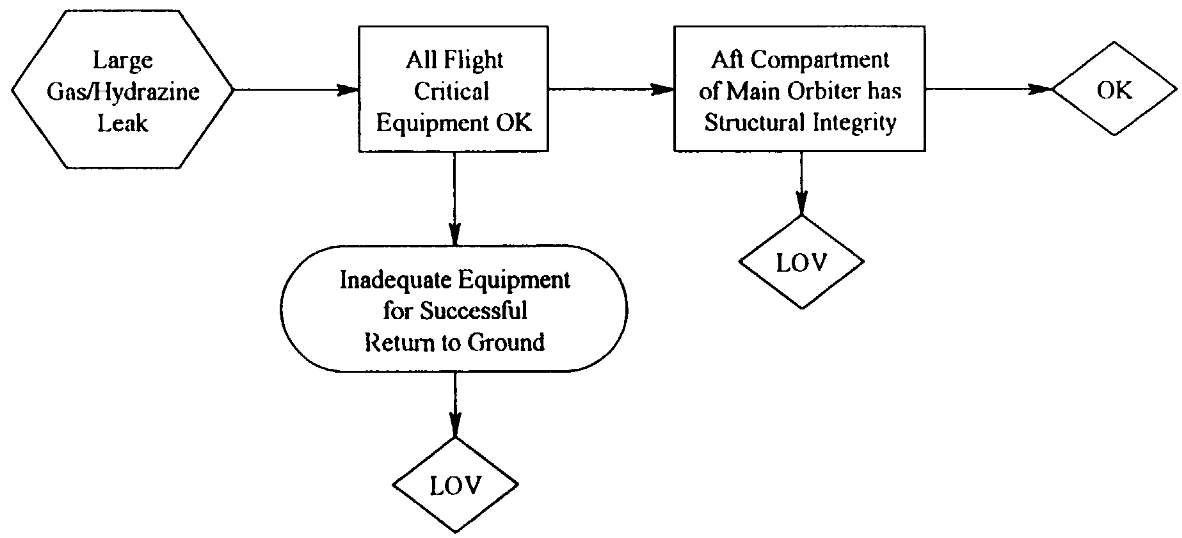


UPDATE PARAMETERS	Buttons
0@.5,1@.5 failures	
189 time/trials	

	PRIOR	UPDATE
Mean	1.330E-03	1.464E-03
Median	1.041E-03	1.159E-03
Mode	6.693E-04	7.381E-04
5th %	3.321E-04	3.646E-04
20th %	5.805E-04	6.452E-04
80th %	1.864E-03	2.053E-03
95th %	3.250E-03	3.449E-03
σ	9.472E-04	1.005E-03

Figure 9.4-1: APU Failures on Ascent Causing SSME Hydraulic Lockup (POF)

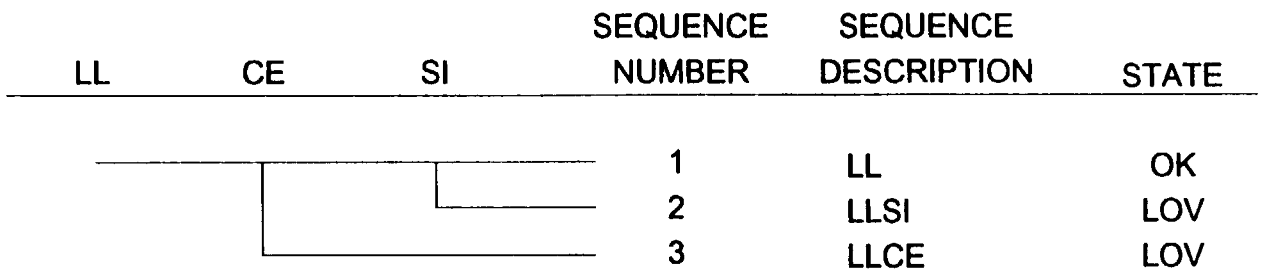
Event Sequence Diagram of a Large Gas/Hydrazine Leak



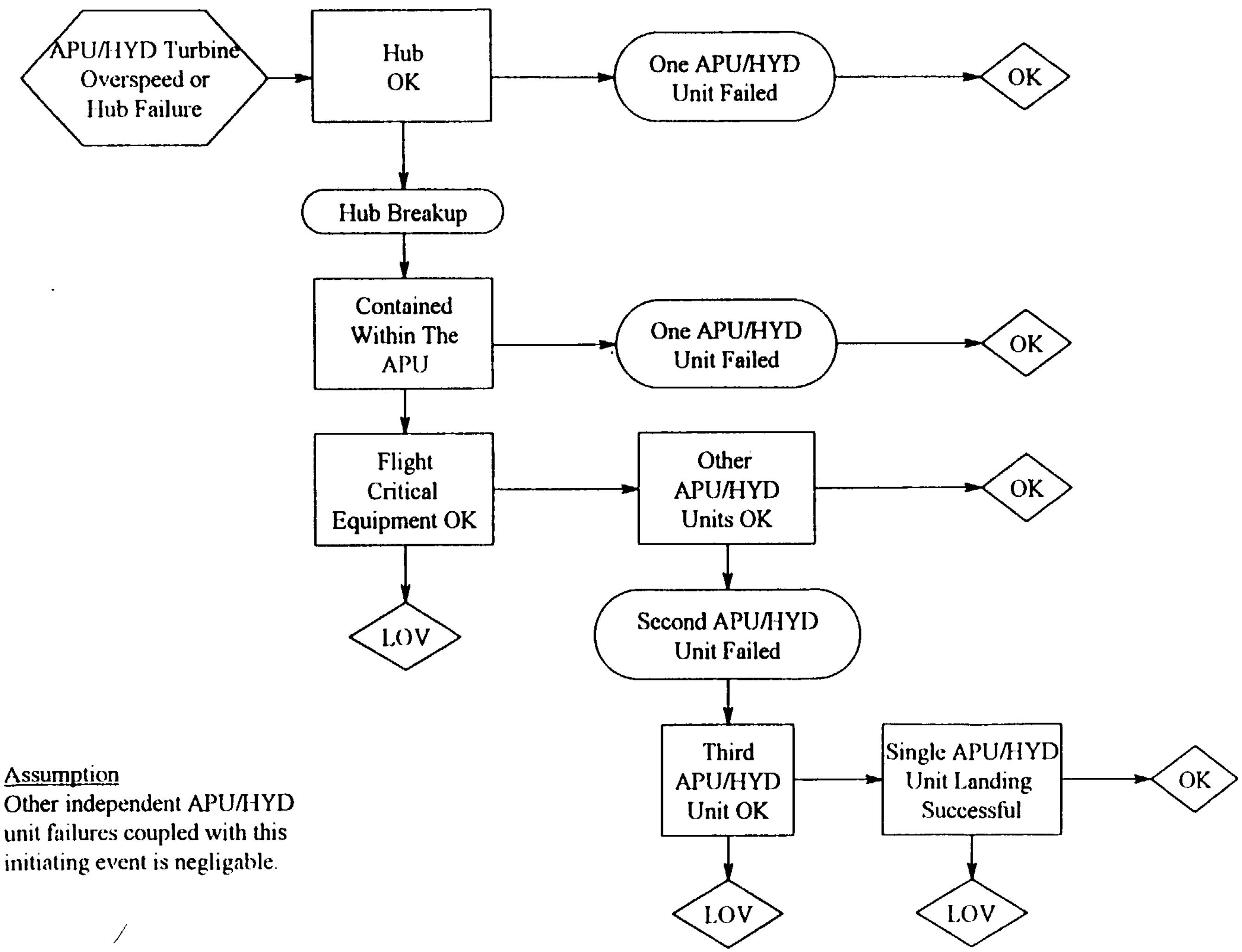
<u>Assumption</u>

Because of the low frequency of severe exhaust gas leak, we have categorized this event with the unisolatable leaks. Separate categorization of the events would insignificantly change the estimated risk.

EVENT TREE OF A LARGE GAS/HYDRAZINE LEAK

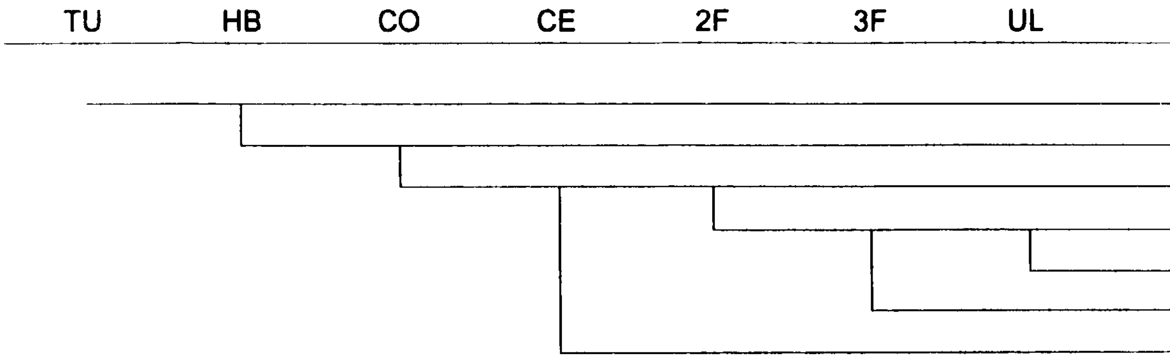


Event Sequence Diagram for APU/HYD Turbine Overspeed and/or Hub Failure



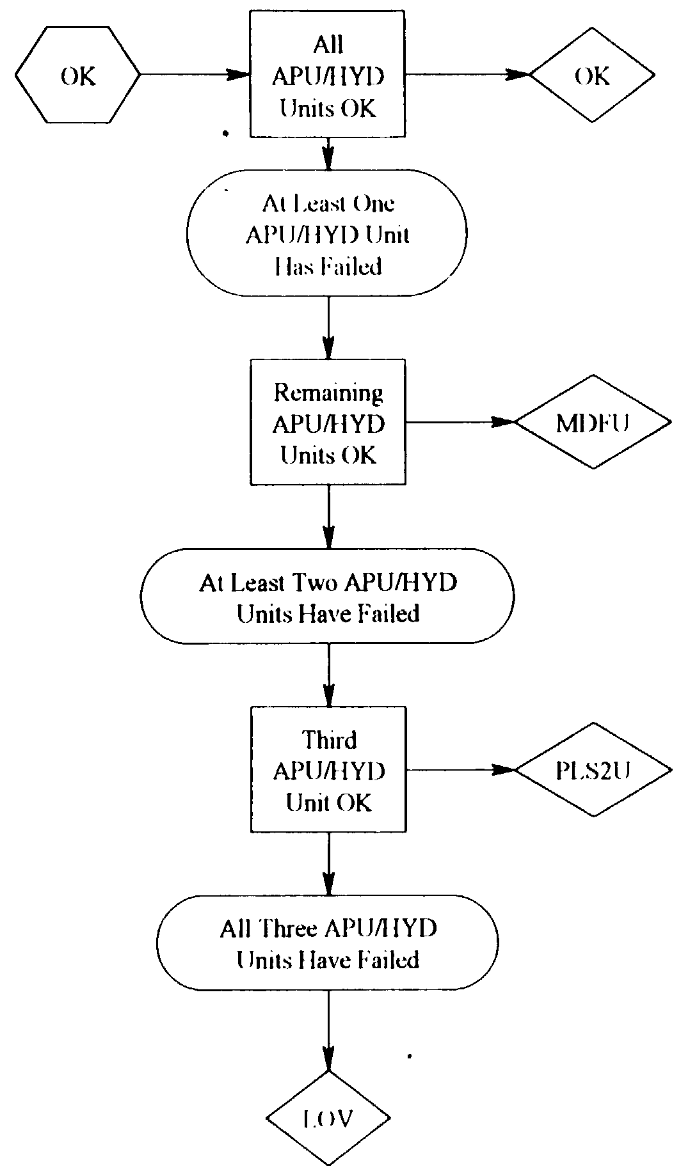
Assumption
Other independent APU/HYD unit failures coupled with this initiating event is negligable.

EVENT TREE OF APU/HYD TURBINE OVERSPEED AND/OR BREAKUP

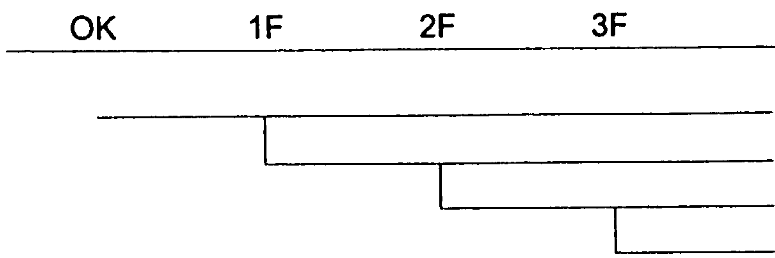


SEQUENCE NUMBER	SEQUENCE DESCRIPTION	STATE
1	TU	OK
2	TUHB	OK
3	TUHBCO	OK
4	TUHBCO2F	OK
5	TUHBCO2FUL	LOV
6	TUHBCO2F3F	LOV
7	TUHBCOCE	LOV

Event Sequence Diagram for OK Start Without a Hydrazine Leak During Ascent

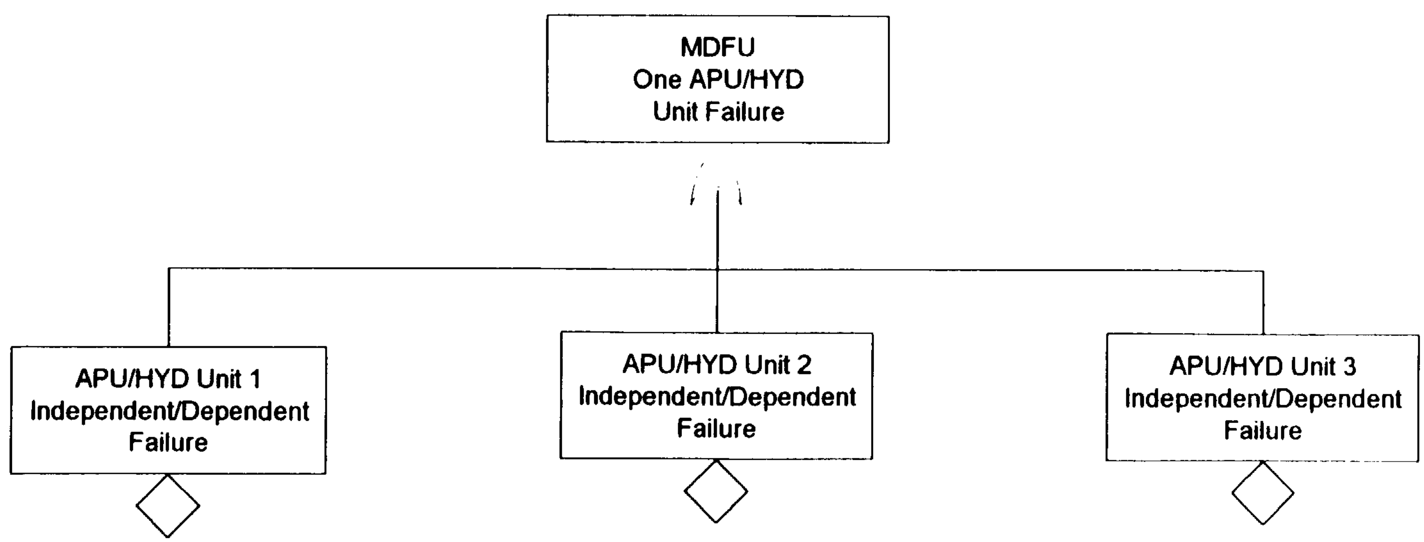


EVENT TREE OF AN OK START WITHOUT A HYDRAZINE LEAK DURING ASCENT

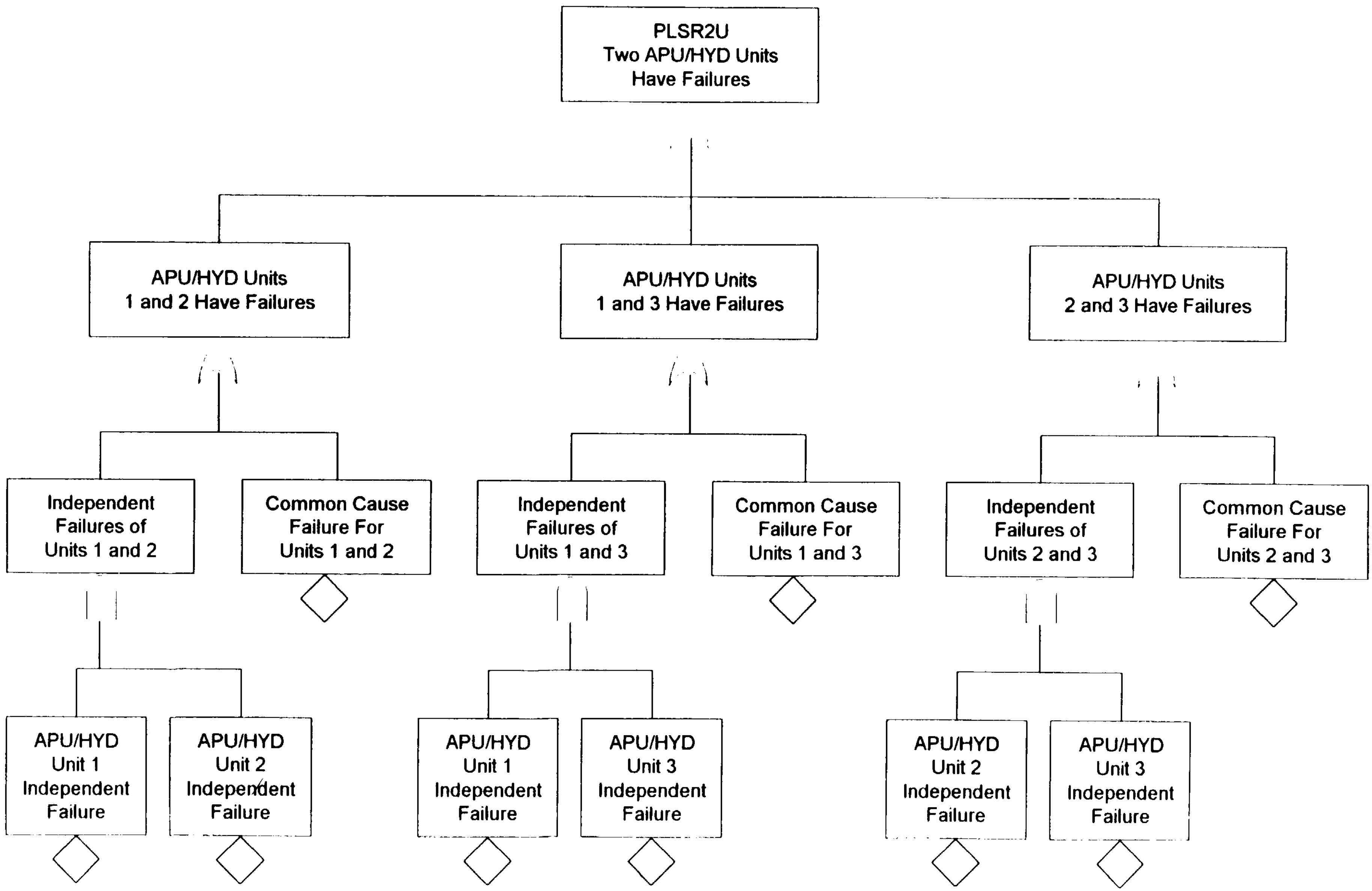


SEQUENCE NUMBER	SEQUENCE DESCRIPTION	STATE
1	OK	OK
2	OK1F	MDFU
3	OK1F2F	PLSR2U
4	OK1F2F3F	LOV

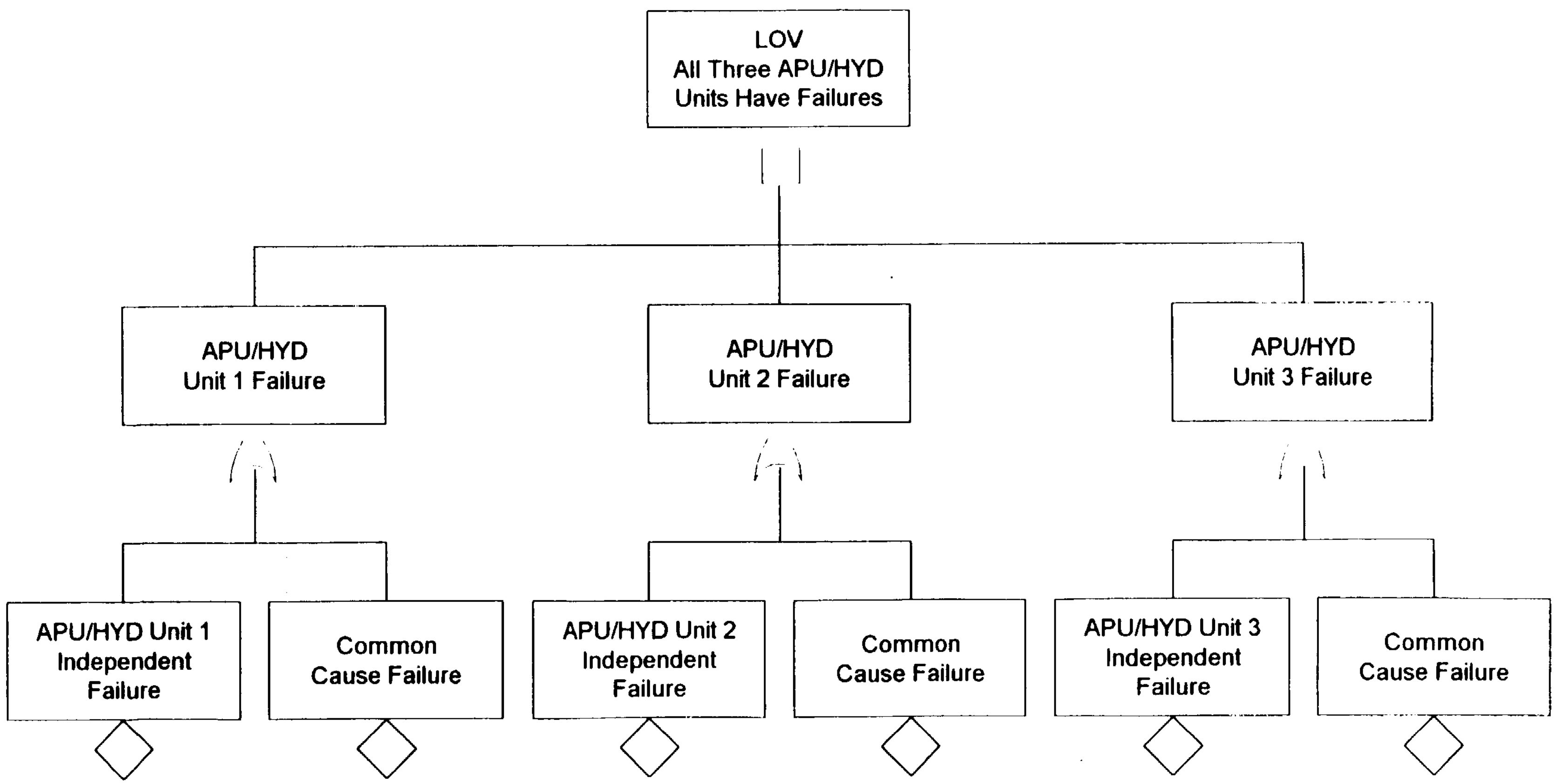
Fault Tree For Sequence 2 MDFU State From OK Start Without A Hydrazine Leak During Ascent



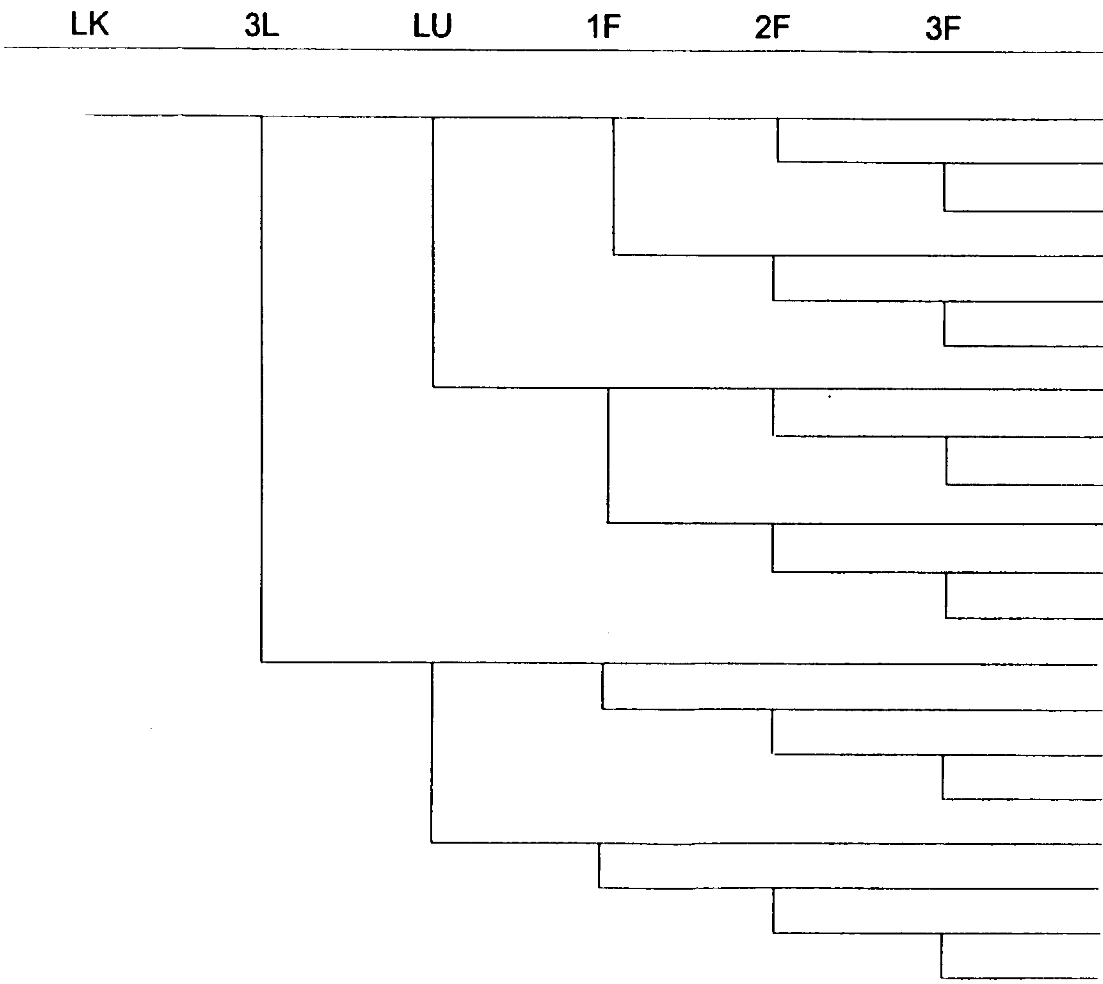
Fault Tree For Sequence 3 PLSR2U State From OK Start Without A Hydrazine Leak During Ascent



Fault Tree For Sequence 4 LOV State From OK Start Without A Hydrazine Leak During Ascent

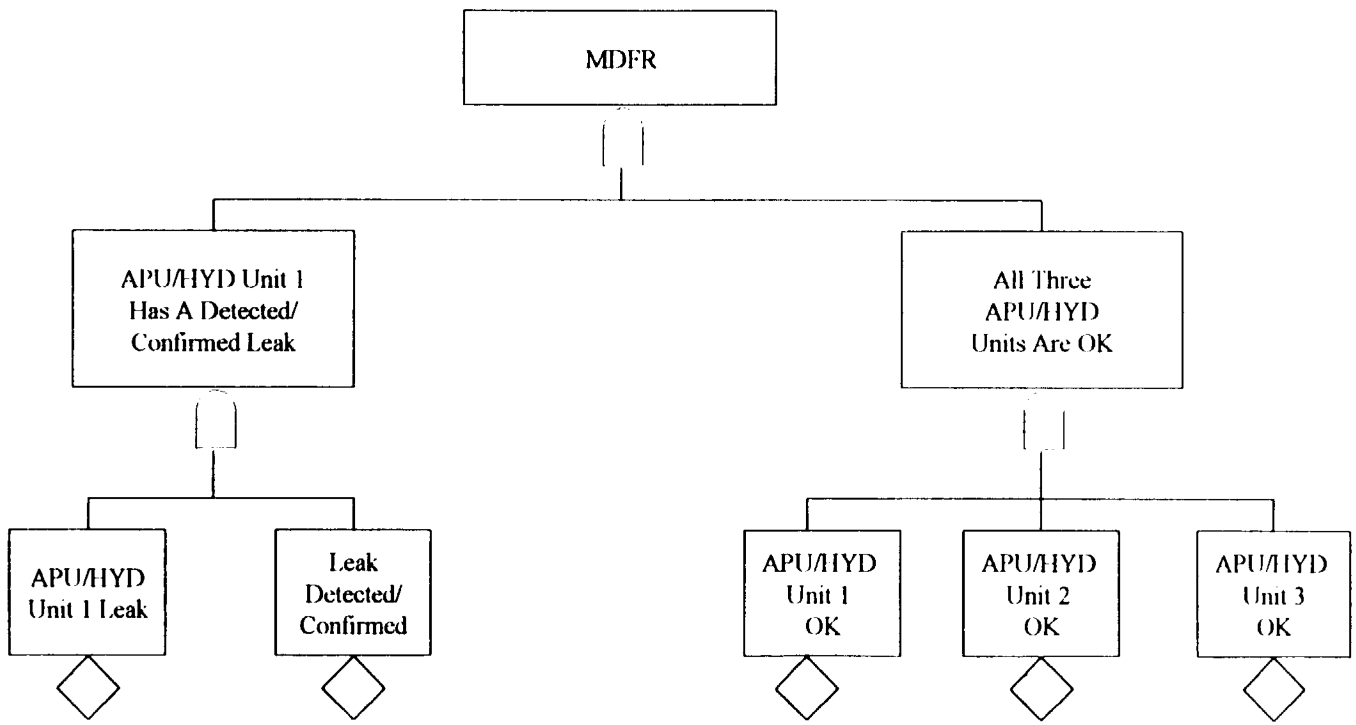


EVENT TREE OF APU/HYD HYDRAZINE LEAK STATE DURING ASCENT

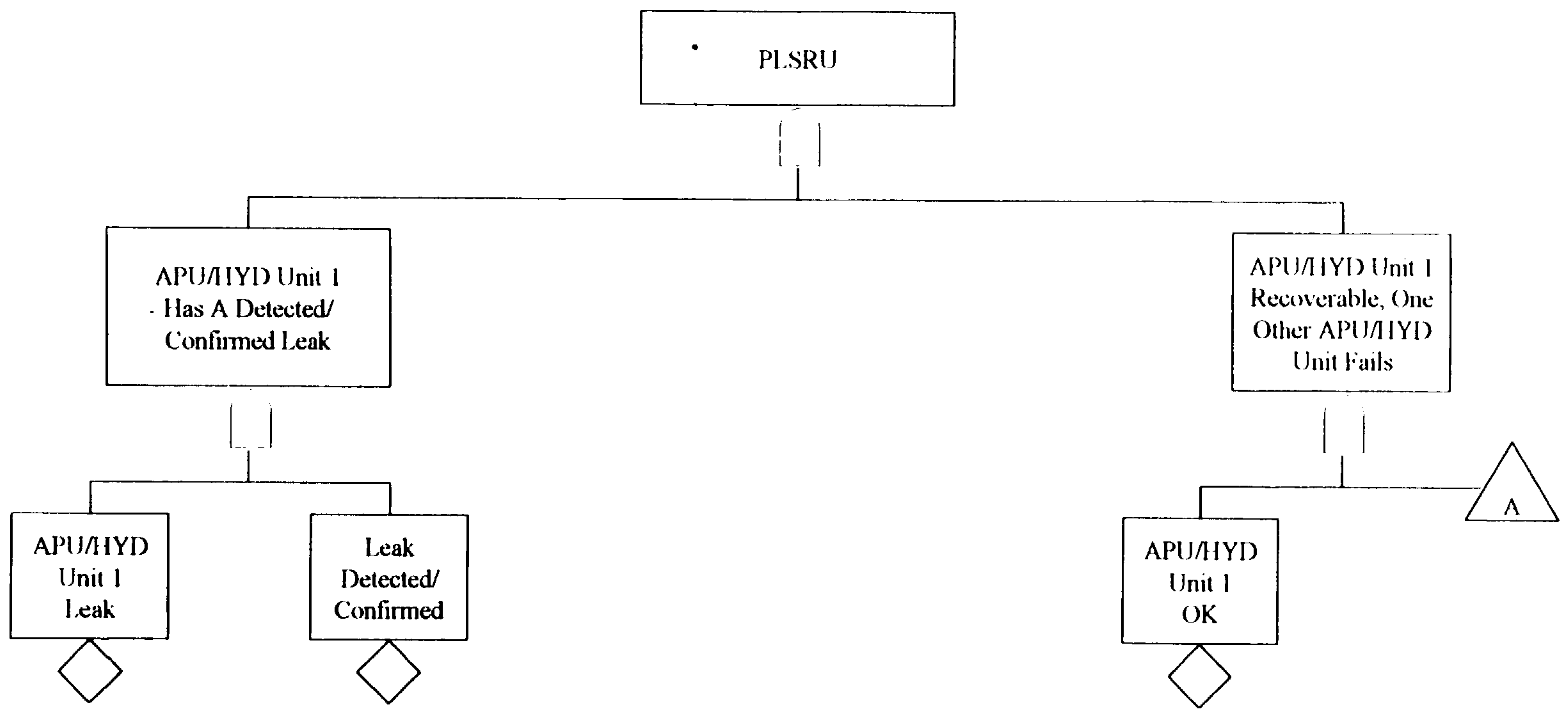


SEQUENCE NUMBER	SEQUENCE DESCRIPTION	STATE
1	LK	MDFR
2	LK2F	PLSRU
3	LK2F3F	PLSR2U
4	LK1F	MDFU
5	LK1F2F	PLS2U
6	LK1F2F3F	LOV
7	LKLU	IL0
8	LKLU2F	MDFRU
9	LKLU2F3F	PLSR2U
10	LKLU1F	MDFU
11	LK1F2F	PLS2U
12	LK1F2F3F	LOV
13	LK3L	PLS3R
14	LK3L1F	PLS2RU
15	LK3L1F2F	PLSR2U
16	LK3L1F2F3F	LOV
17	LK3LLU	ILT
18	LK3LLU1F	MDF2RU
19	LK3LLU1F2F	PLSR2U
20	LK3LLU1F2F3F	LOV

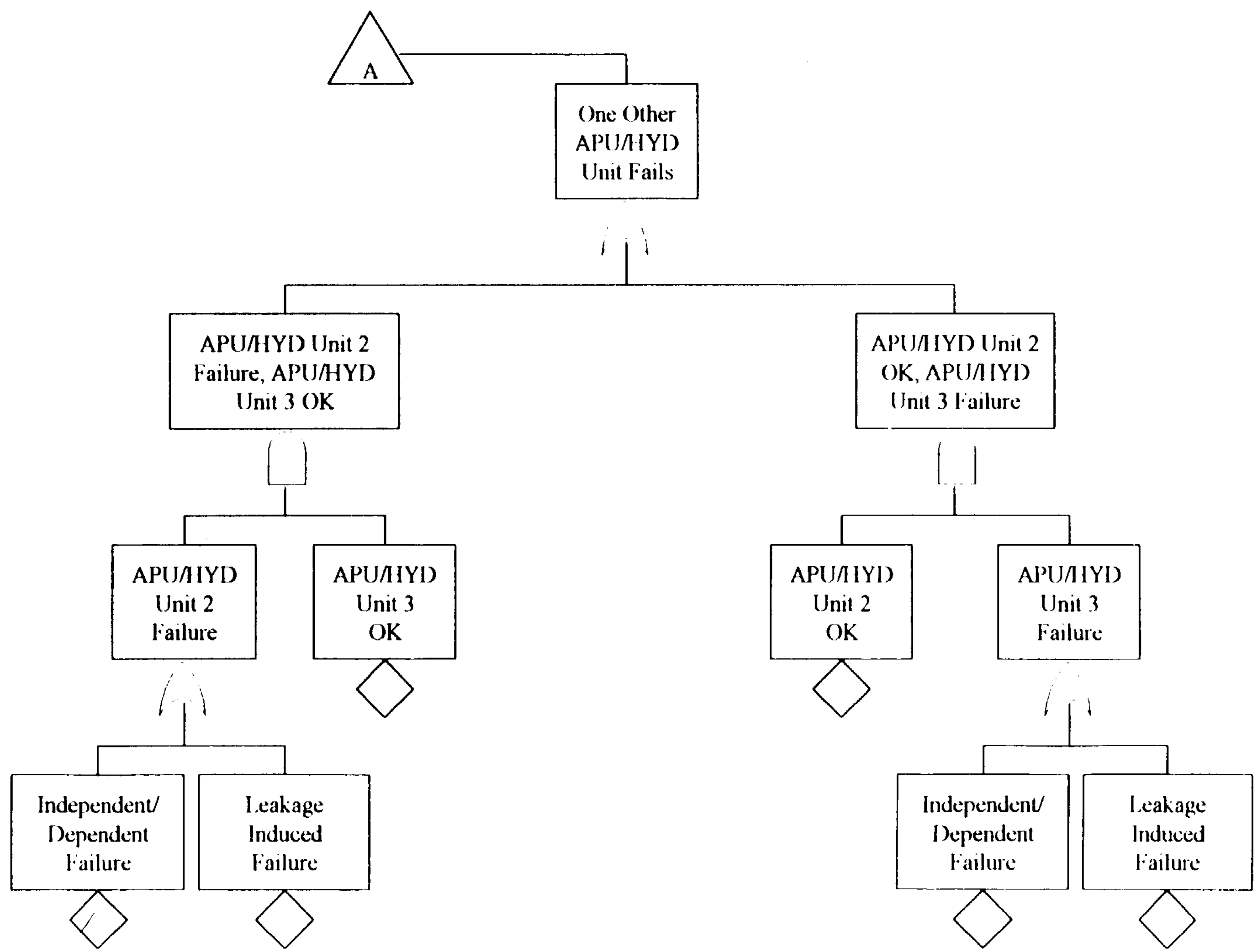
Fault Tree for Sequence 1: MDFR State From a Hydrazine Leak State During Ascent one APU/HYD Unit has a Detected/Confirmed Leak and is Recoverable



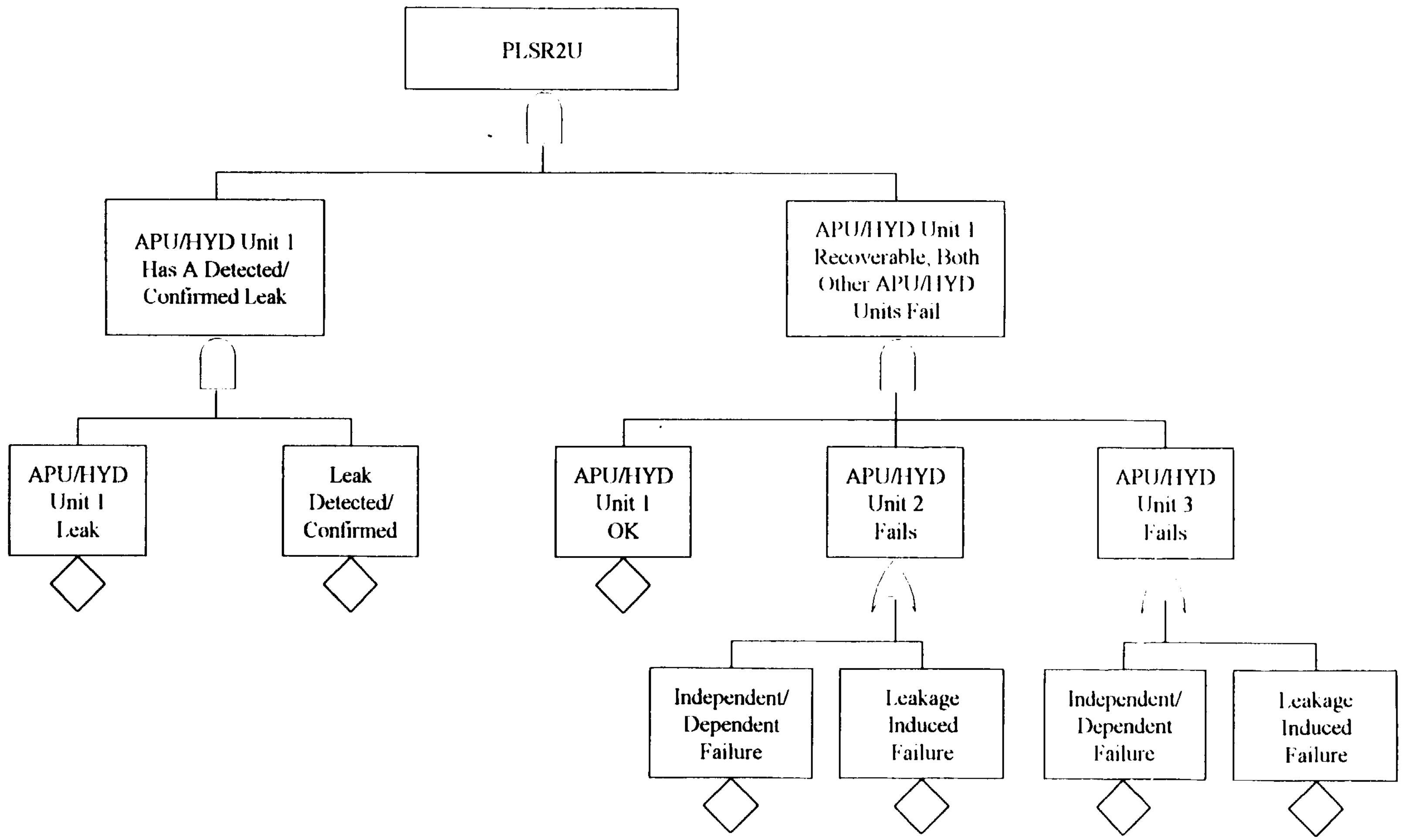
Fault Tree for Sequence 2: PLSRU End State
From a Hydrazine Leak During Ascent,
one APU/HYD Unit has a Detected/Confirmed Leak
and is Recoverable, one Other APU/HYD Unit Fails



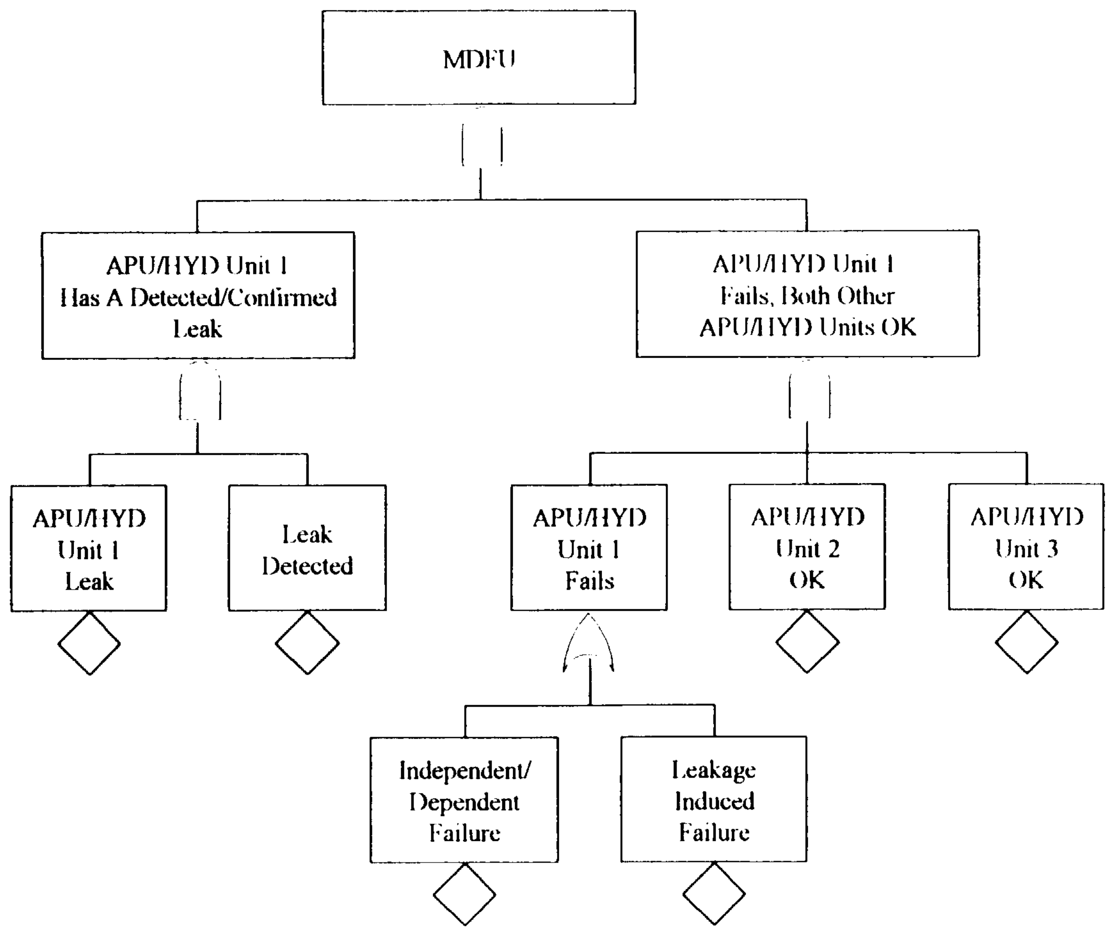
Fault Tree for Sequence 2: PLSRU End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has a Detected/Confirmed Leak and is Recoverable, one Other APU/HYD Unit Fails (Continued)



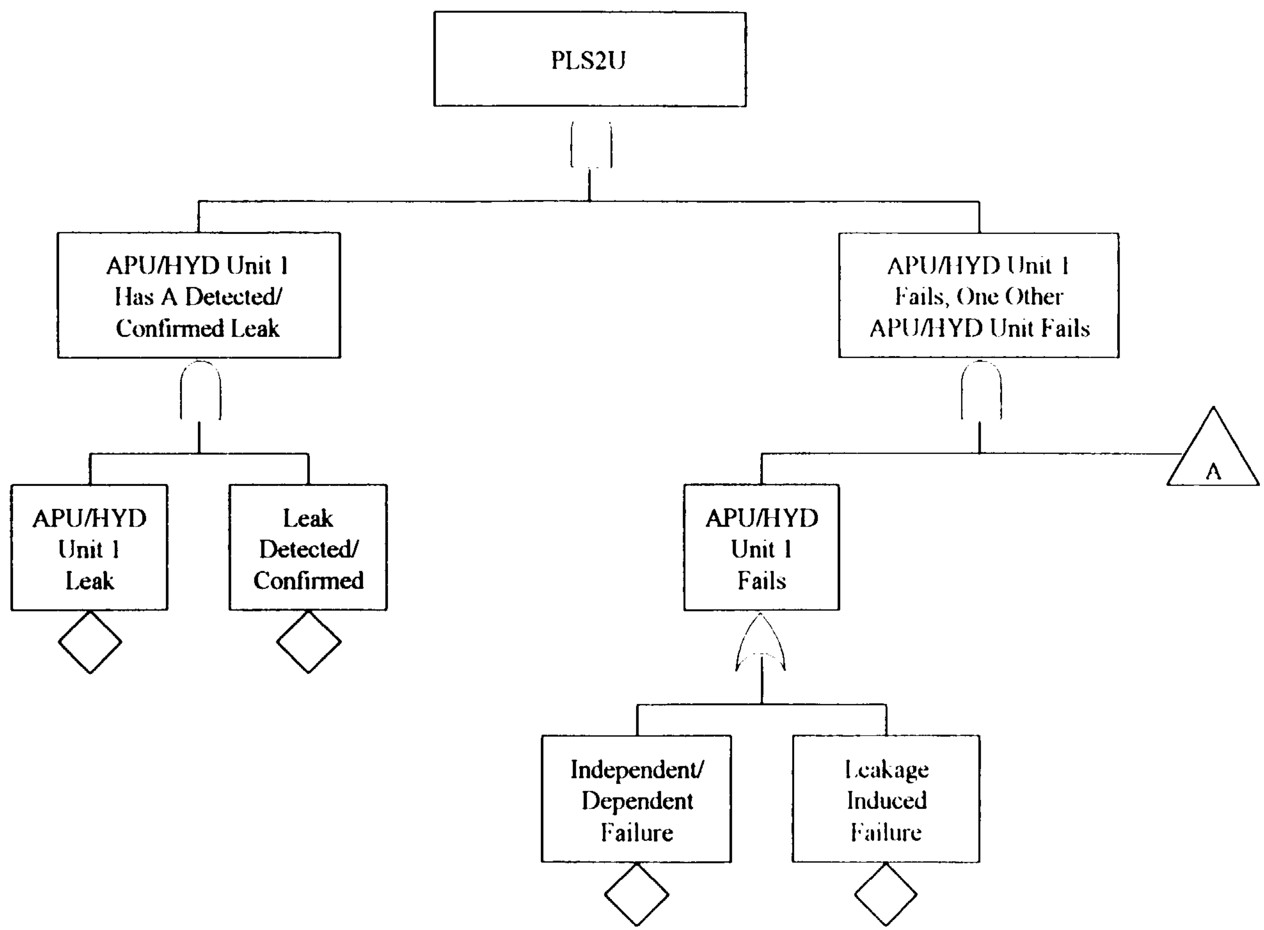
Fault Tree for Sequence 3: PLSR2U End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has a Detected/Confirmed Leak and is Recoverable, Both Other APU/HYD Units Fail



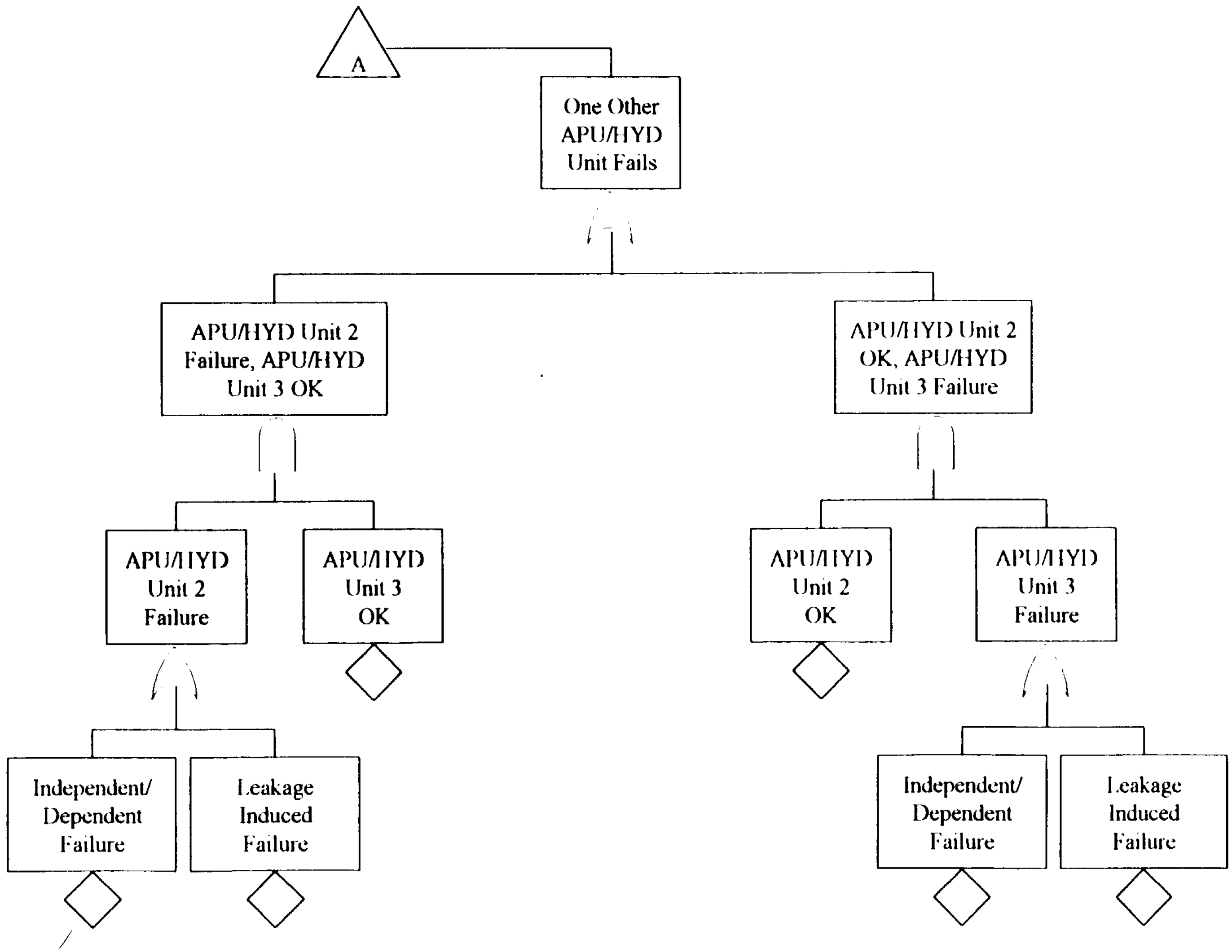
Fault Tree for Sequence 4: MDFU End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has a Detected/Confirmed Leak and Subsequent Failure



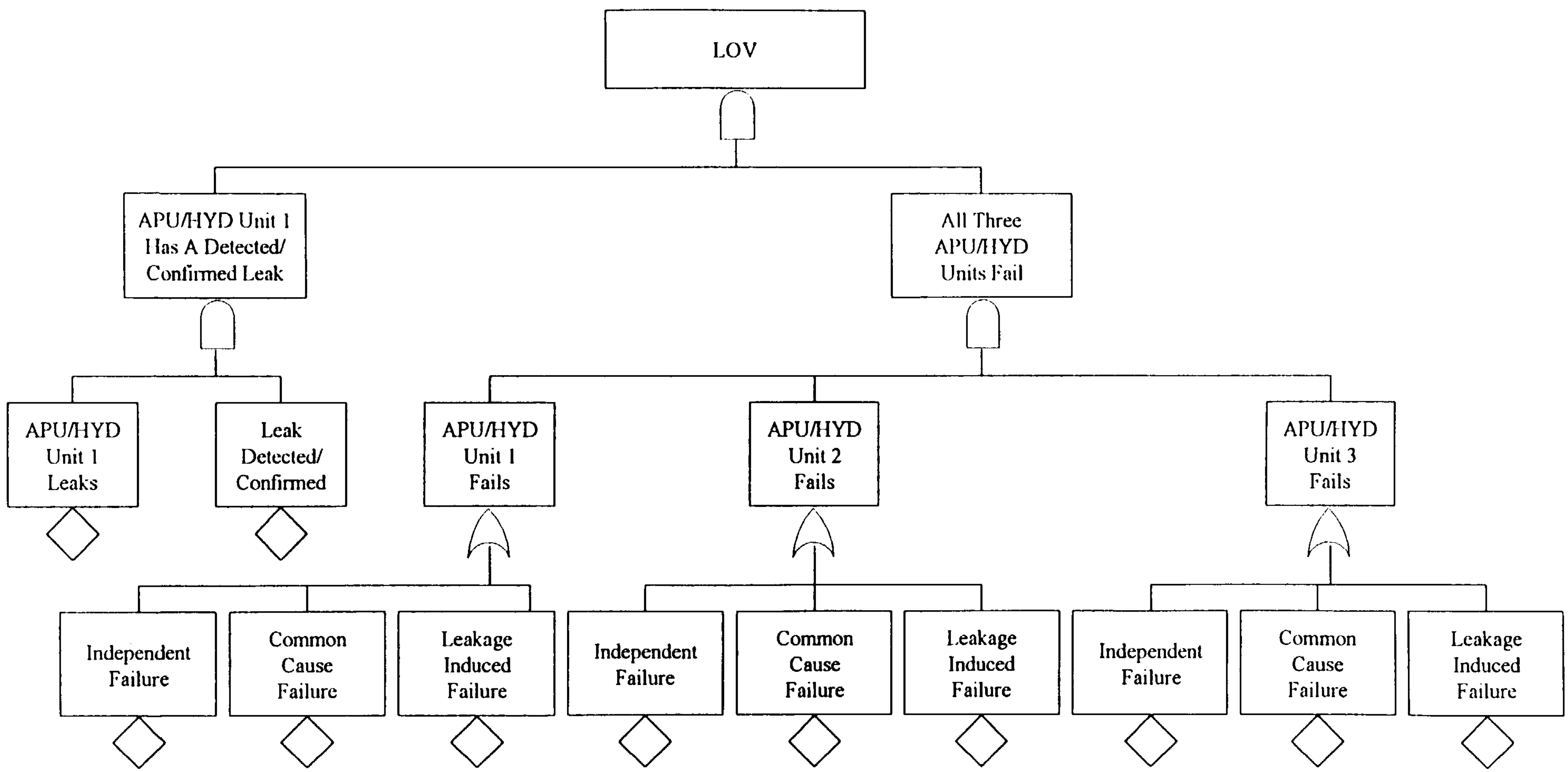
Fault Tree for Sequence 5: PLS2U End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has a Detected/Confirmed Leak and Subsequent Failure, one Other APU/HYD Unit Also Fails



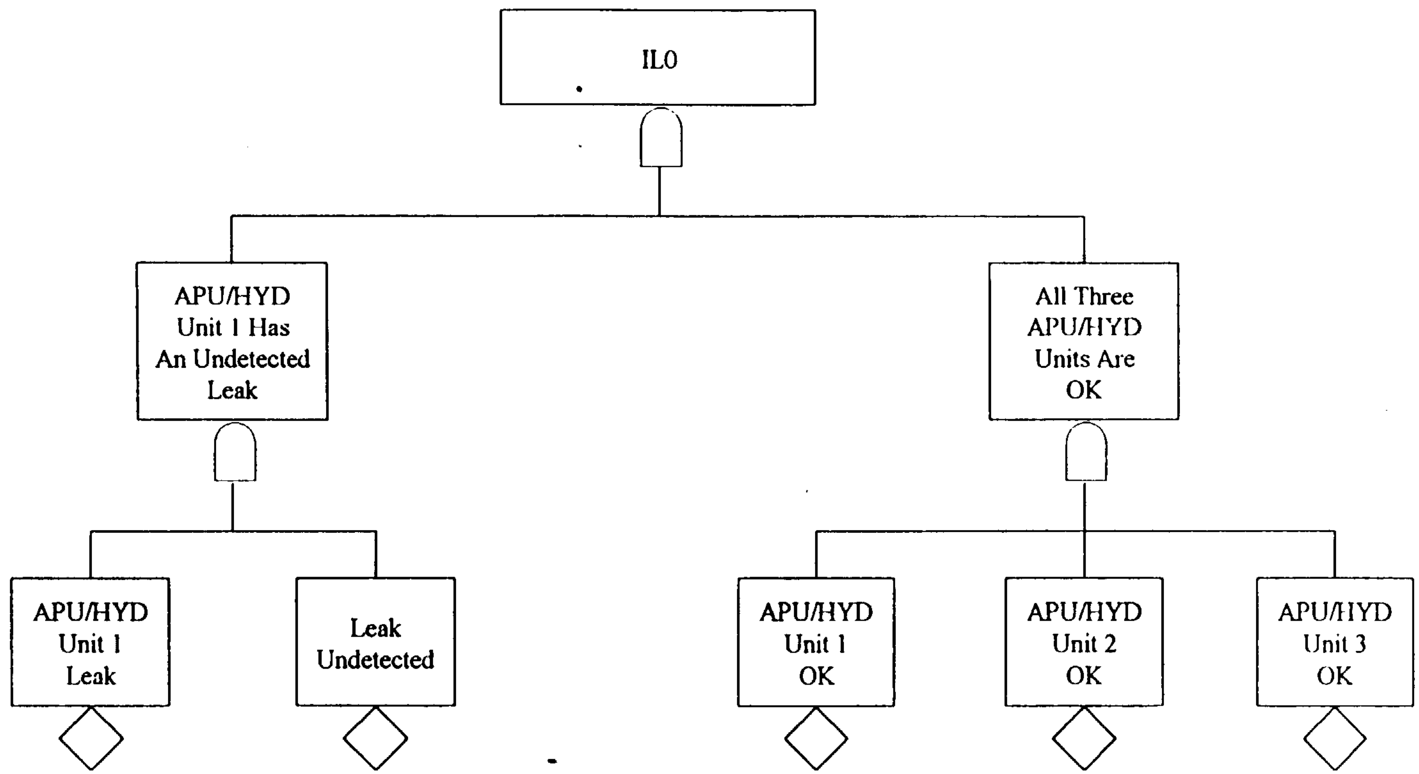
Fault Tree for Sequence 5: PLS2U End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has a Detected/Confirmed Leak and Subsequent Failure, one Other APU/HYD Unit Also Fails (Continued)



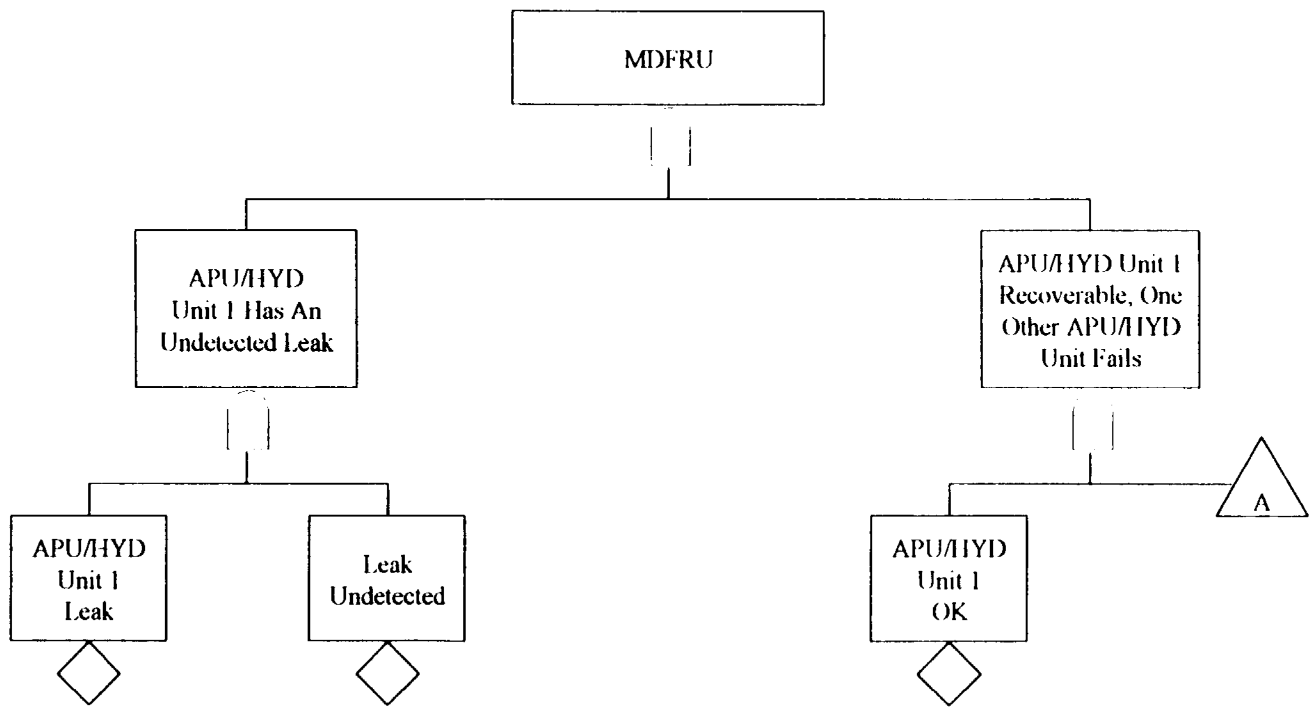
Fault Tree for Sequence [illegible]: LOV End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has a Detected/Confirmed Hydrazine Leak and all Three APU/HYD Units Have Failures



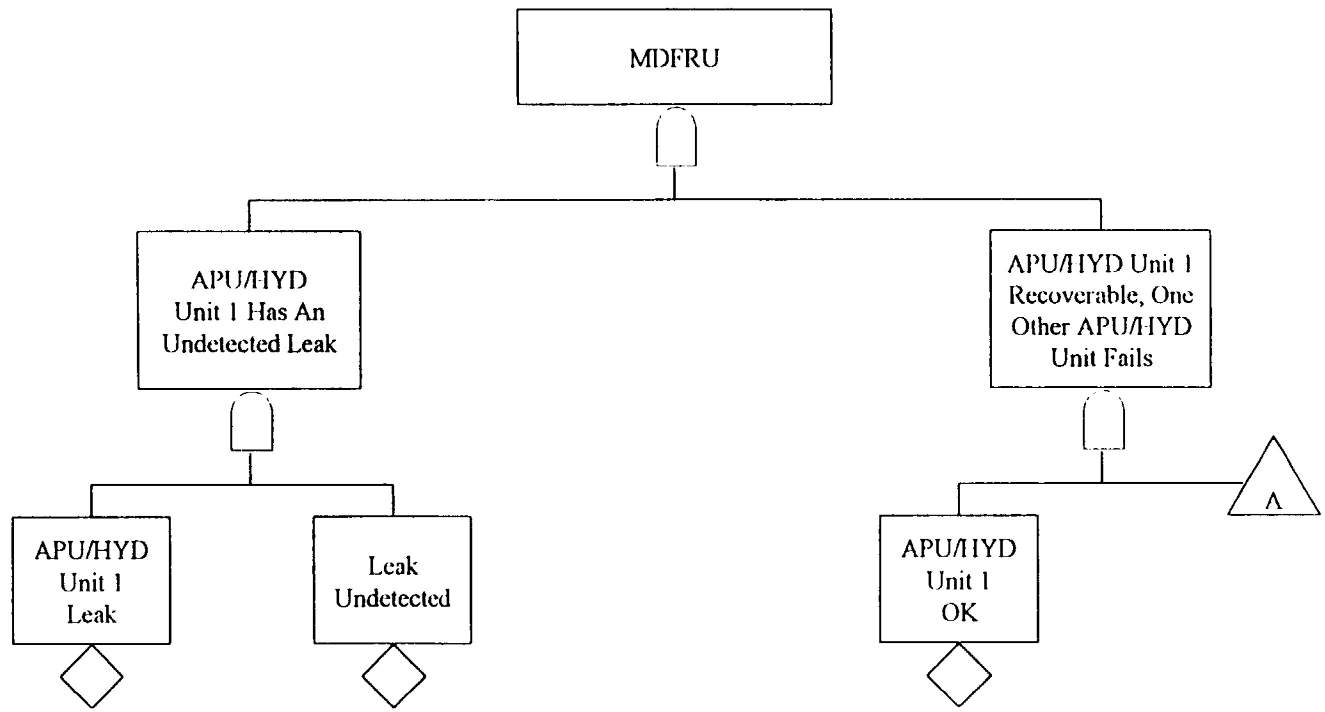
Fault Tree for Sequence 7: IL0 End State From Hydrazine Leak During Ascent, one APU/HYD Unit has an Undetected Leak and no APU/HYD Units Have Failures



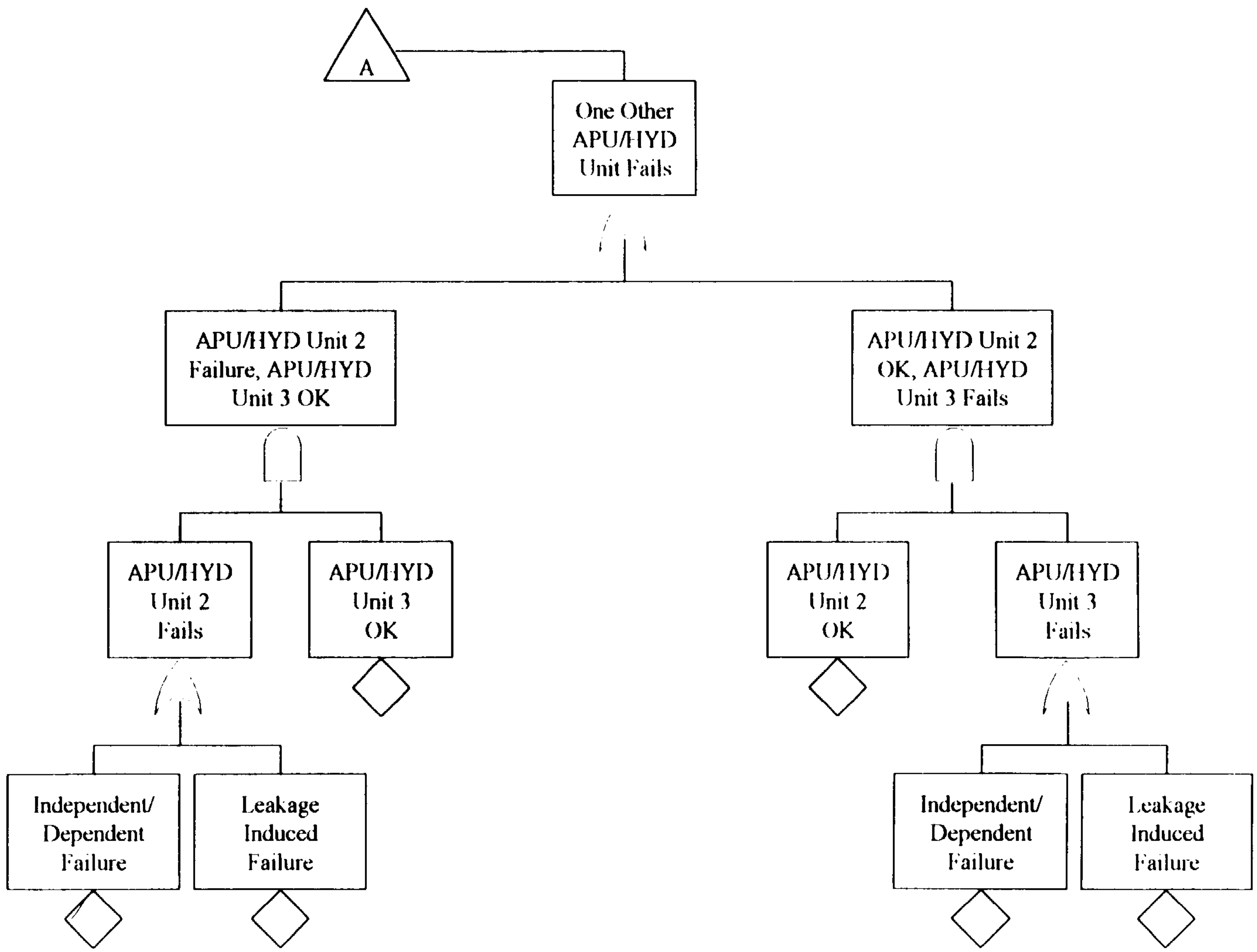
Fault Tree for Sequence σ: MDFRU End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has an Undetected Leak and is Recoverable, one Other APU/HYD Unit Fails



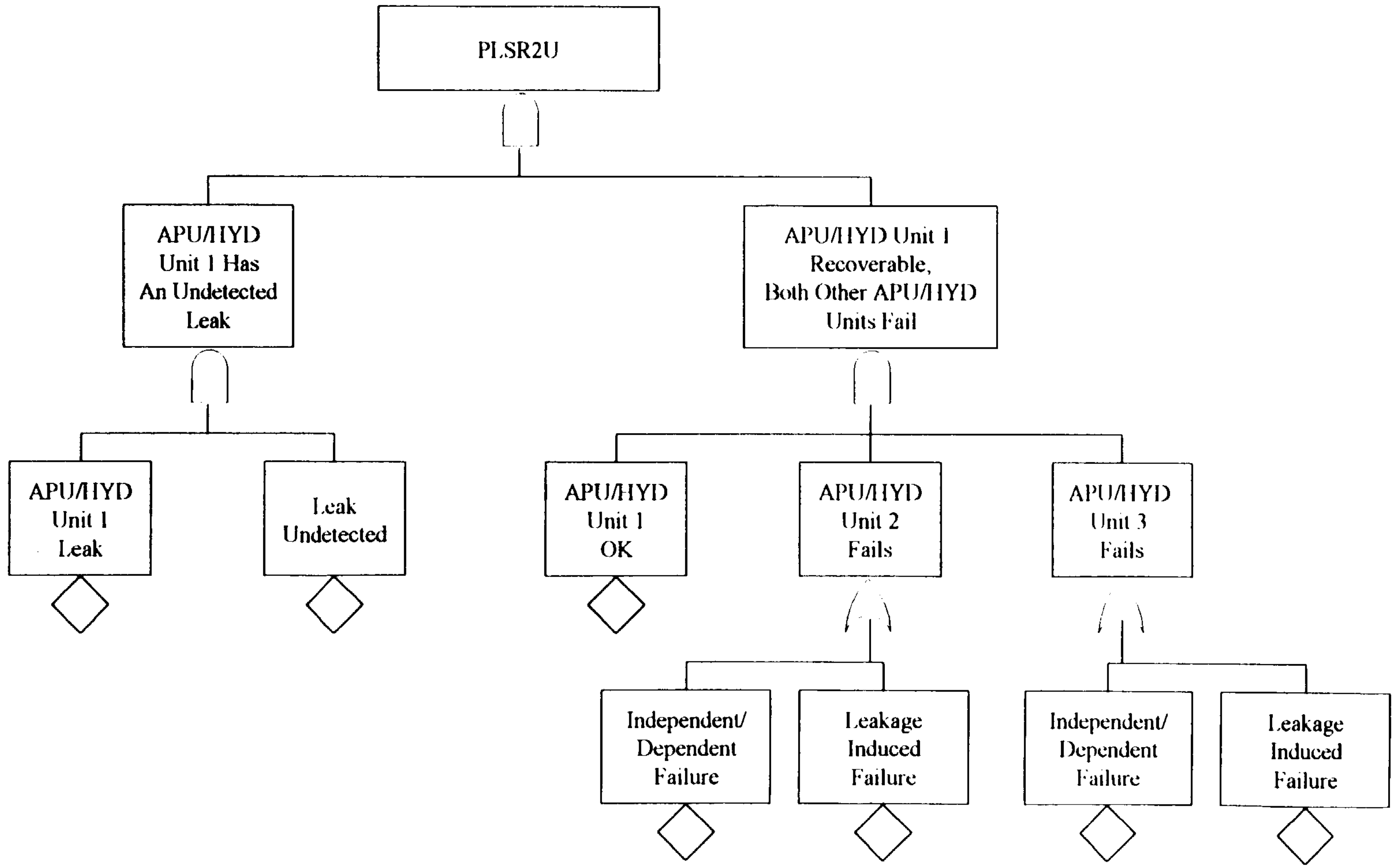
Fault Tree for Sequence 6: MDFRU End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has an Undetected Leak and is Recoverable, one Other APU/HYD Unit Fails



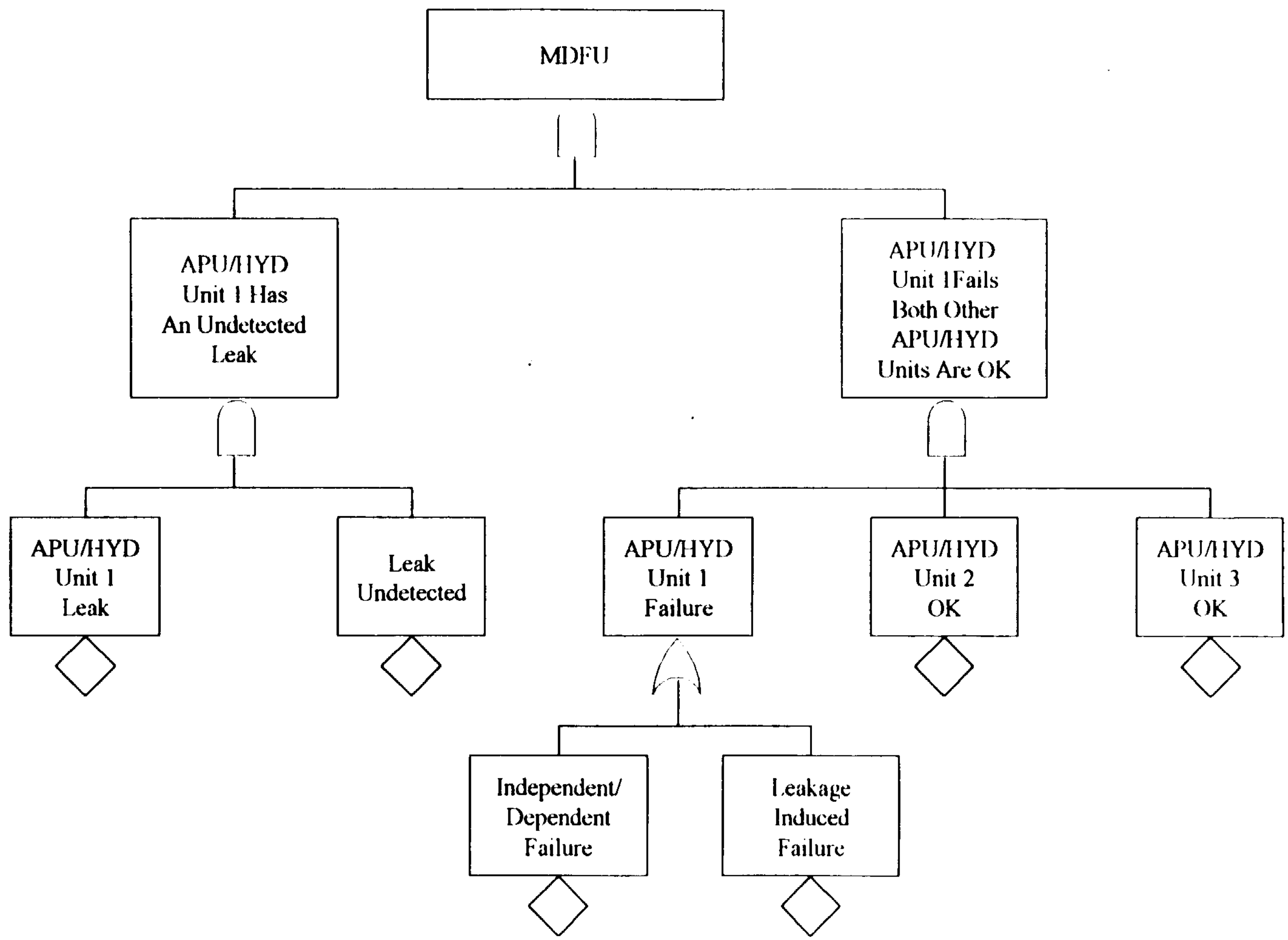
Fault Tree for Sequence 8: MDFRU End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has an Undetected Leak and is Recoverable, one Other APU/HYD Unit Fails (Continued)



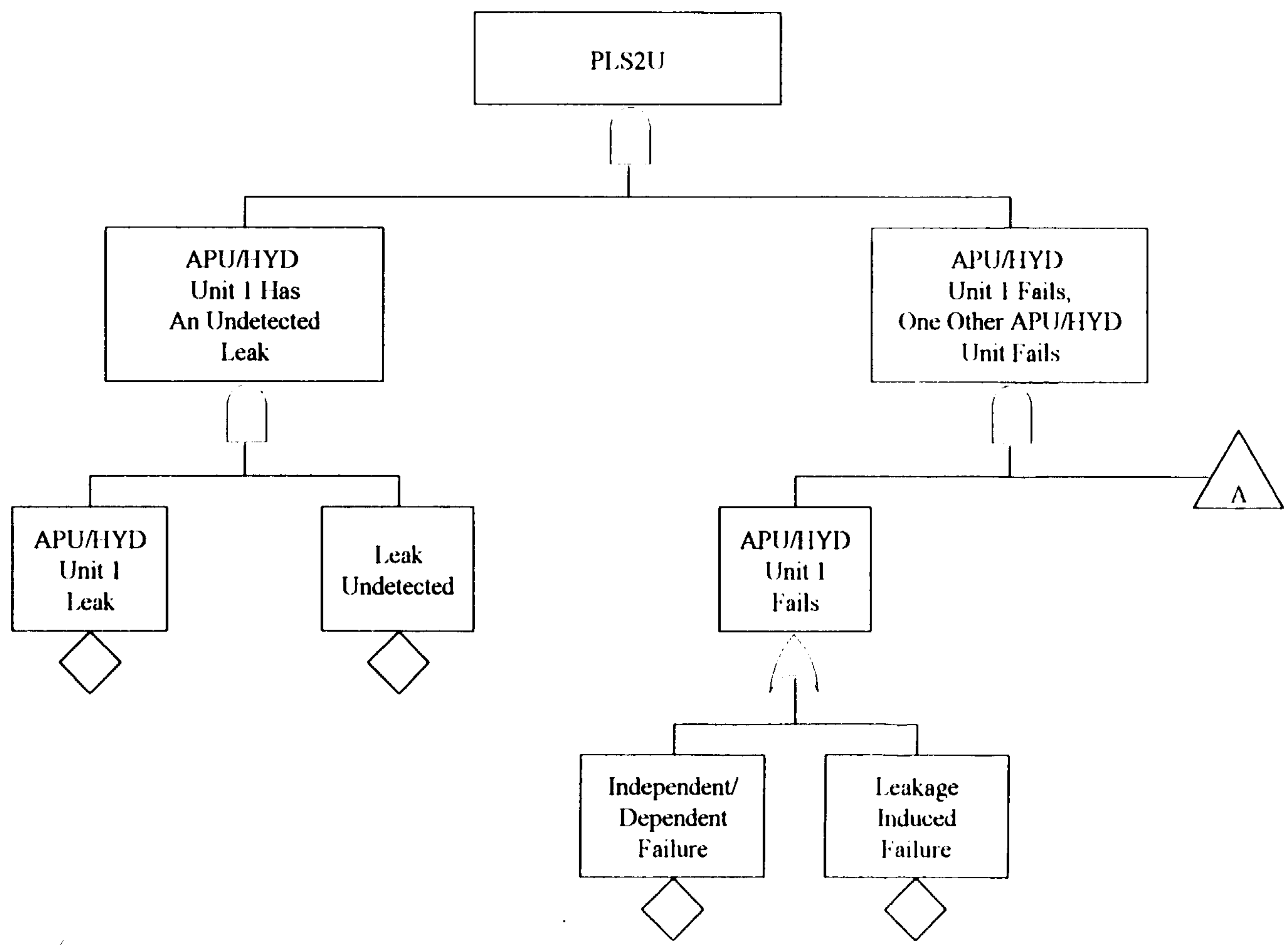
Fault Tree for Sequence 9: PLSR2U End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has an Undetected Leak and is Recoverable, Both Other APU/HYD Units Fail



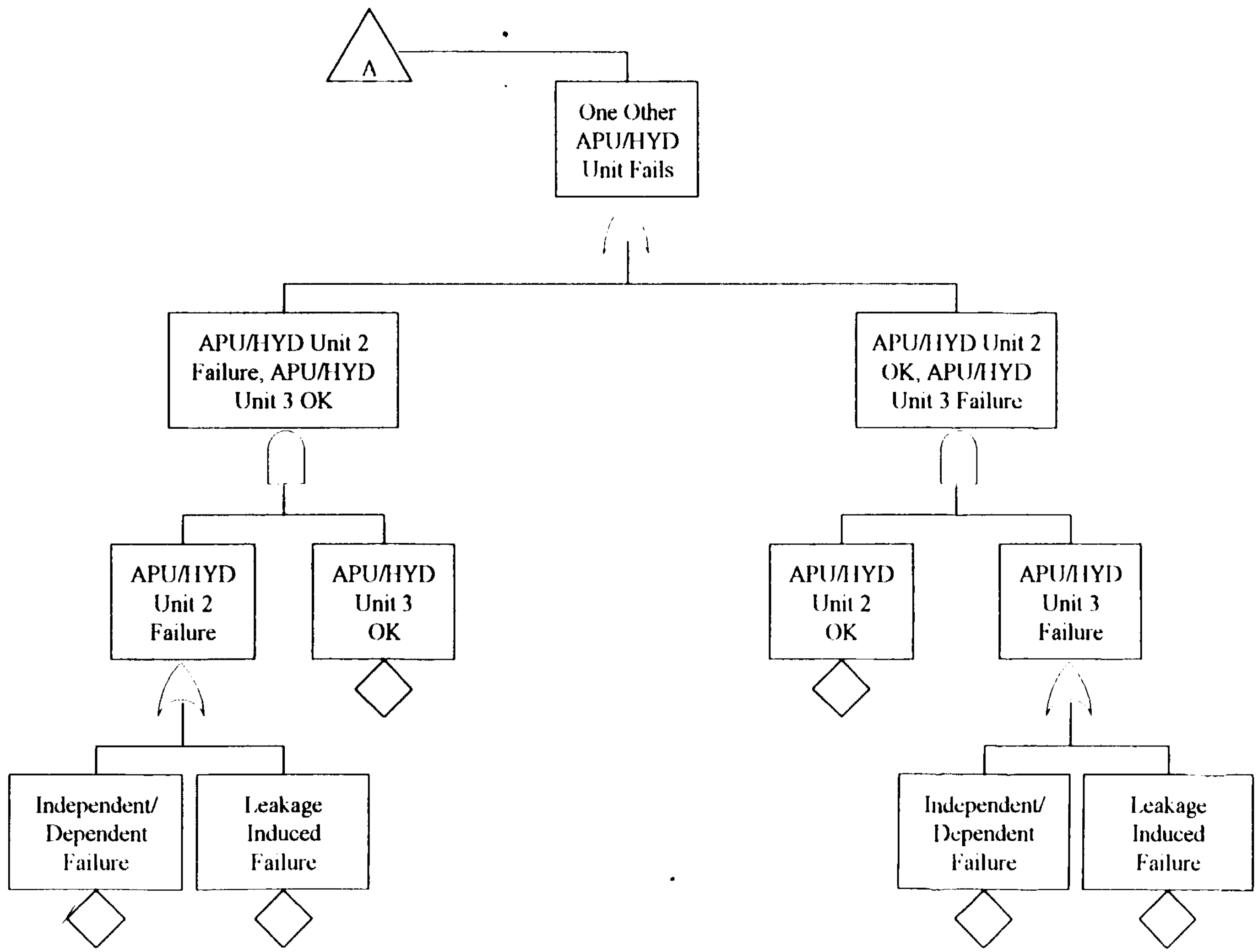
Fault Tree for Seqence 10: MDFU End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has an Undetected Leak and Subsequent Failure, no Other APU/HYD Units Fail



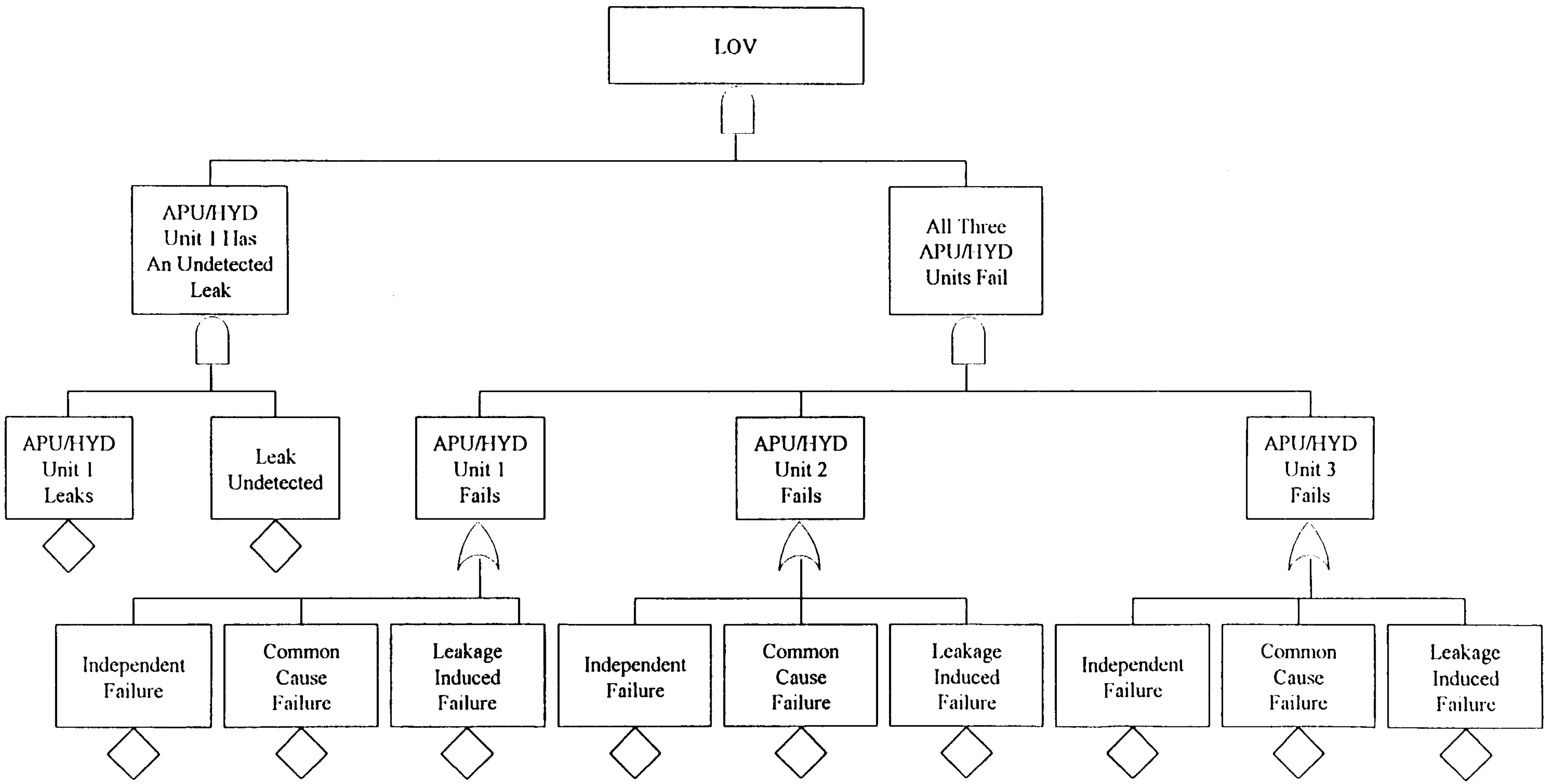
Fault Tree for Sequence 11: PLS2U End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has an Undetected Leak and Subsequent Failure, one Other APU/HYD Unit Also Fails



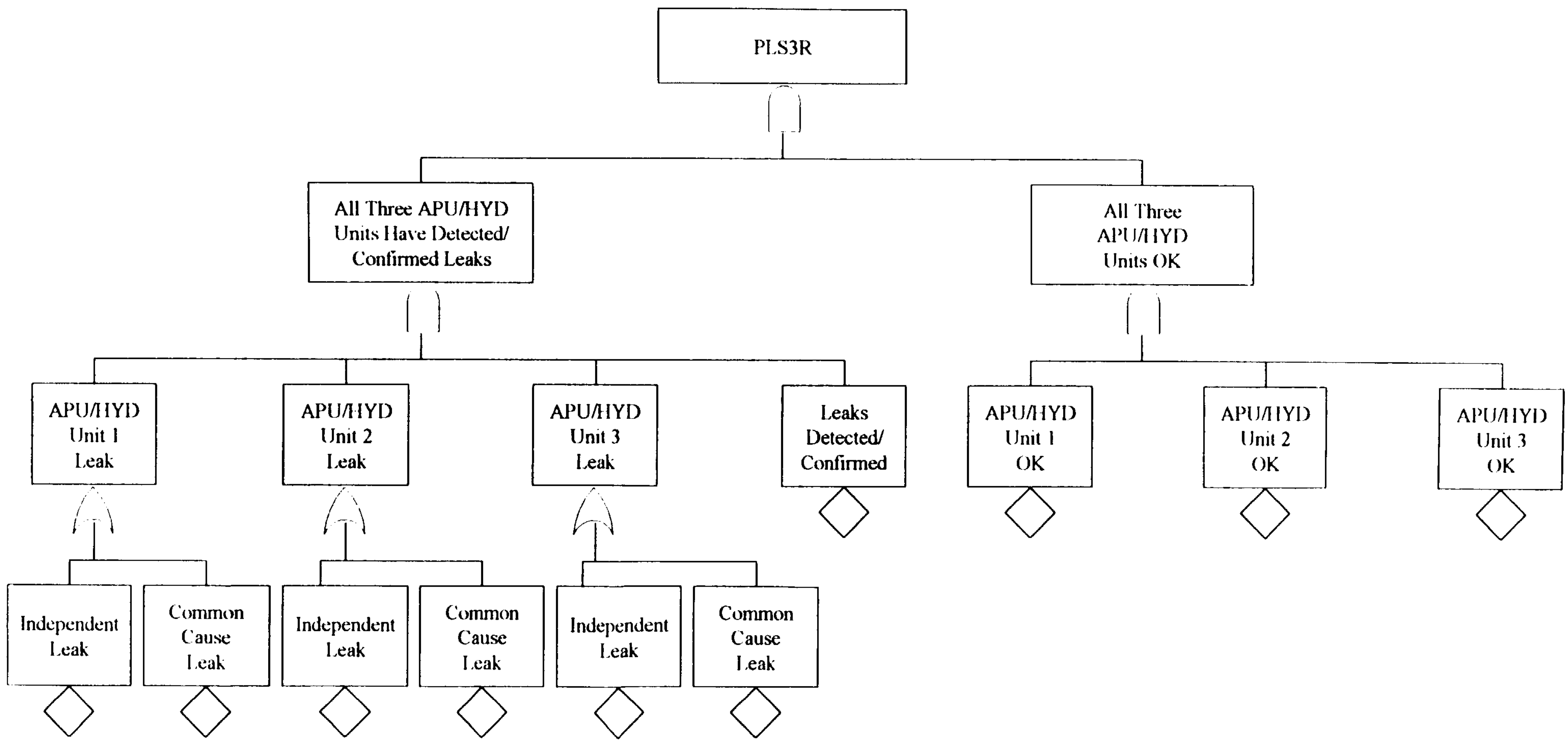
Fault Tree for Sequence 11: PLS2U End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has an Undetected Leak and Subsequent Failure, one Other APU/HYD Unit Also Fails (Continued)



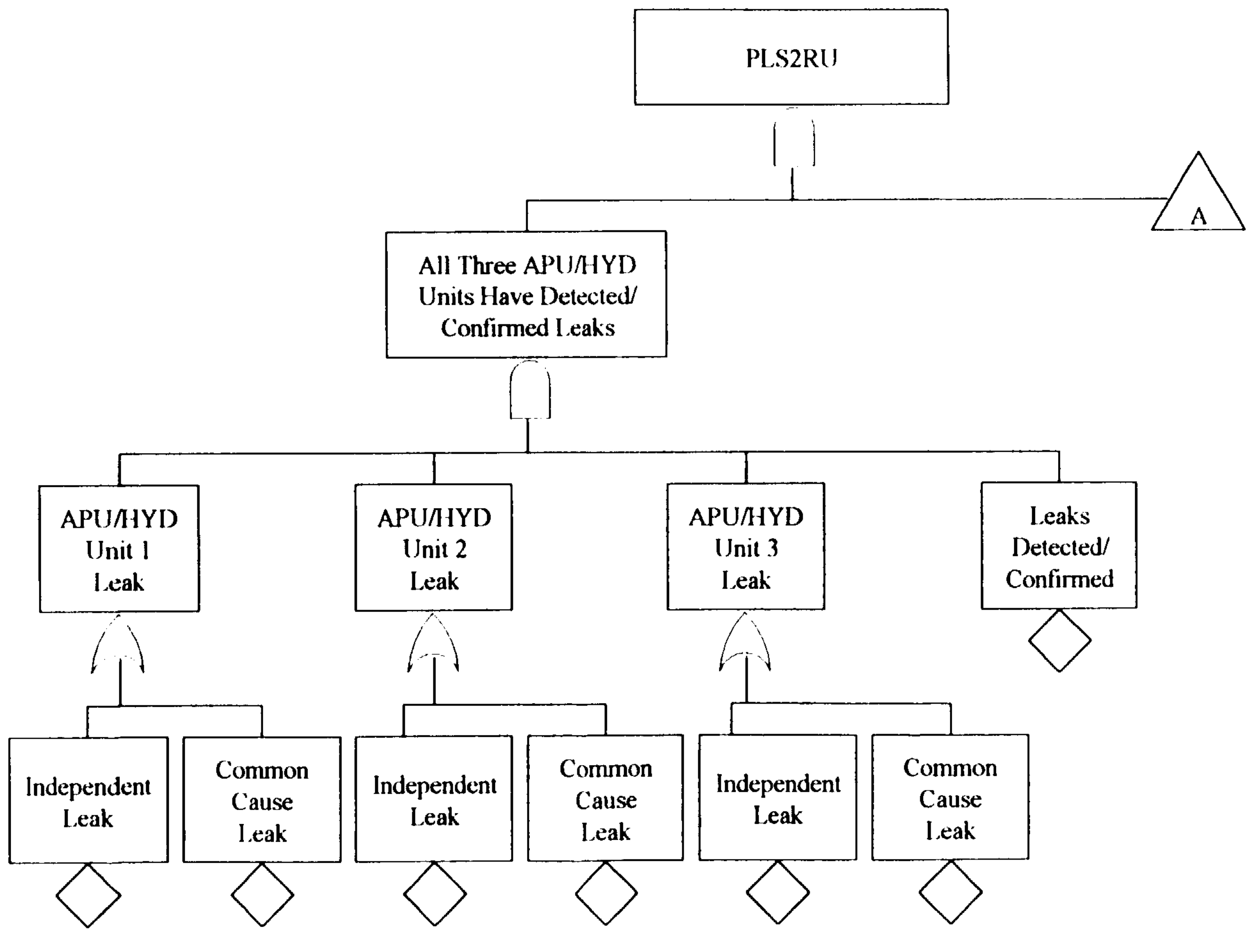
Fault Tree for Sequence 12. LOV End State From a Hydrazine Leak During Ascent, one APU/HYD Unit has an Undetected Leak and all Three APU/HYD Units Fail



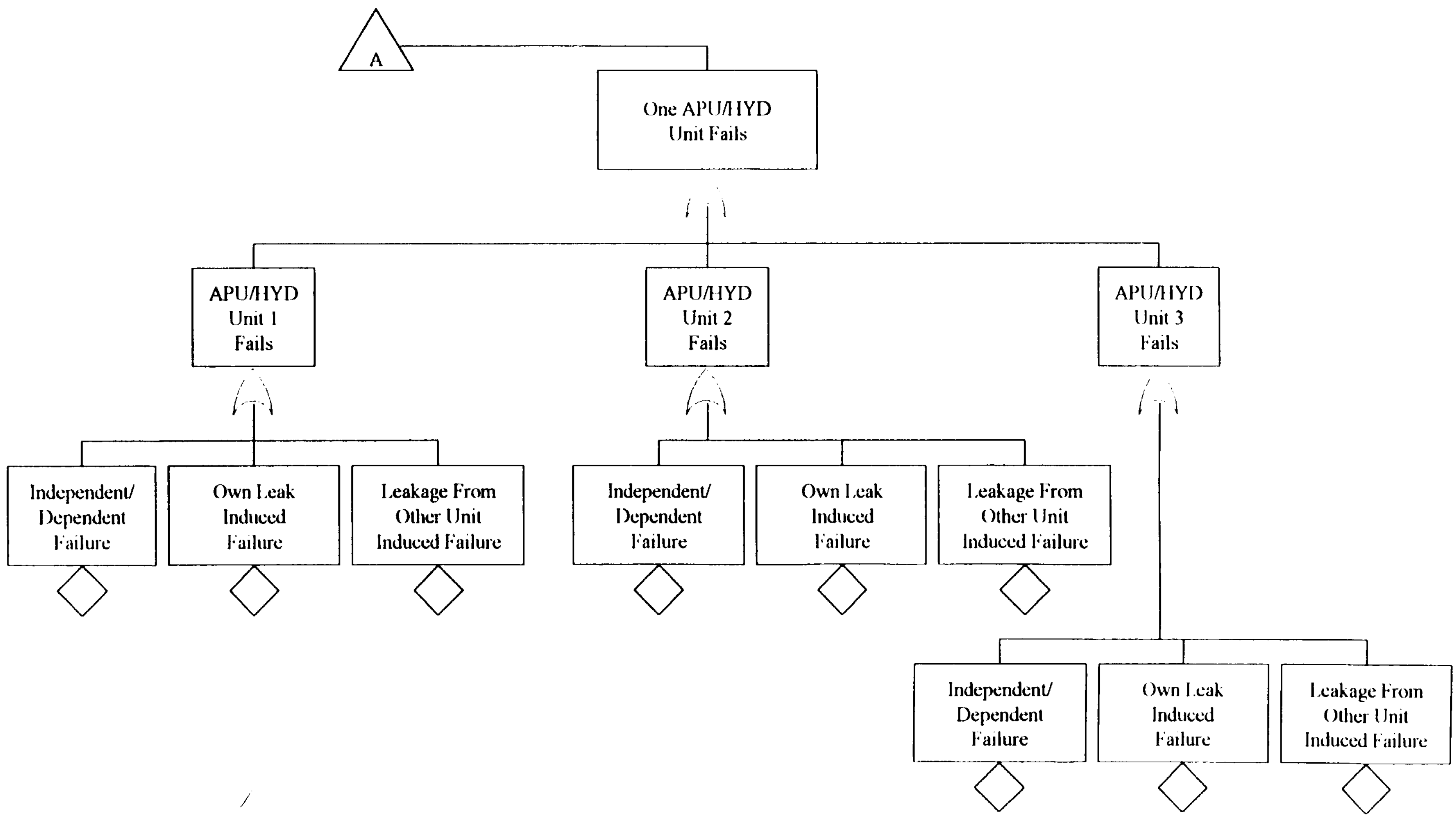
Fault Tree for Sequence 13: PLS3R End State From a Hydrazine Leak During Ascent, all Three APU/HYD Units Have Detected/Confirmed Leaks and no Failures



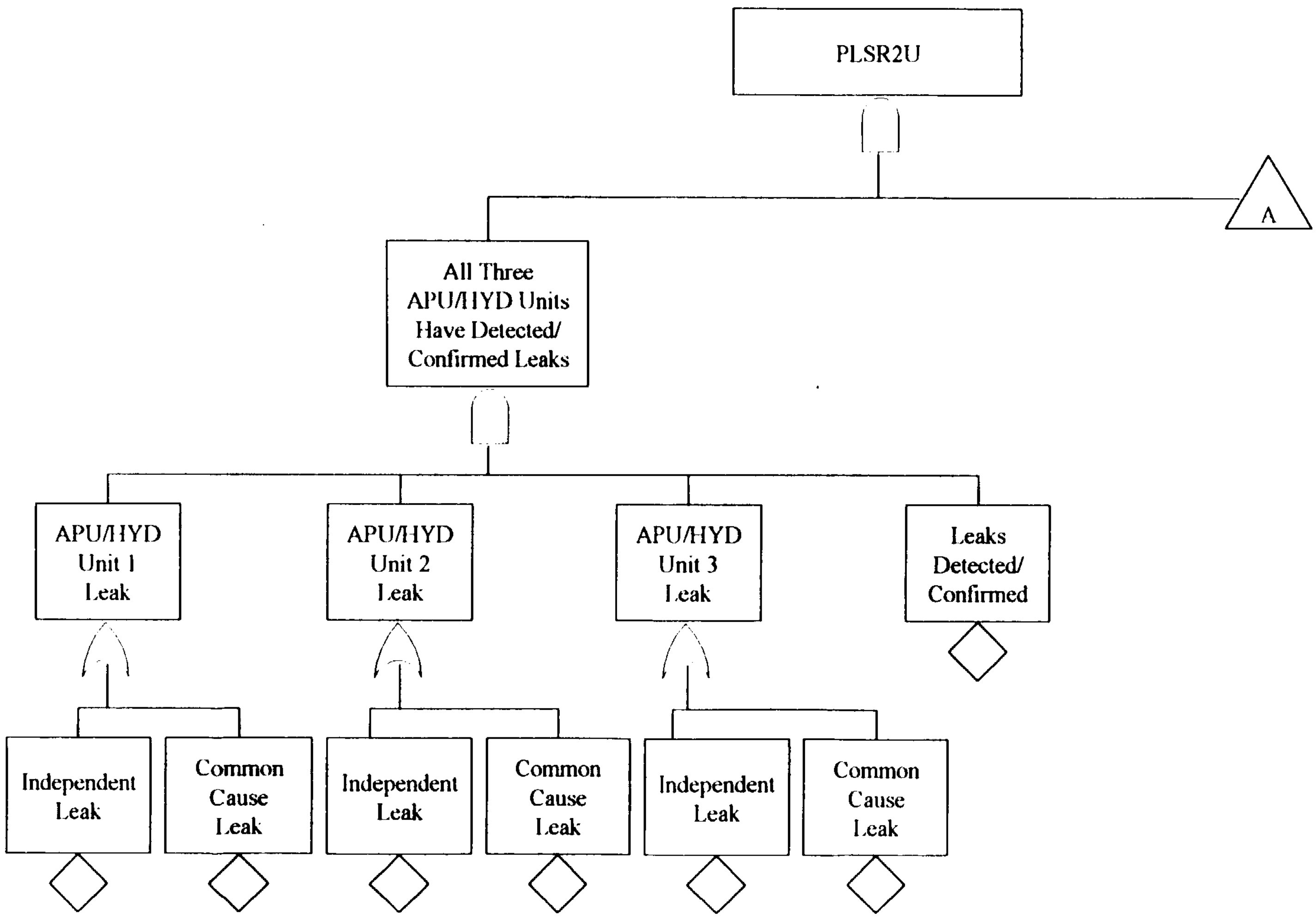
Fault Tree for Sequence 14: PLS2RU End State From a Hydrazine Leak During Ascent, all Three APU/HYD Units Have Detected/Confirmed Leaks and one APU/HYD Unit Fails



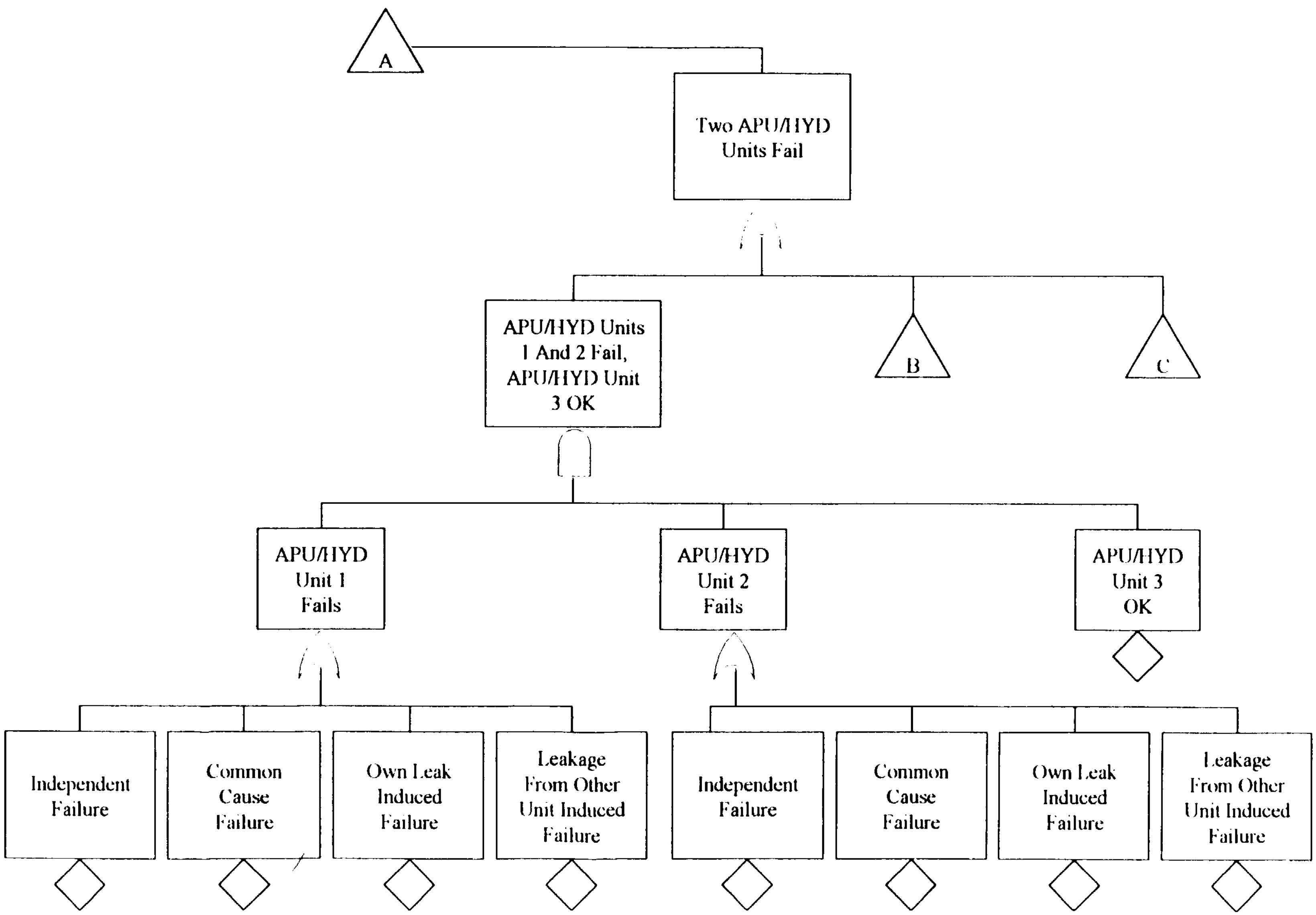
Fault Tree for Sequence 14: PLS2RU End State From a Hydrazine Leak During Ascent, all Three APU/HYD Units Have Detected/Confirmed Leaks and one APU/HYD Unit Fails (Continued)



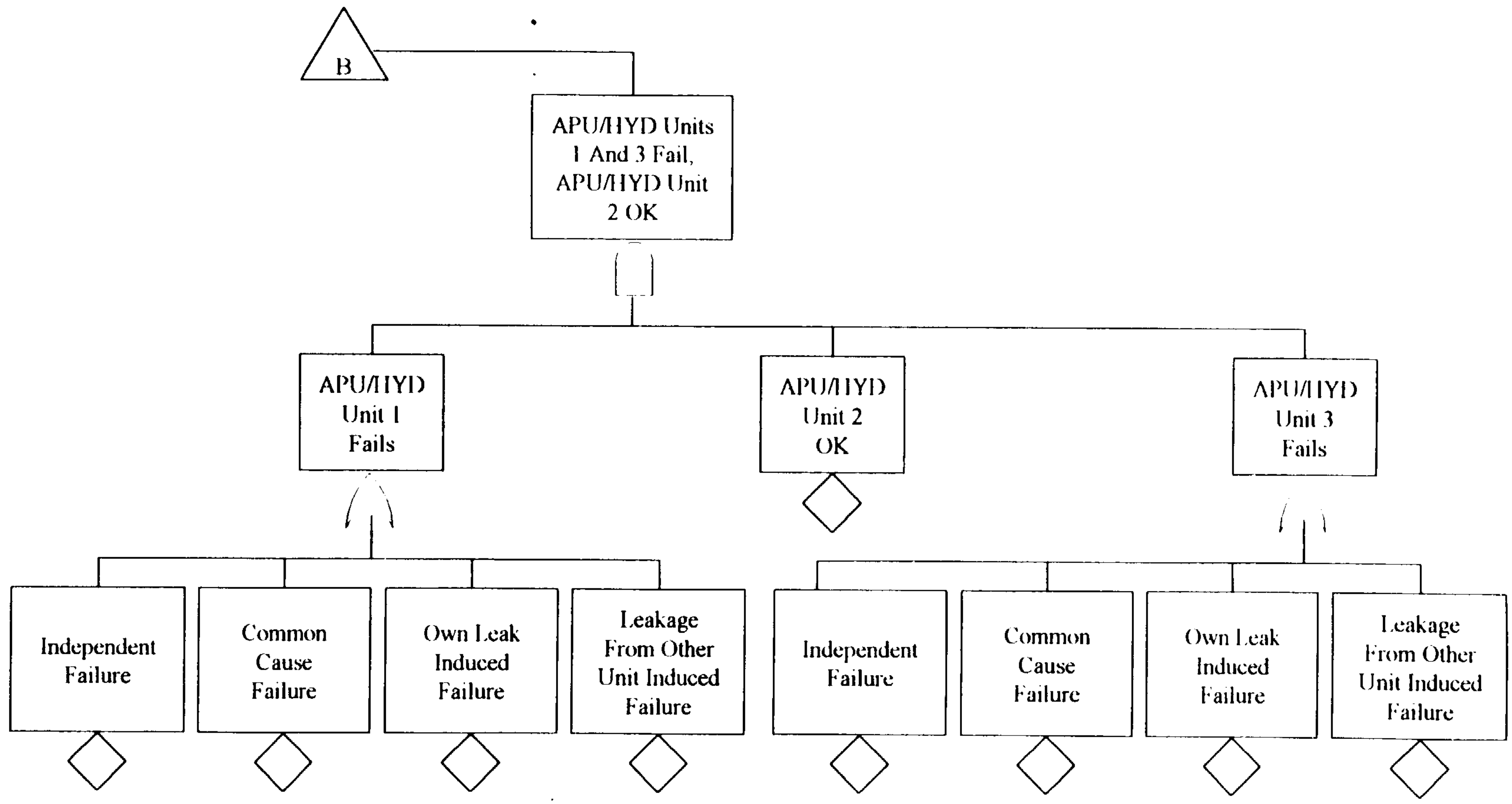
Fault Tree for Sequence 15: PLSR2U End State From Hydrazined Leak During Ascent, all Three APU/HYD Units Have Detected/Confirmed Leaks, two APU/HYD Units Fail



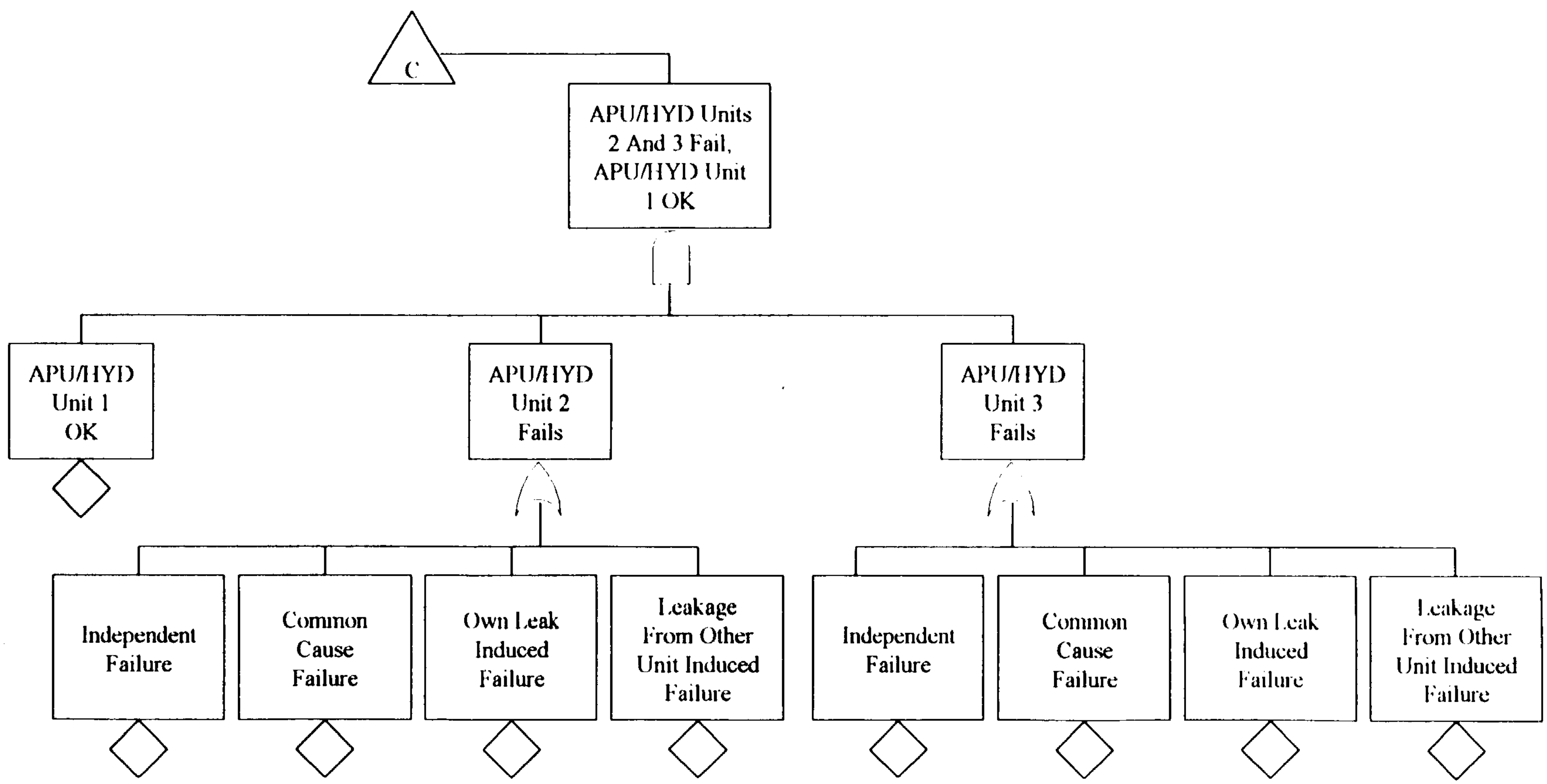
Fault Tree for Sequence 15: PLSR2U End State From Hydrazined Leak During Ascent, all Three APU/HYD Units Have Detected/Confirmed Leaks, two APU/HYD Units Fail (Continued)



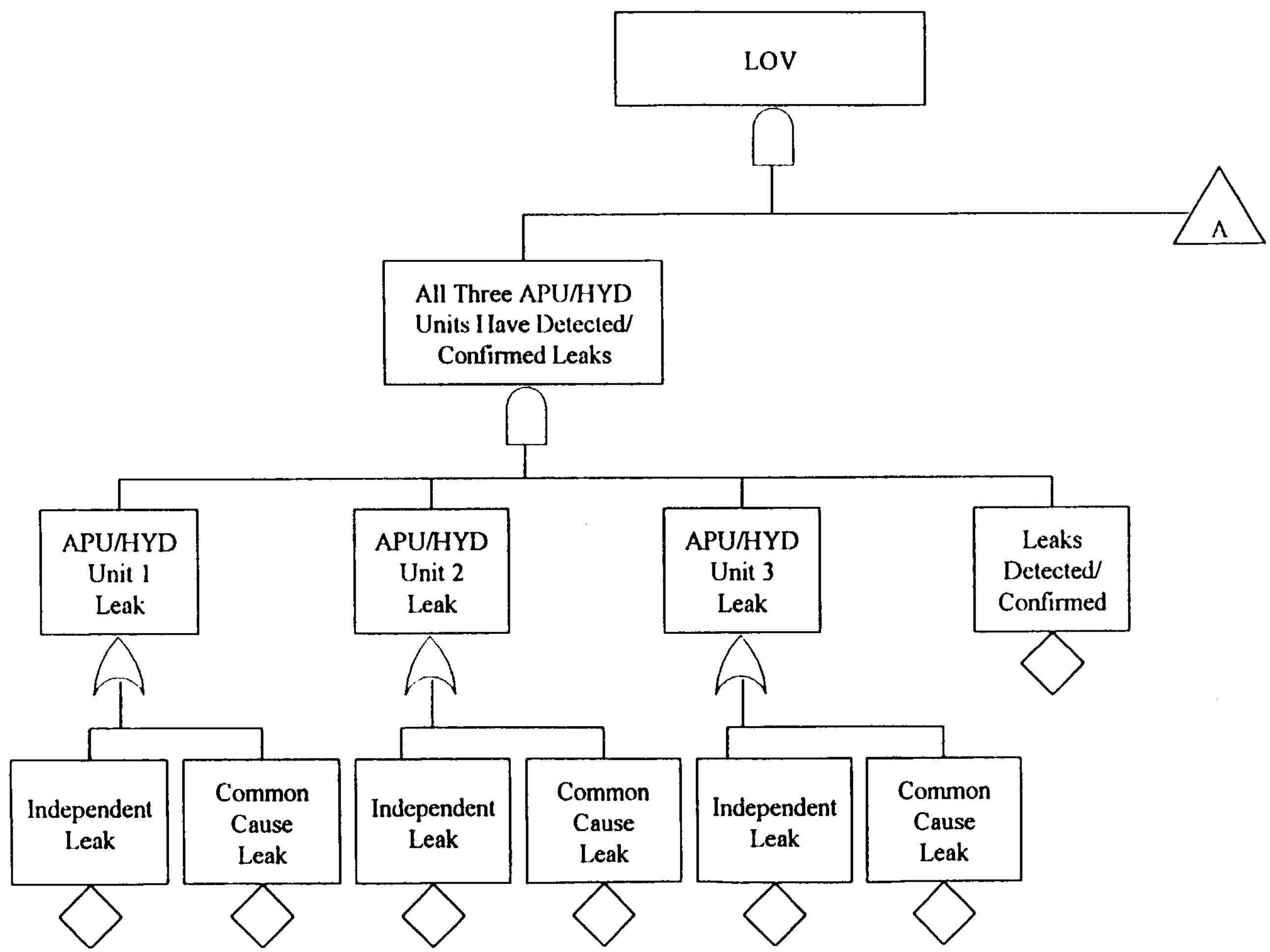
Fault Tree for Sequence 15: PLSR2U End State From Hydrazined Leak During Ascent, all Three APU/HYD Units Have Detected/Confirmed Leaks, two APU/HYD Units Fail (Continued)



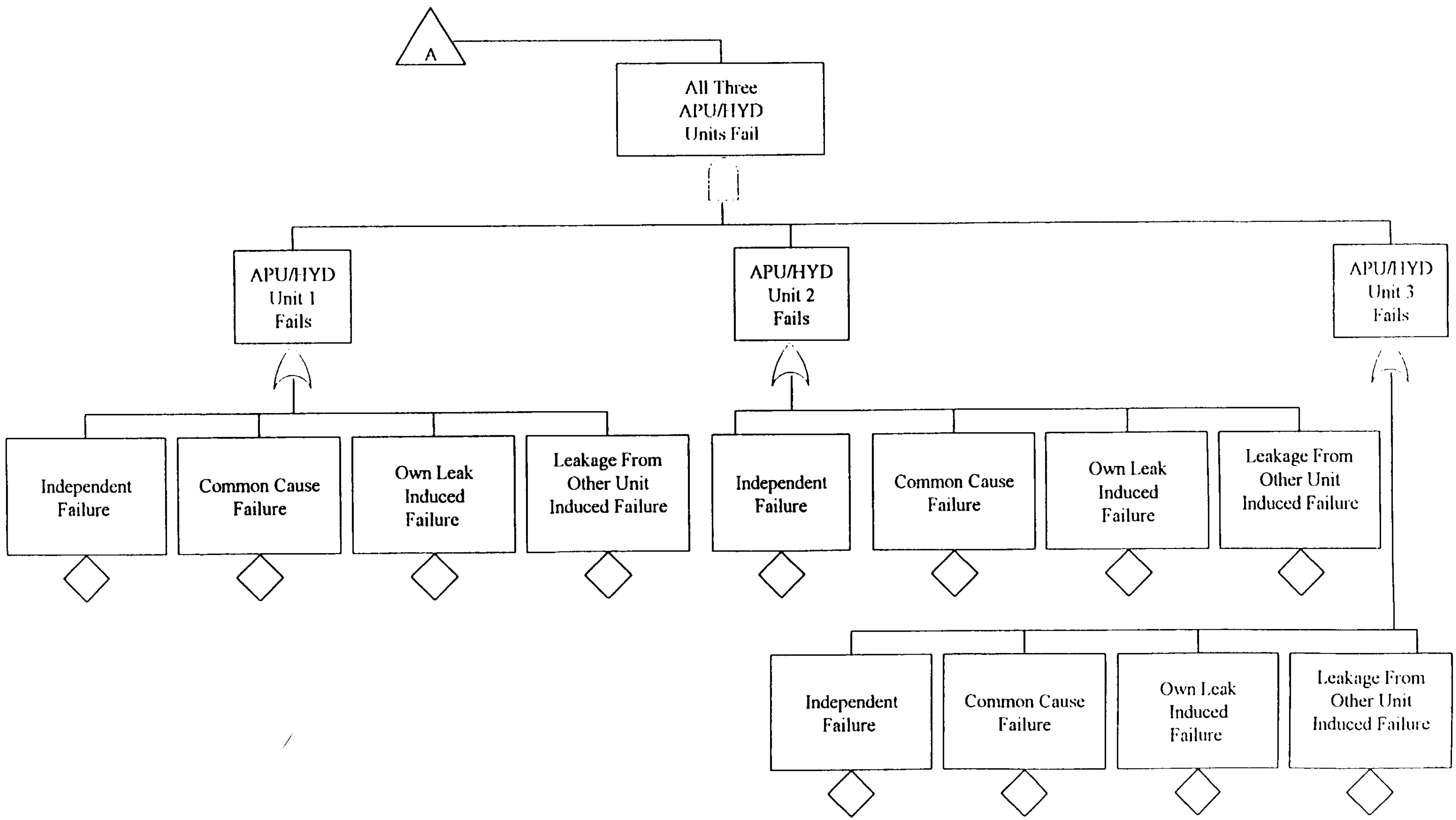
Fault Tree for Sequence 15: PLSR2U End State From Hydrazined Leak During Ascent, all Three APU/HYD Units Have Detected/Confirmed Leaks, two APU/HYD Units Fail (Continued)



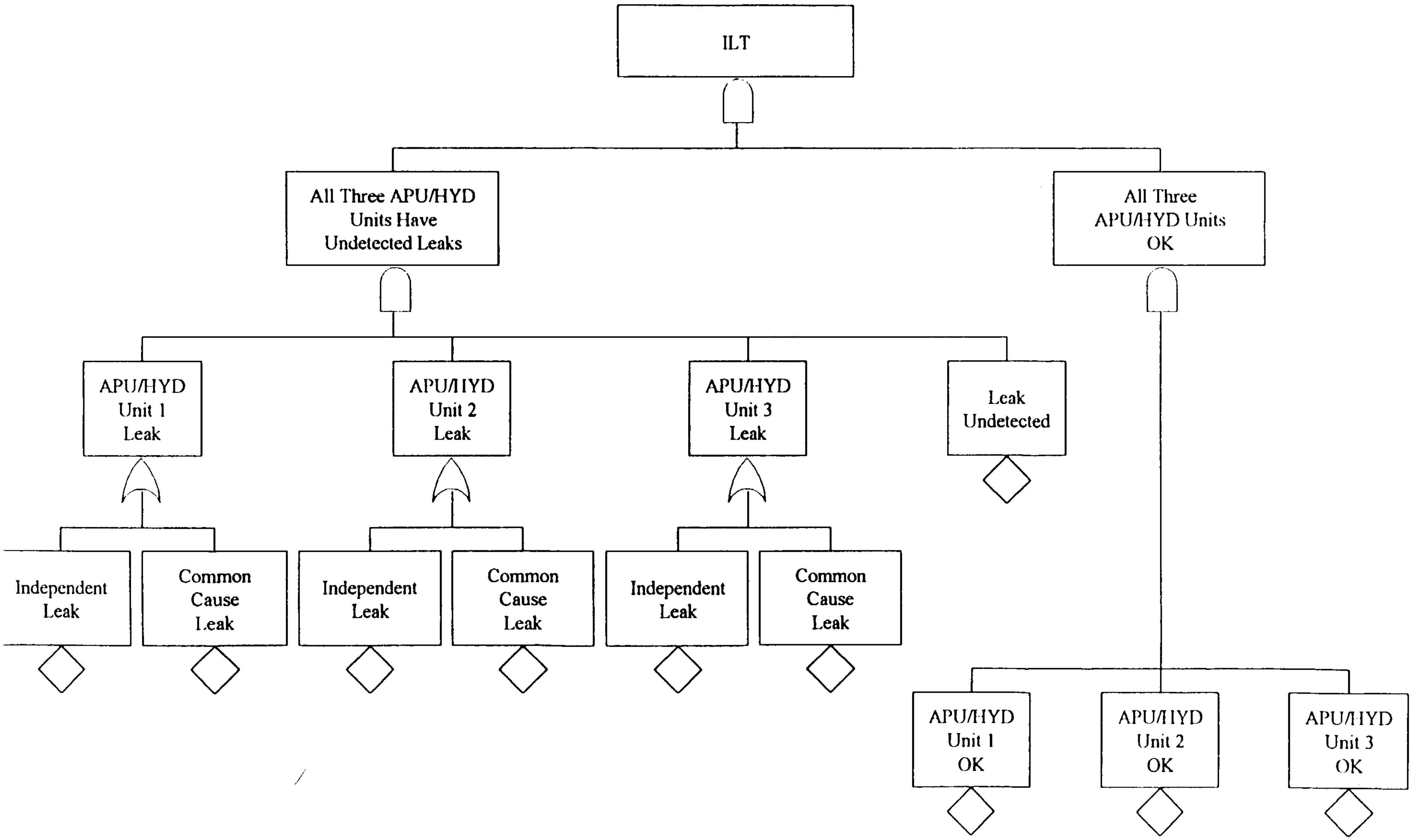
Fault Tree for Sequence 16: LOV End State From Hydrazine Leak During Ascent, all Three APU/HYD Units Have Detected/ Confirmed Leaks and all Three APU/HYD Units Fail



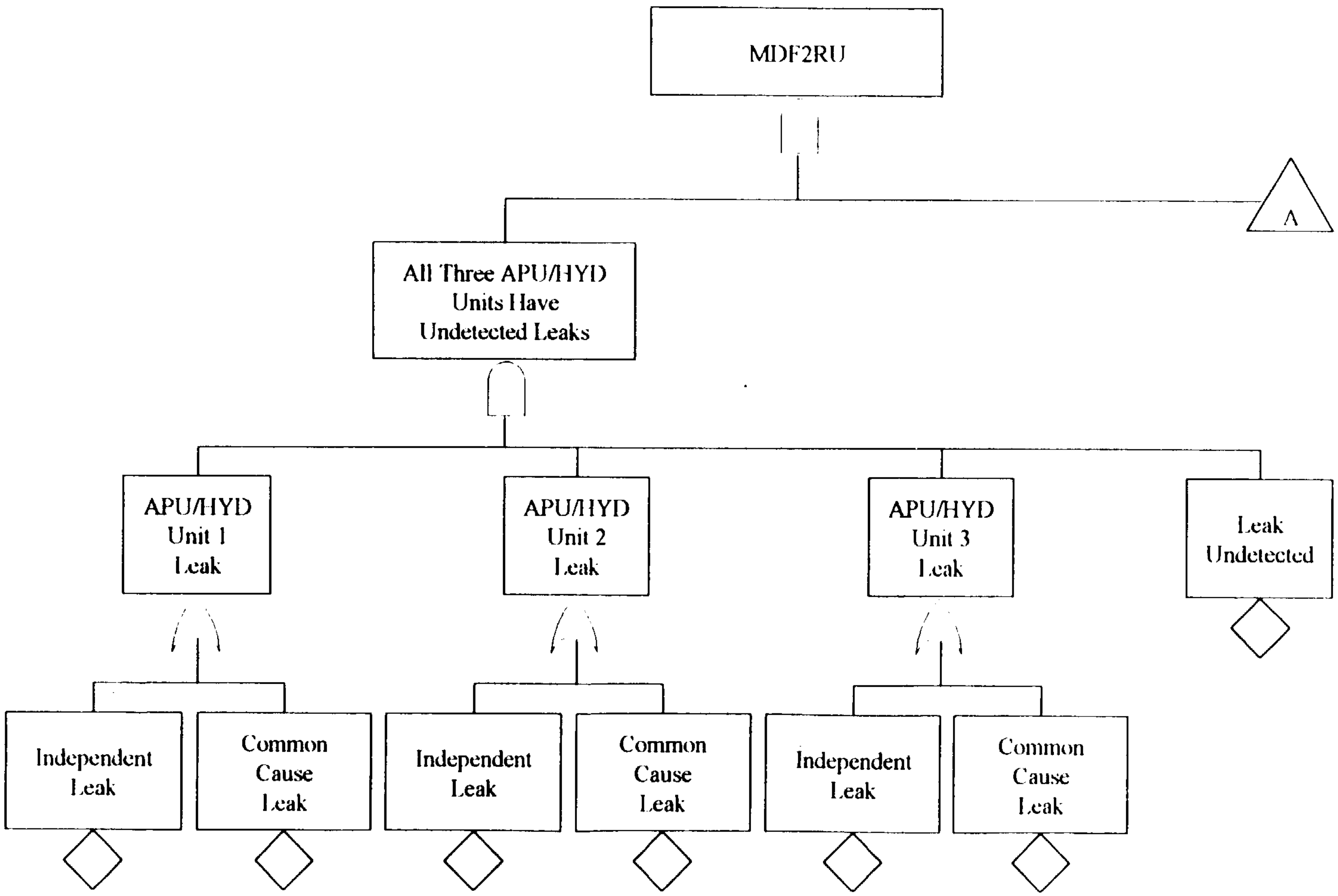
Fault Tree for Sequence 16: LOV End State From Hydrazine Leak During Ascent, all Three APU/HYD Units Have Detected/ Confirmed Leaks and all Three APU/HYD Units Fail (Continued)



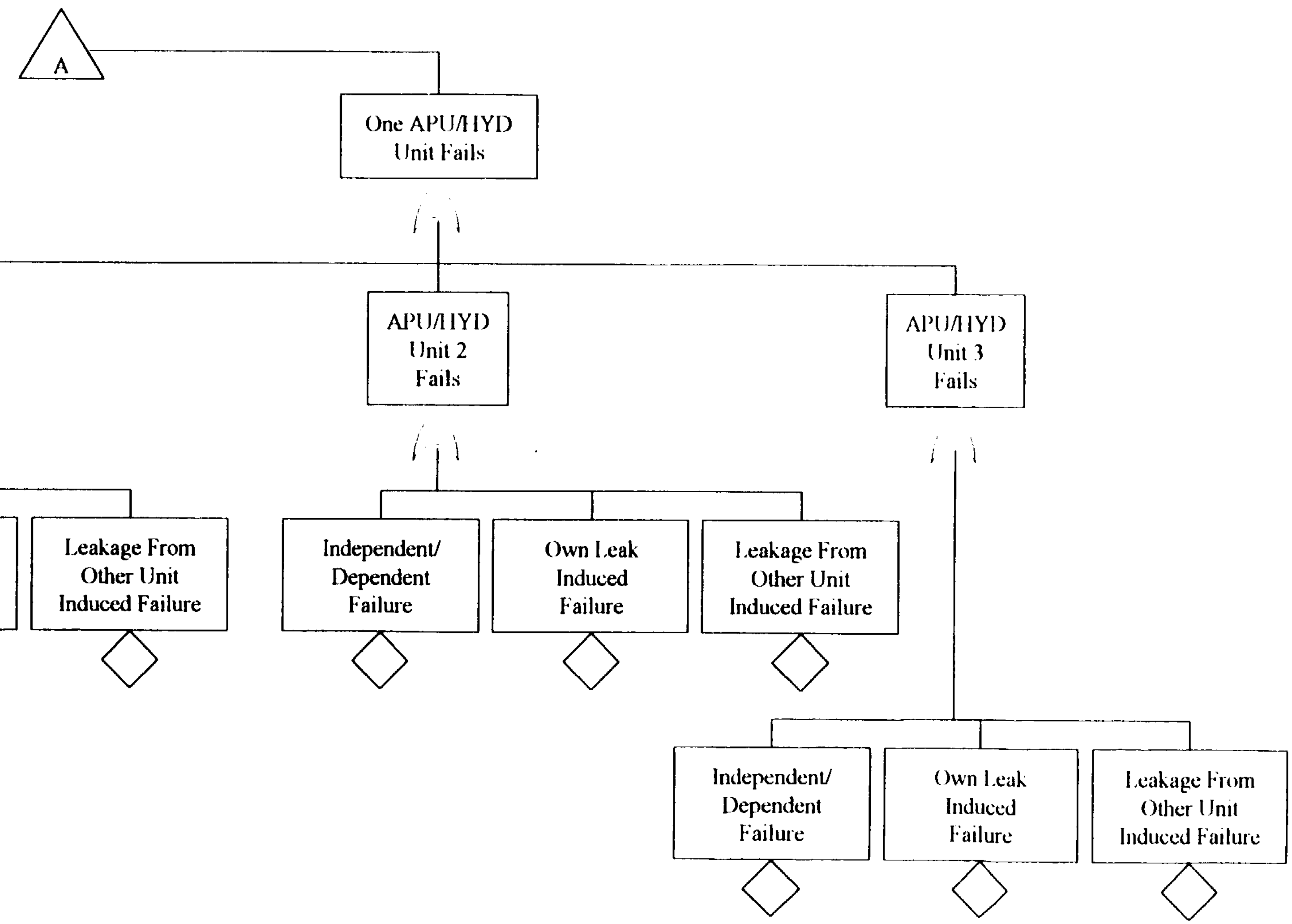
Fault Tree for Sequence 17: ILT End State From a Hydrazine Leak During Ascent, all Three APU/HYD Units Have Undetected Leaks and no Failures



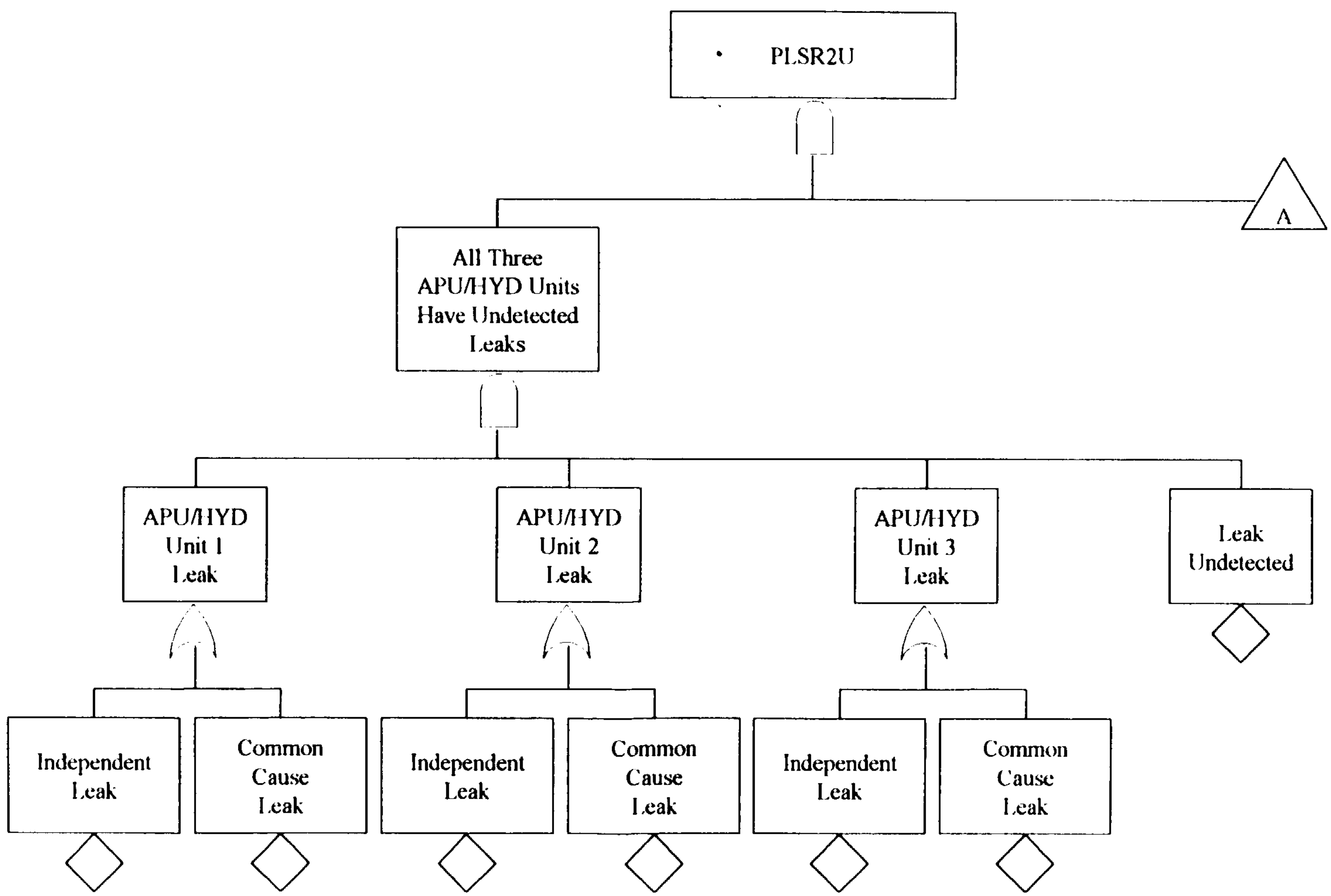
Fault Tree for Sequence 18: MDF2RU End State From a Hydrazine Leak During Ascent, one APU/HYD Unit Fails



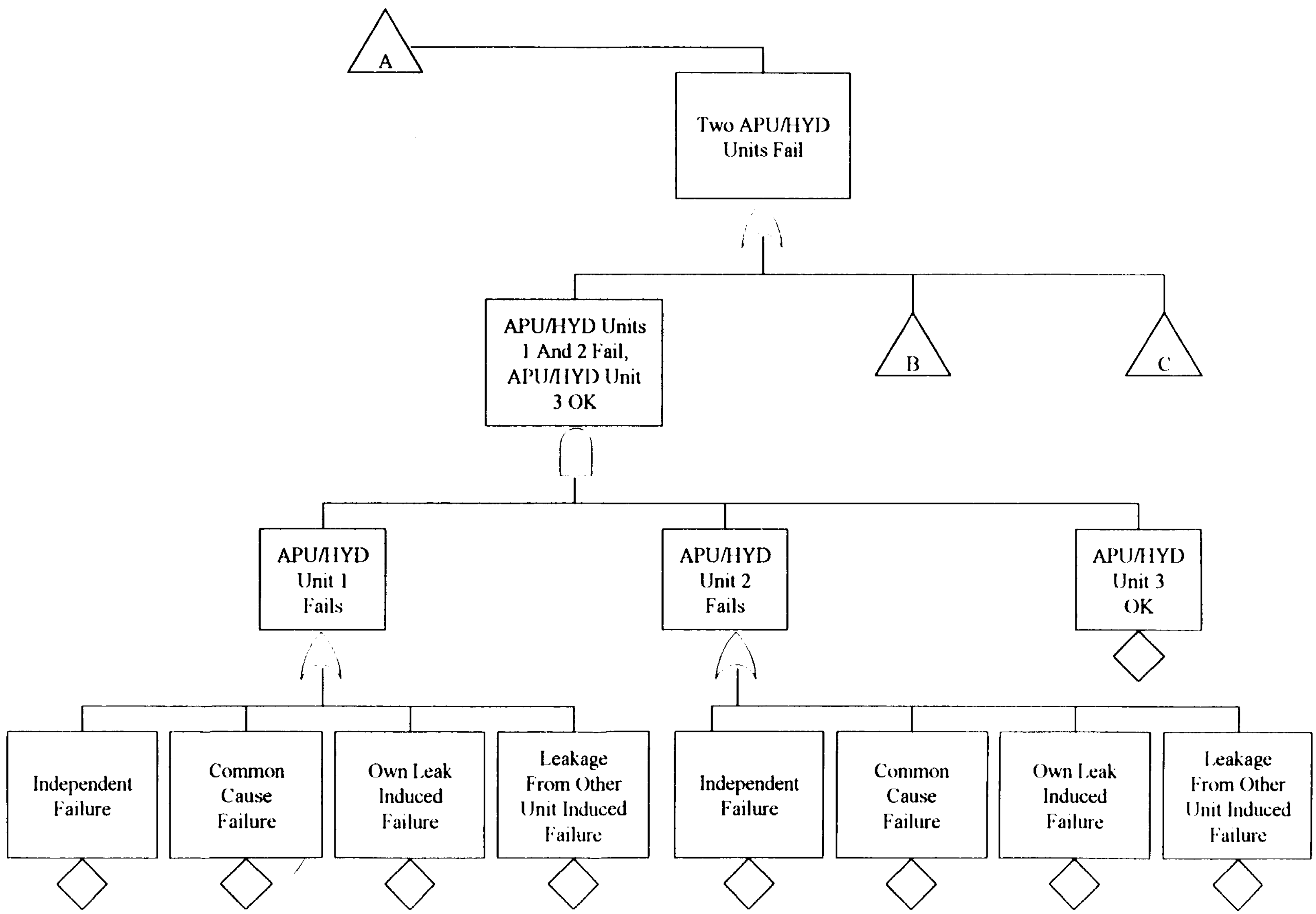
Fault Tree for Sequence 18: MDF2RU End State From a Hydrazine Leak During Ascent, one APU/HYD Unit Fails (Continued)



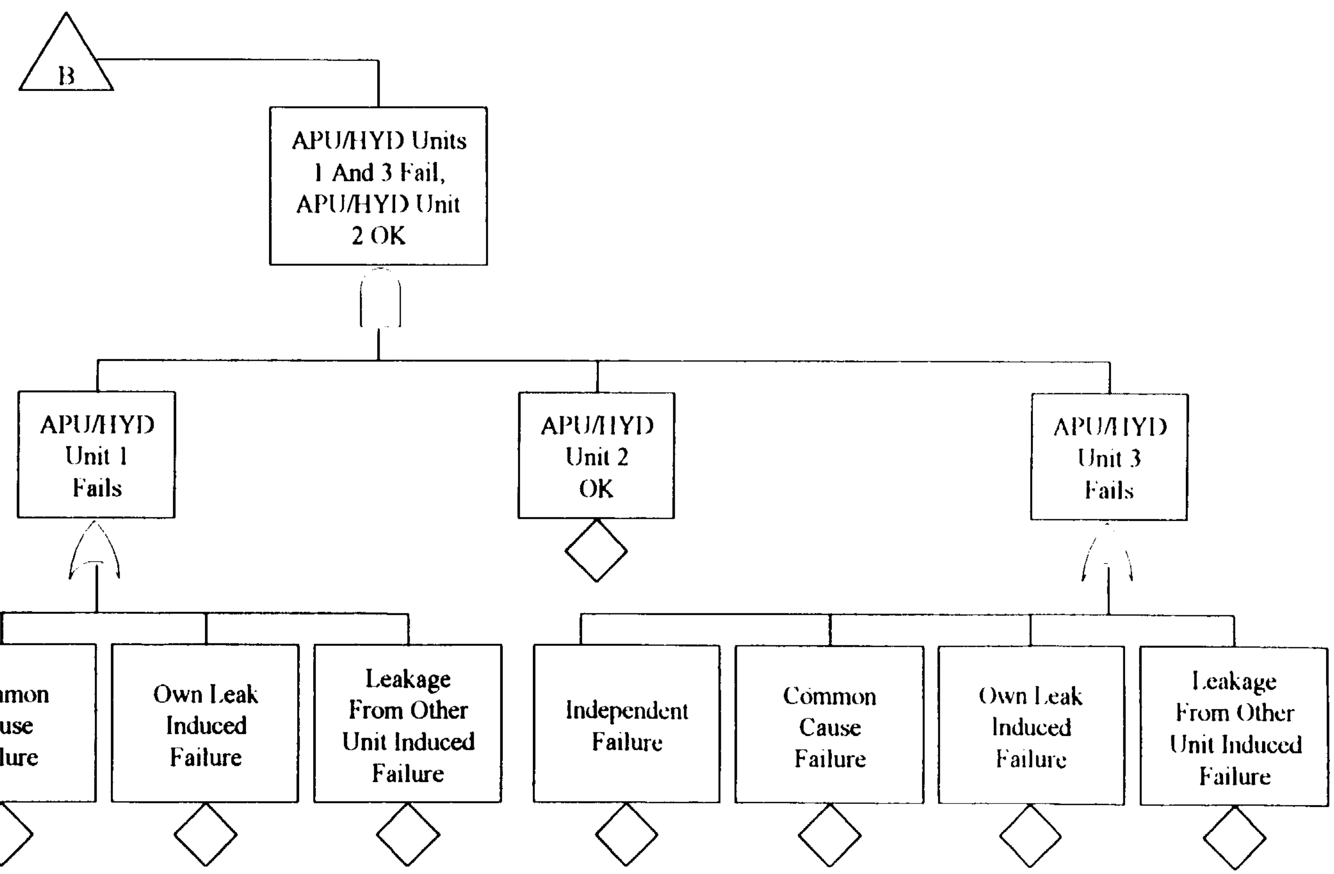
Fault Tree for Sequence 19: PLSR2U End State From a Hydrazine Leak During Ascent, all Three APU/HYD Units Have Undetected Leaks, two APU/HYD Units Fail



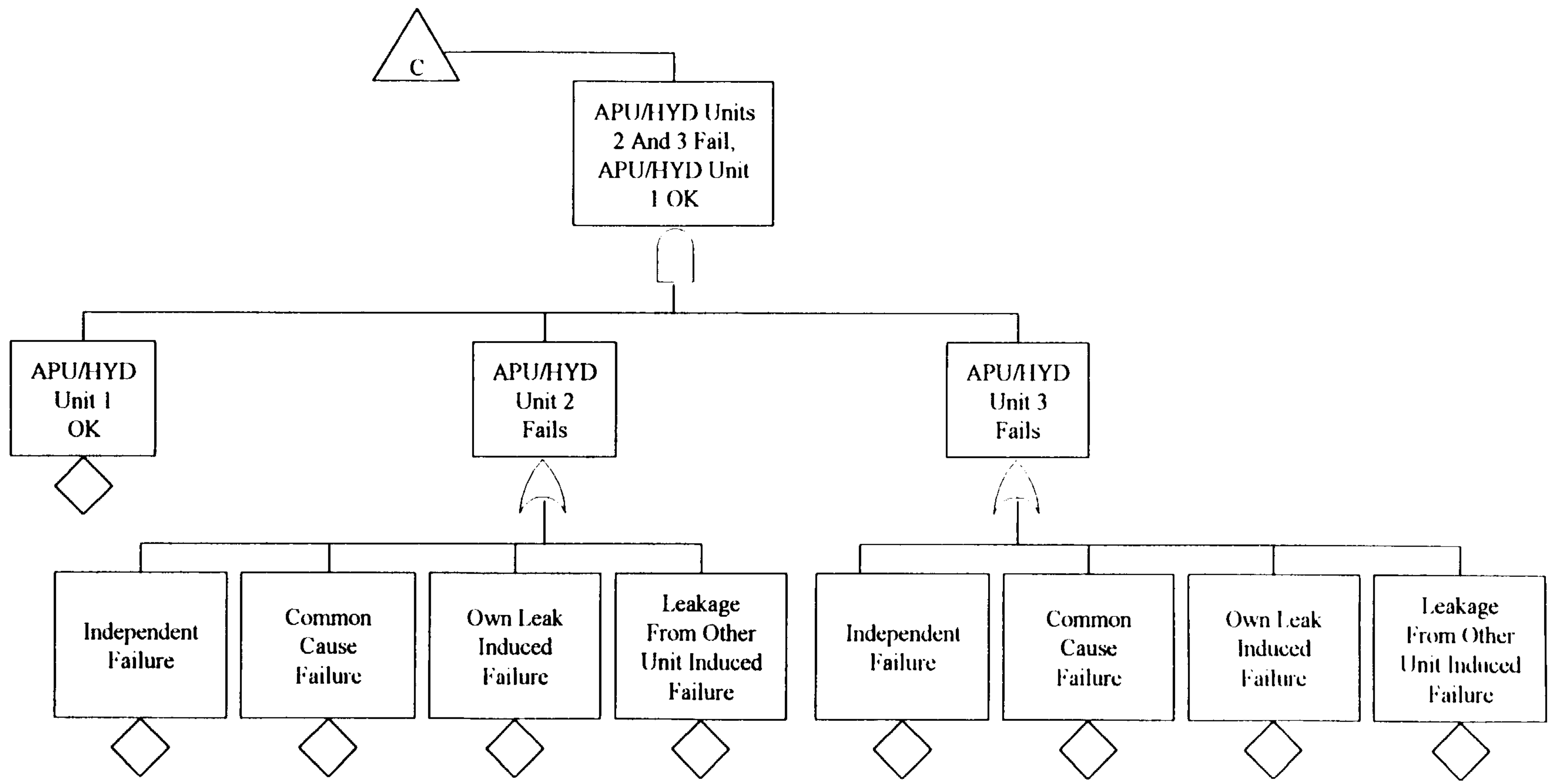
Fault Tree for Sequence 19: PLSR2U End State From a Hydrazine Leak During Ascent, all Three APU/HYD Units Have Undetected Leaks, two APU/HYD Units Fail (Continued)



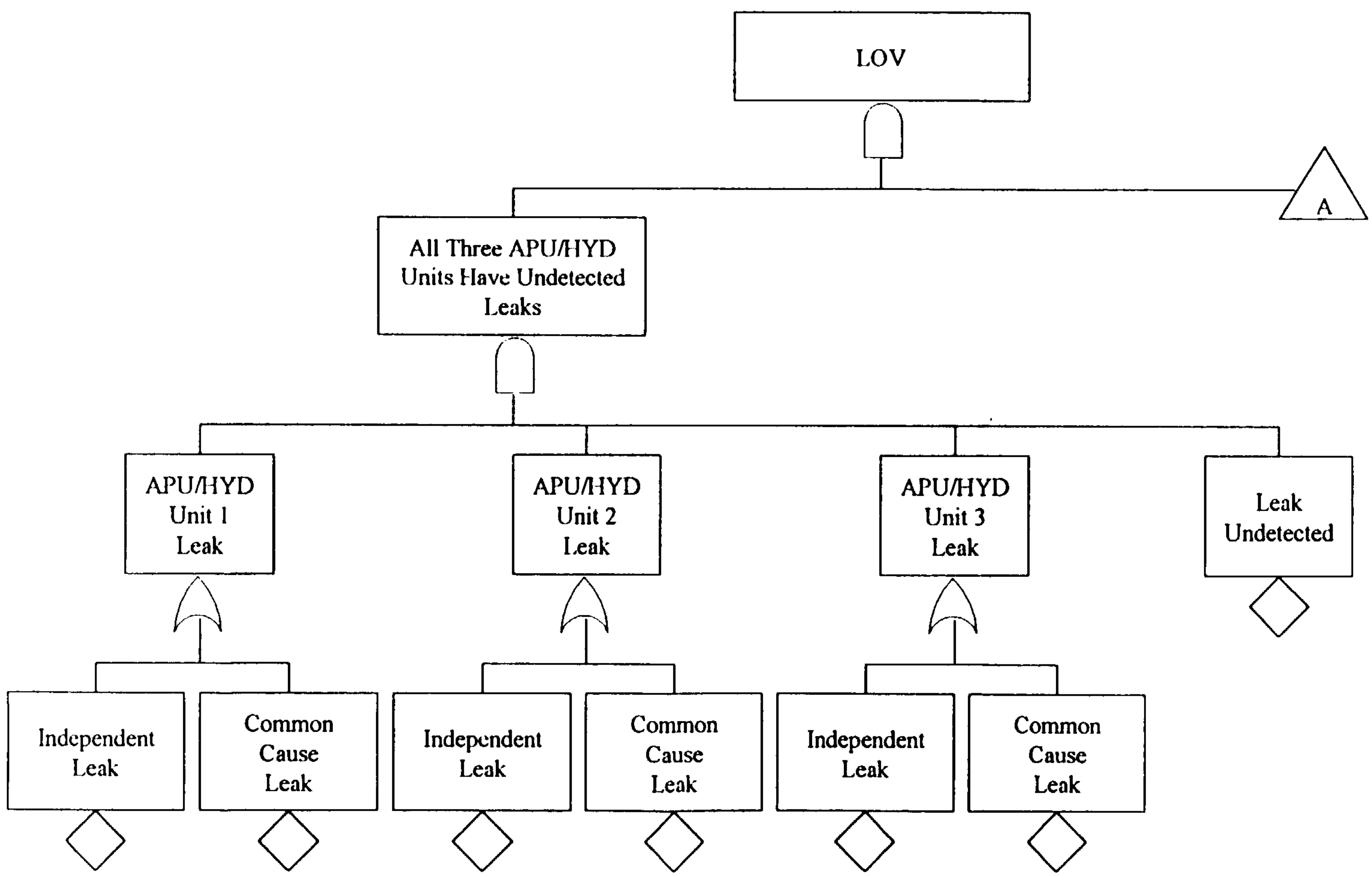
Fault Tree for Sequence 19: PLSR2U End State From a Hydrazine Leak During Ascent, all Three APU/HYD Units Have Undetected Leaks, two APU/HYD Units Fail (Continued)



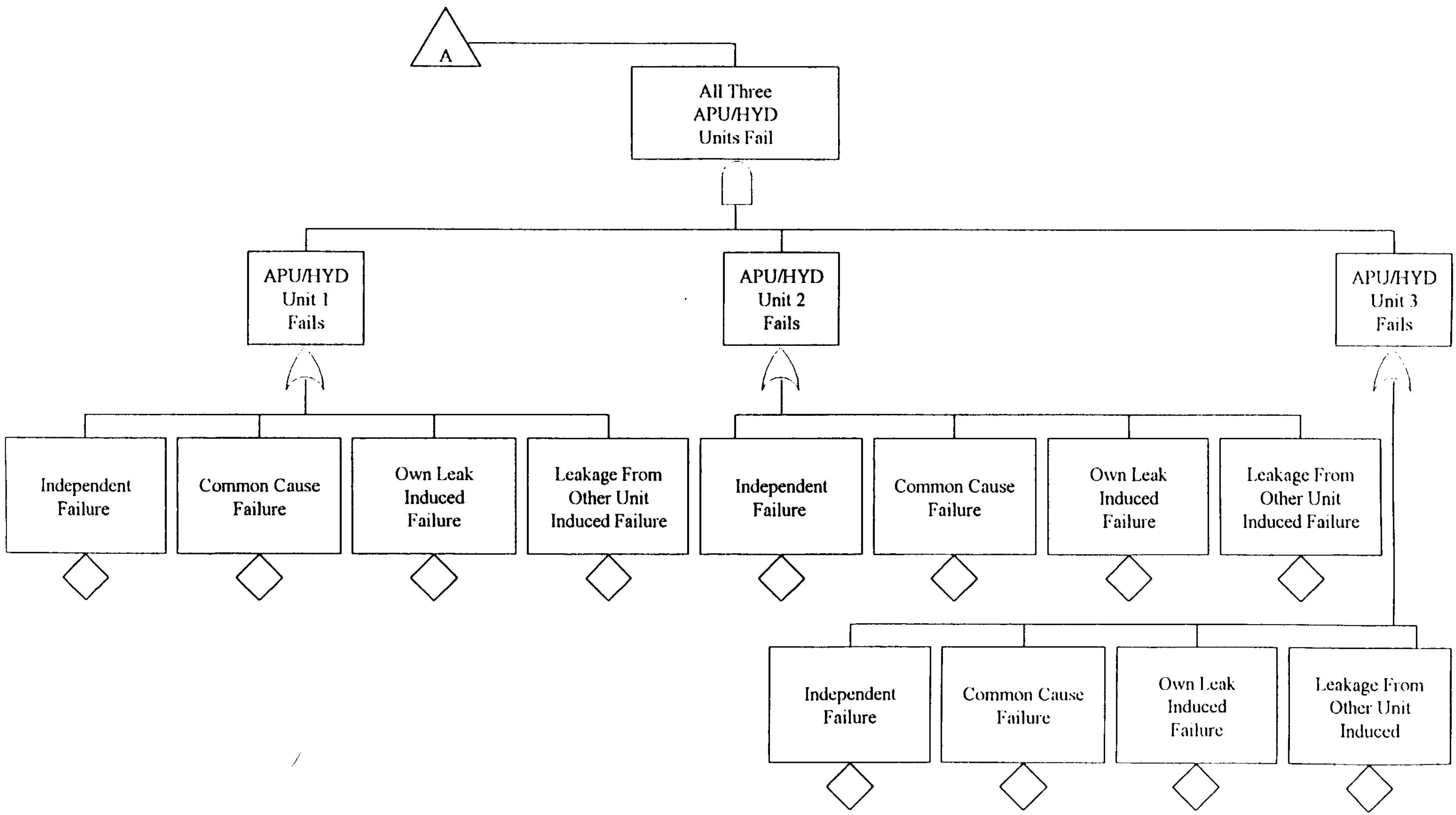
Fault Tree for Sequence 19: PLSR2U End State From a Hydrazine Leak During Ascent, all Three APU/HYD Units Have Undetected Leaks, two APU/HYD Units Fail (Continued)



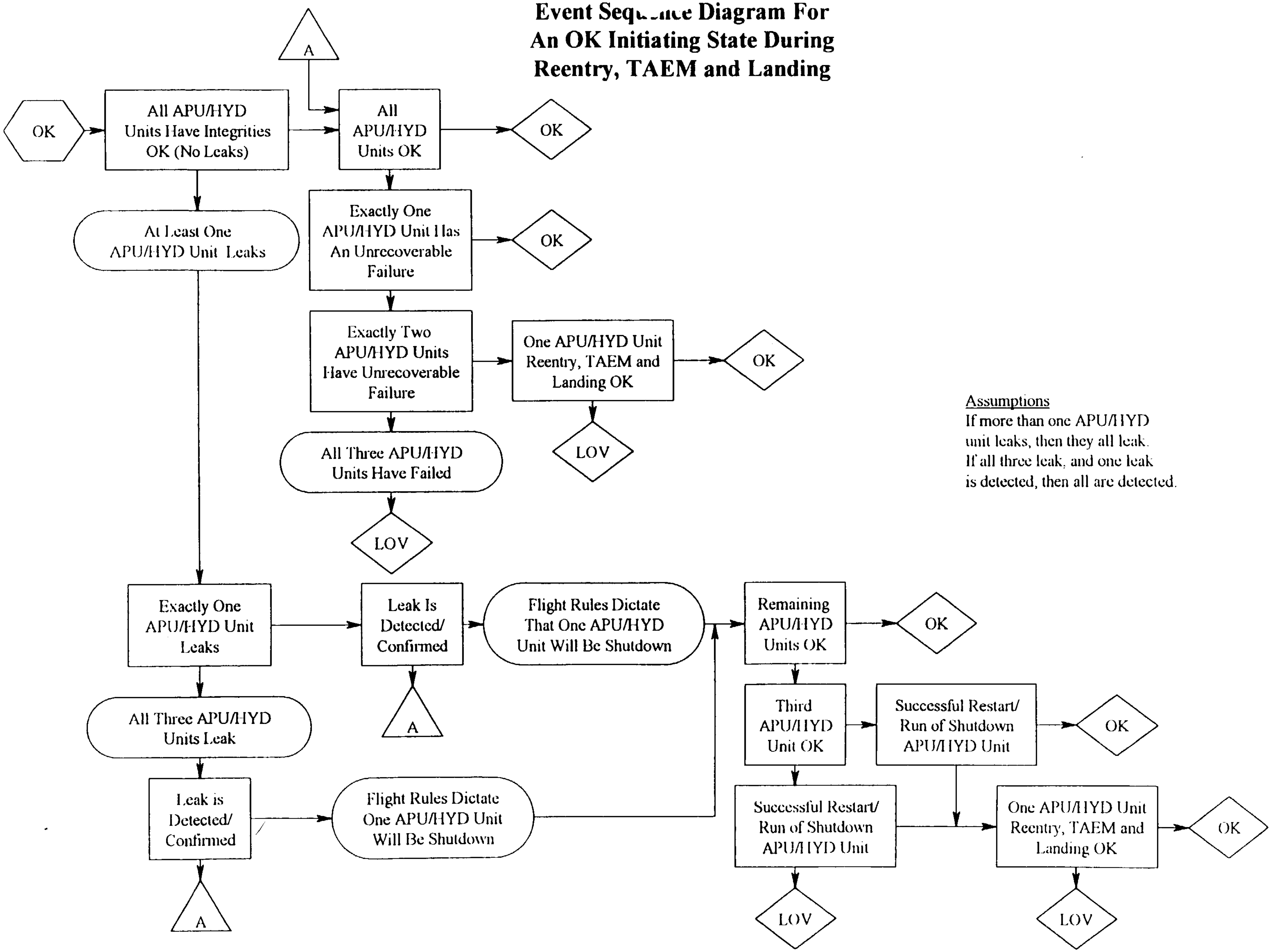
Fault Tree for Sequence 20: LOV End State From a Hydrazine Leak During Ascent, all Three APU/HYD Units Fail



Fault Tree for Sequence 20: LOV End State From a Hydrazine Leak During Ascent, all Three APU/HYD Units Fail (Continued)

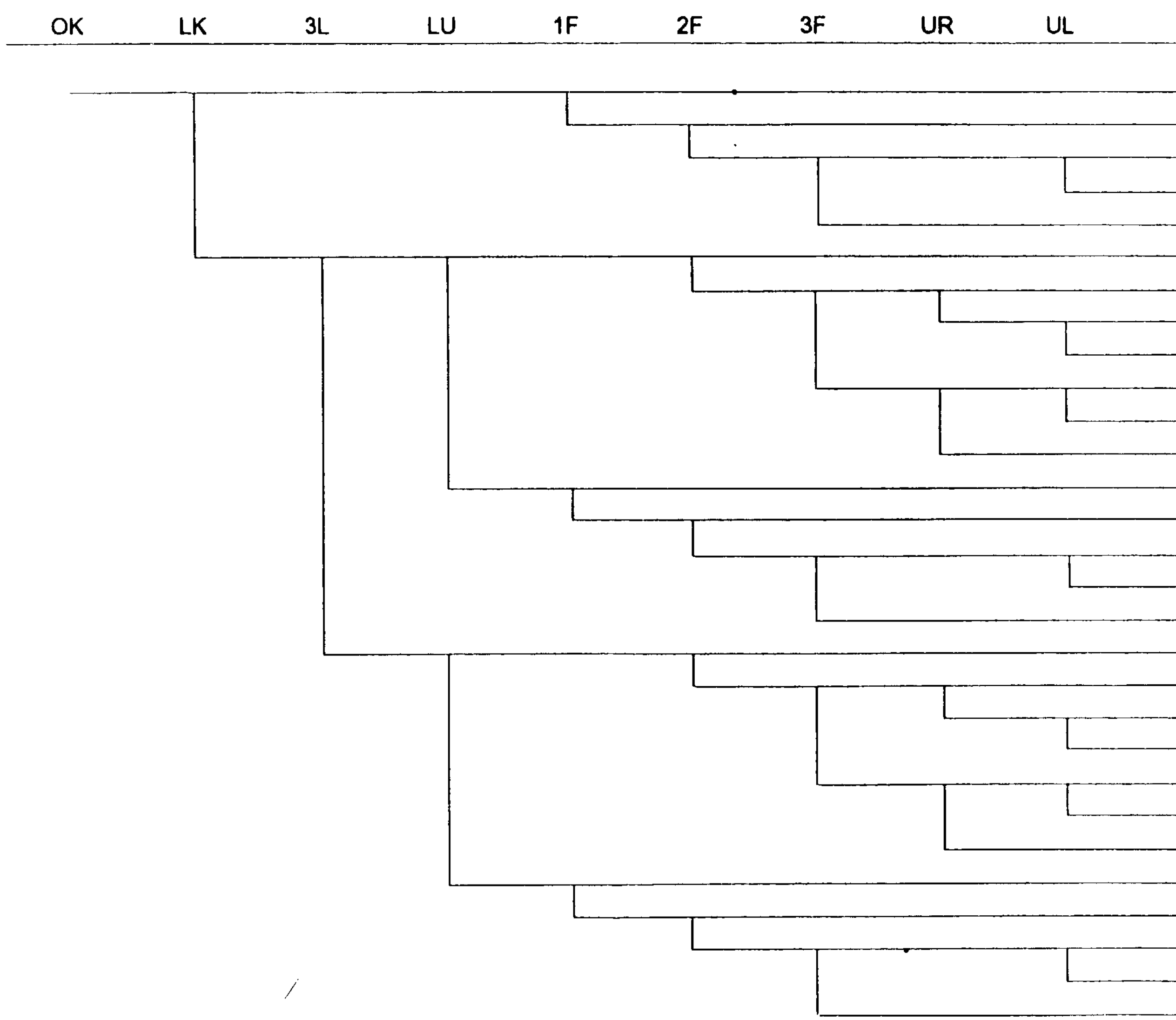


Event Sequence Diagram For An OK Initiating State During Reentry, TAEM and Landing



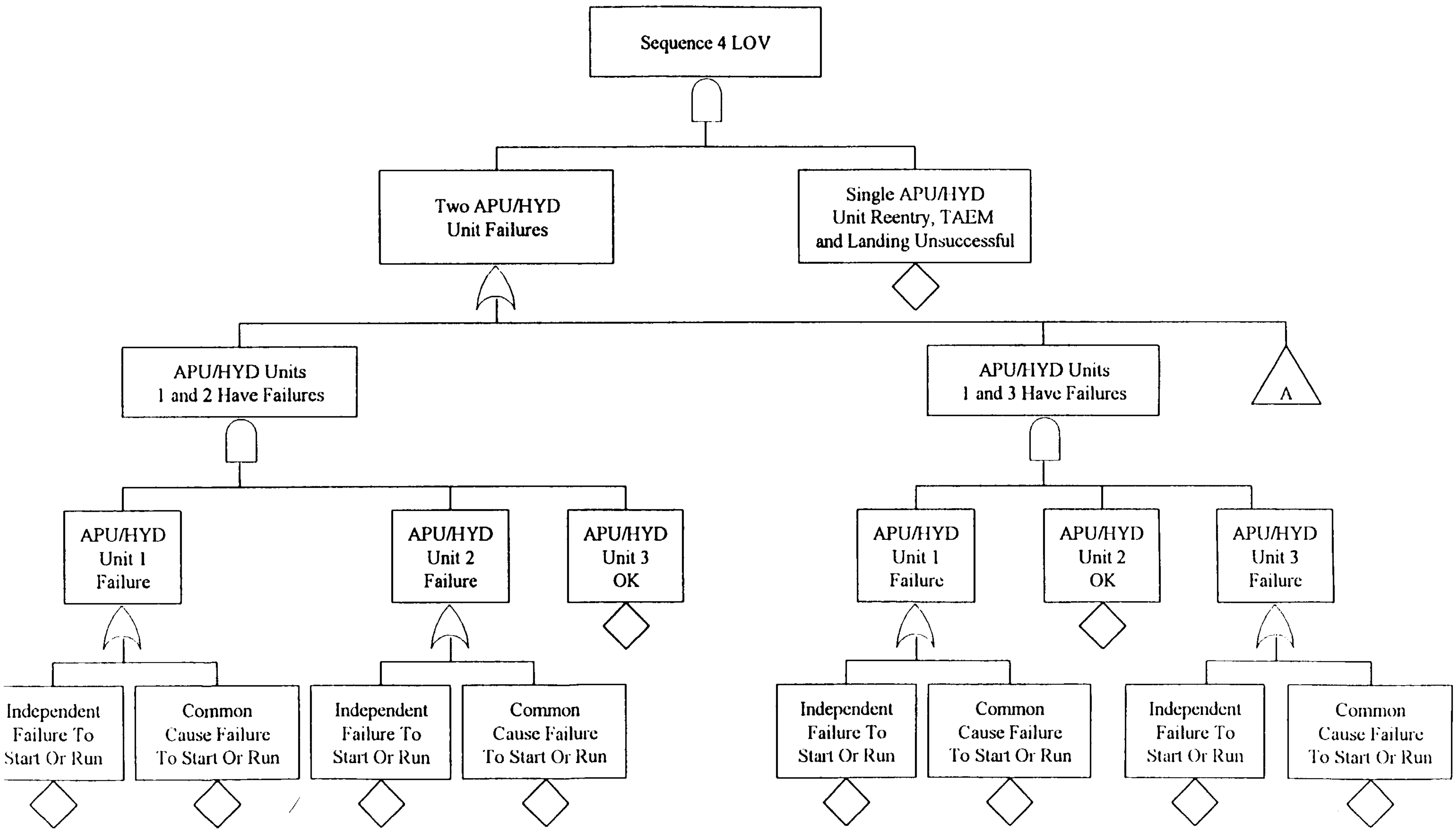
Assumptions
If more than one APU/HYD unit leaks, then they all leak.
If all three leak, and one leak is detected, then all are detected.

EVENT TREE OF OK STATE DURING REENTRY, TAEM AND LANDING

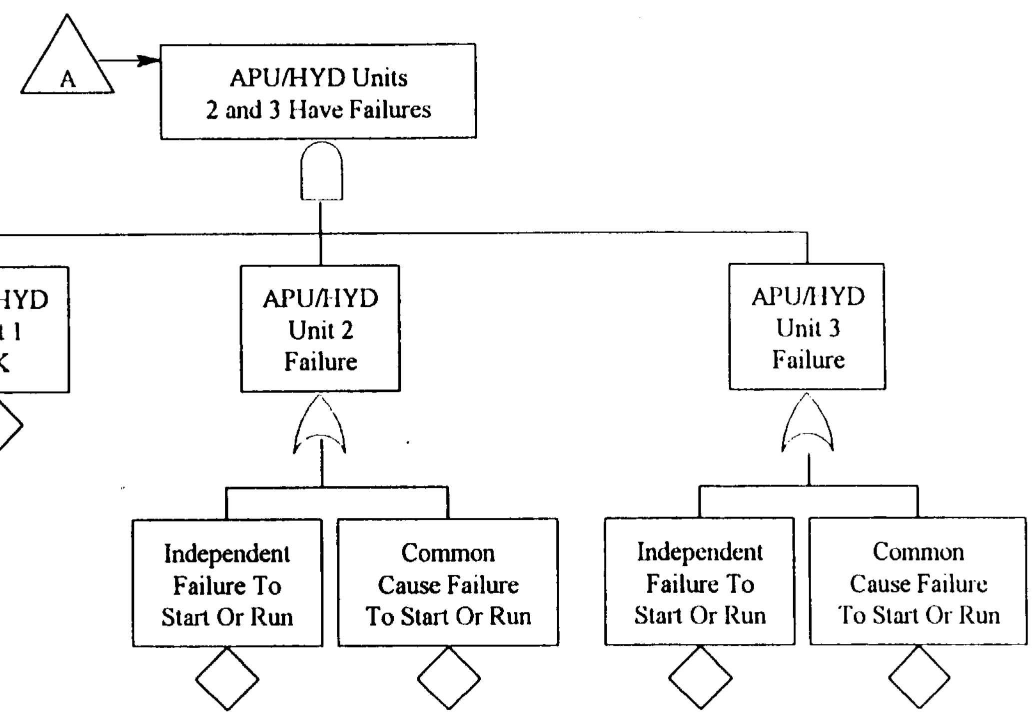


SEQUENCE NUMBER	SEQUENCE DESCRIPTION	STATE
1	OK	OK
2	1F	OK
3	1F2F	OK
4	1F2FUL	LOV
5	1F2F3F	LOV
6	LK	OK
7	LK2F	OK
8	LK2FUR	OK
9	LK2FURUL	LOV
10	LK2F3F	OK
11	LK2F3FUL	LOV
12	LK2F3FUR	LOV
13	LKLU	OK
14	LKLU1F	OK
15	LKLU1F2F	OK
16	LKLU1F2F3F	LOV
17	LK3L	LOV
18	LK3L2F	OK
19	LK3L2F	OK
20	LK3L2FUR	OK
21	LK3L2FURUL	LOV
22	LK3L2F3F	OK
23	LK3L2F3FUL	LOV
24	LK3L2F3FUR	LOV
25	LK3LLU	OK
26	LK3LLU1F	OK
27	LK3LLU1F2F	OK
28	LK3LLU1F2FUL	LOV
29	LK3LLU1F2F3F	LOV

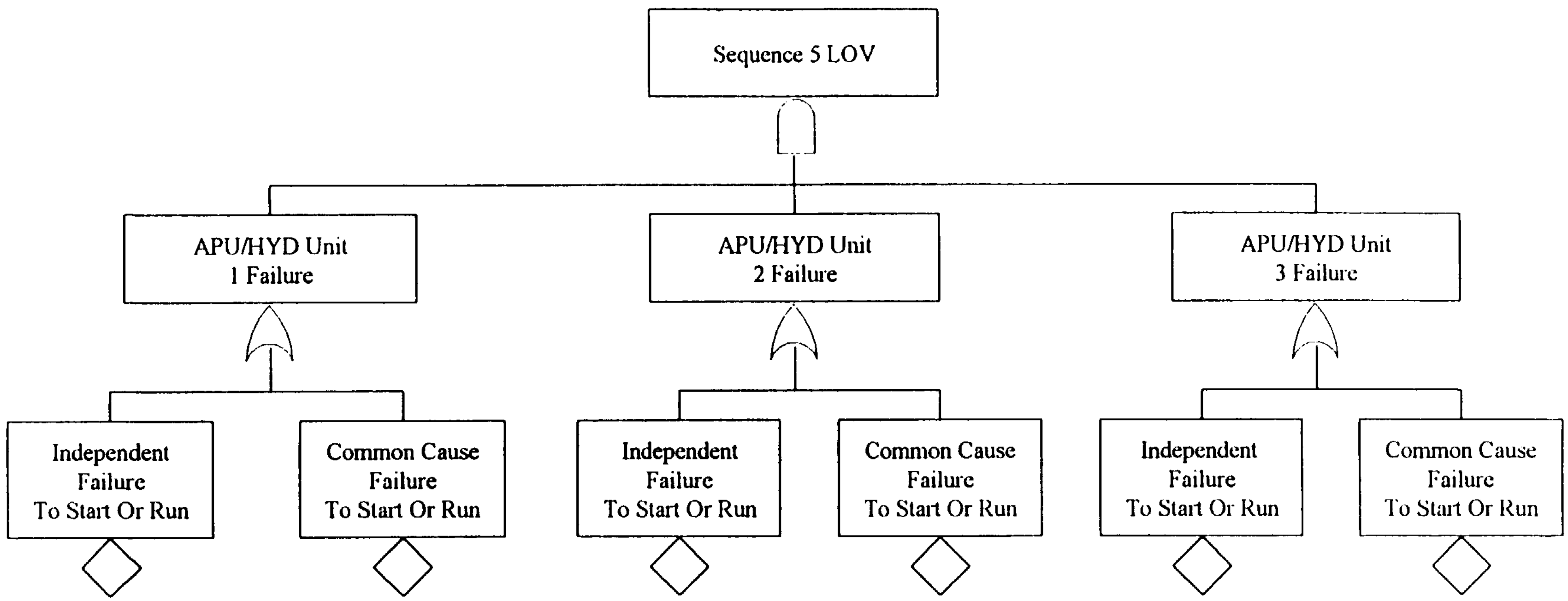
Fault Tree for Sequence 4 LOV: Two APU/HYD Units Fail Without Hydrazine Leaks and Single APU/HYD Unit Reentry, TAEM and Landing is Unsuccessful



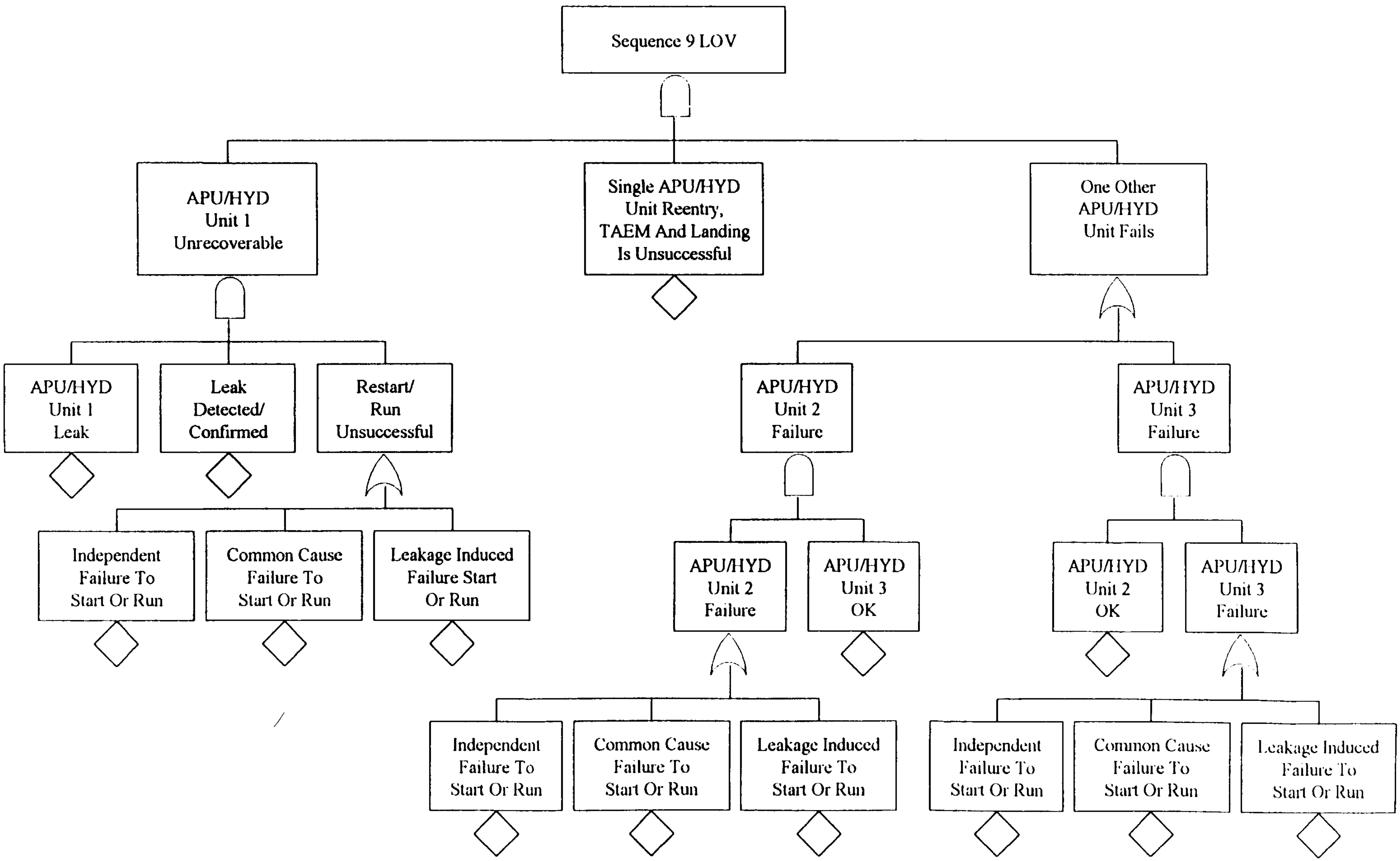
Fault Tree for Sequence 4 LOV: Two APU/HYD Units Fail Without Hydrazine Leaks and Single APU/HYD Unit Reentry, TAEM and Landing is Unsuccessful (Continued)



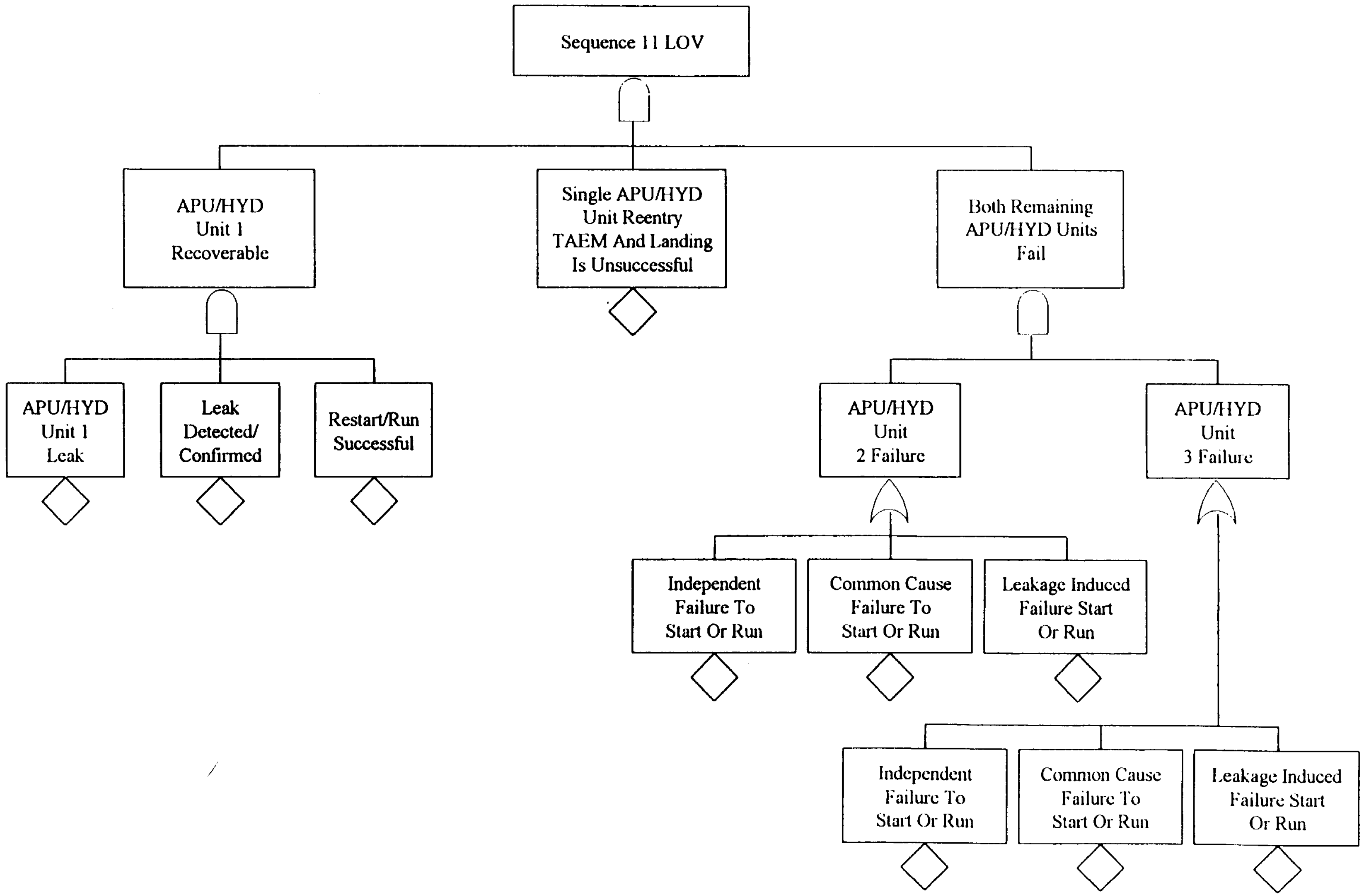
Fault Tree for Sequence 5 LOV: All Three APU/HYD Units Fail Without Hydrazine Leaks During Reentry, TAEM and Landing



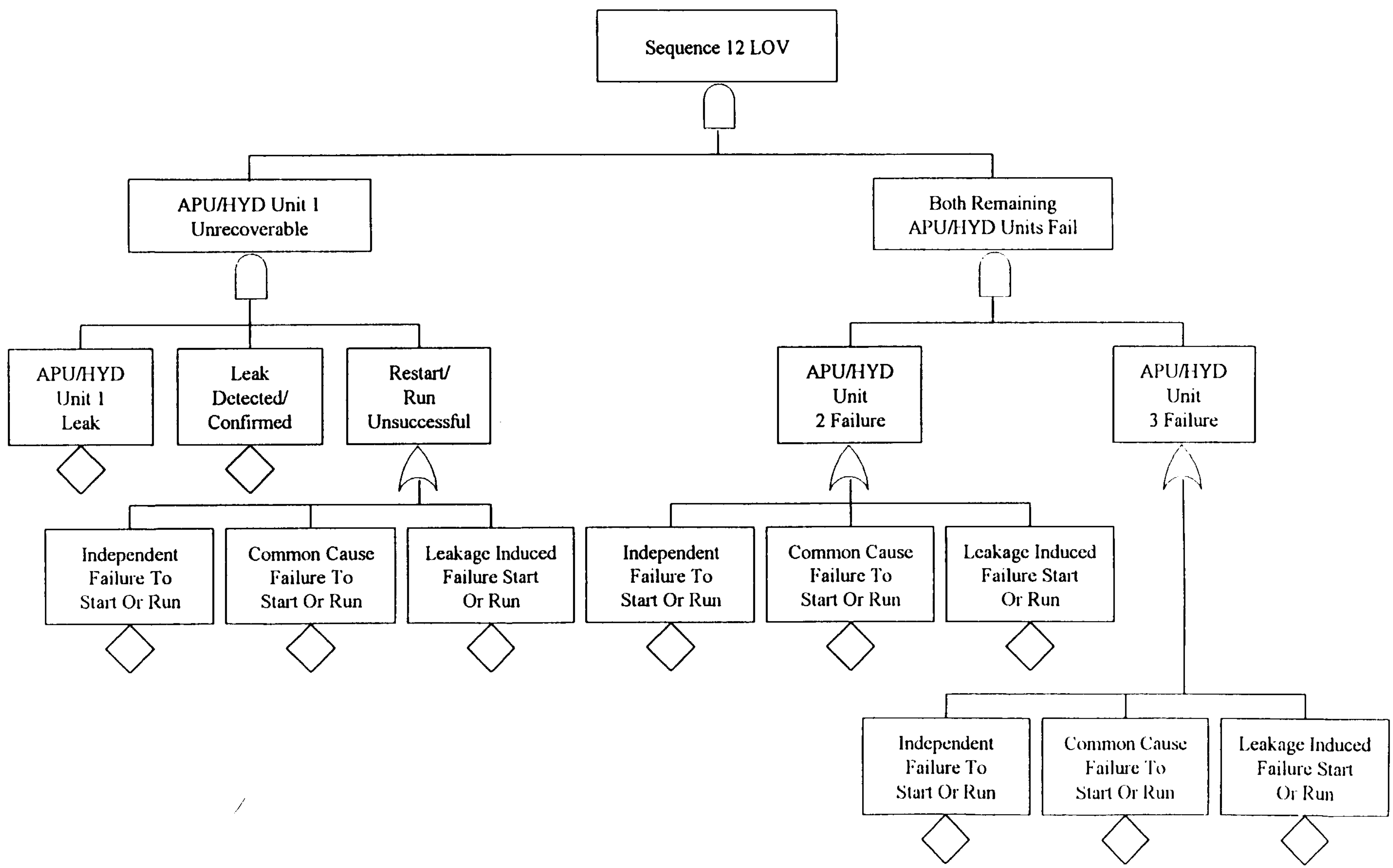
Fault Tree for Sequence 9 LOV: One APU/HYD Unit Leaks and is Shutdown, One Other Unit Fails, Restart of Shutdown APU/HYD Unit is Unsuccessful, and Single APU/HYD Unit Reenty, TAEM and Landing is Unsuccessful



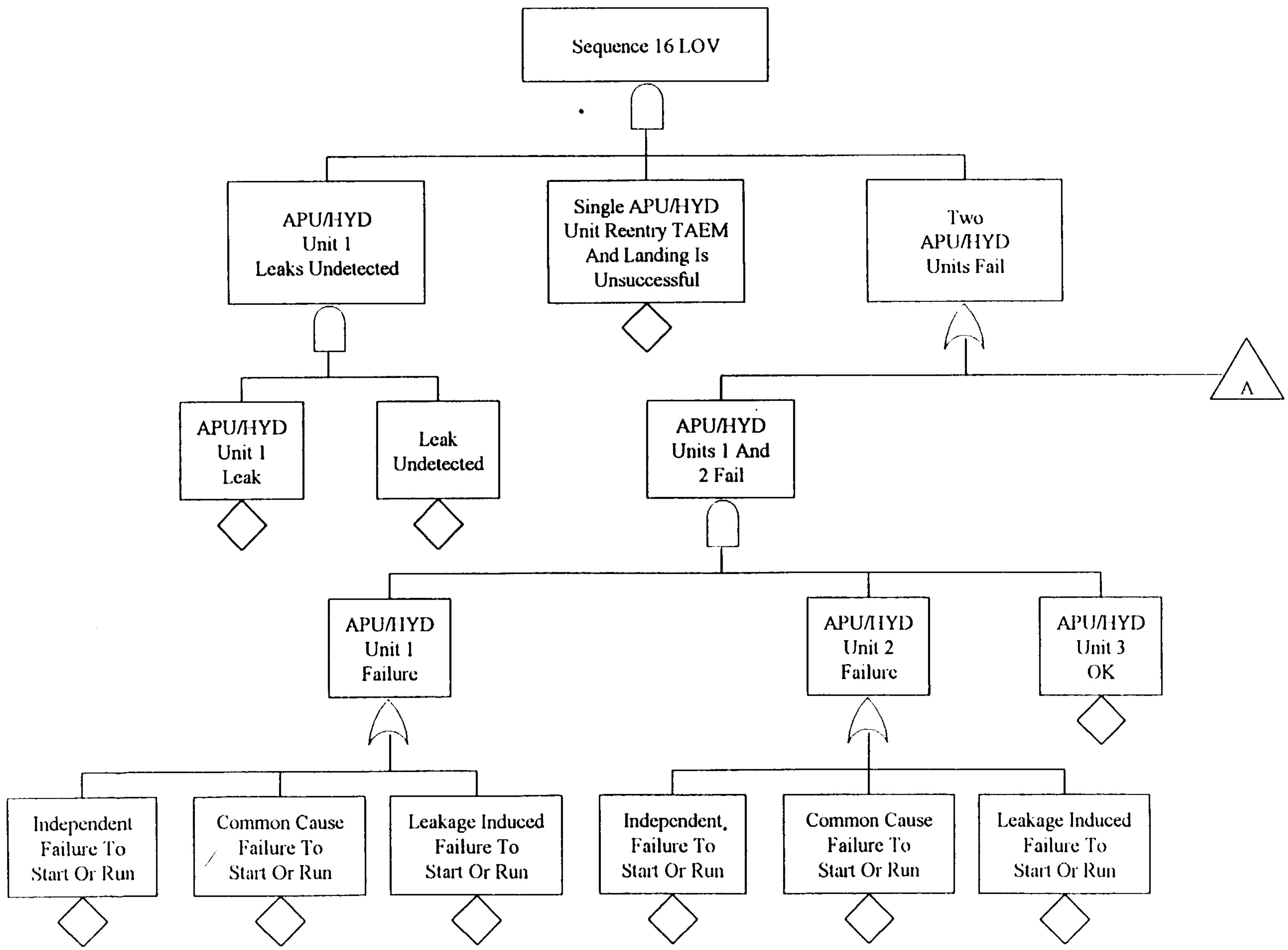
Fault Tree for Sequence 11 LOV: One APU/HYD Unit Leaks and is Shutdown, Remaining Units Both Fail, Restart of Shutdown APU/HYD Unit is Successful, but Single Unit Reentry, TAEM and Landing is Unsuccessful



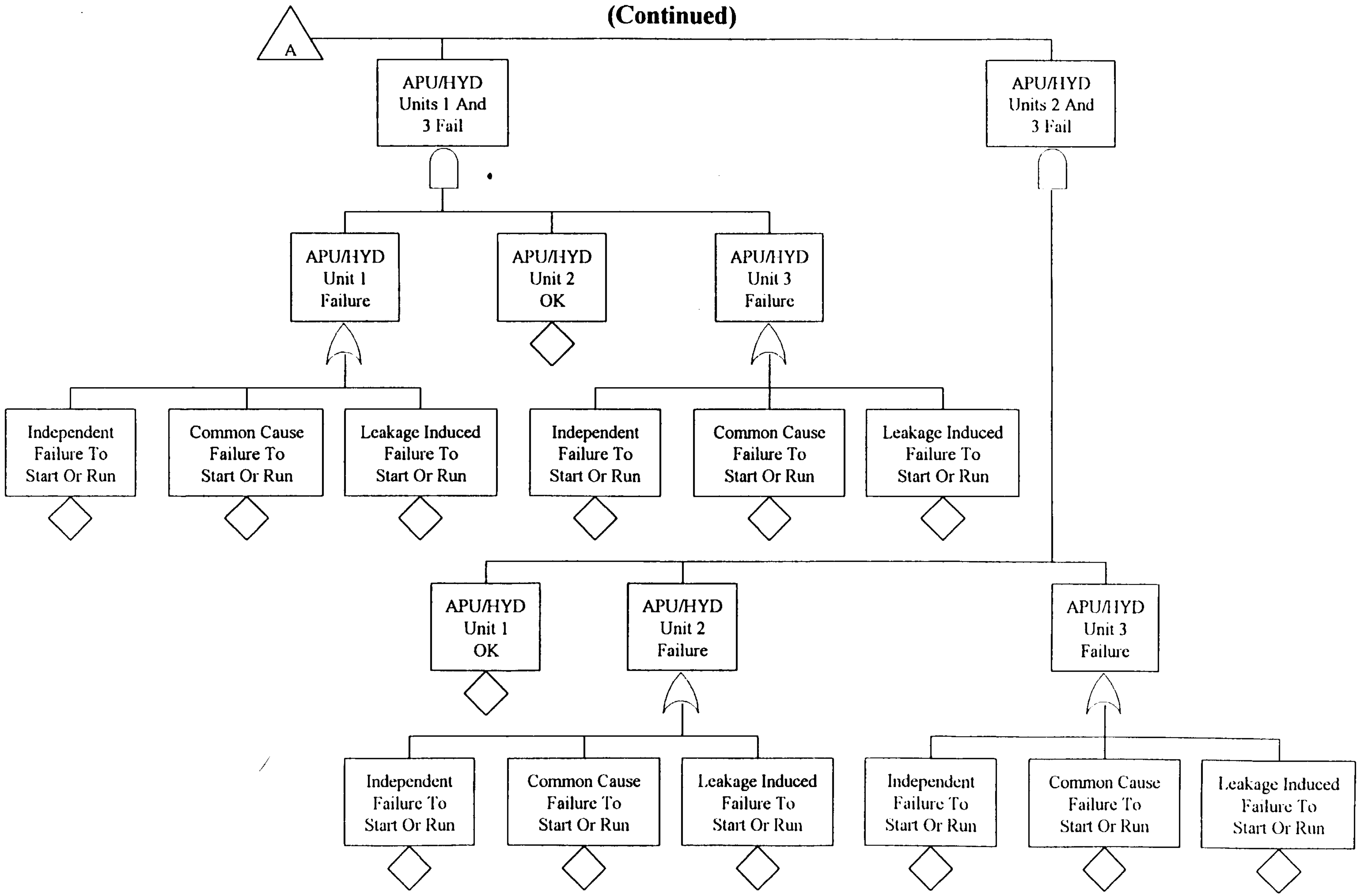
Fault Tree for Sequence 12 LOV: One APU/HYD Unit Leaks and is Shutdown, Both Remaining APU/HYDs Have Failures, and Restart of APU/HYD Unit 1 is Unsuccessful



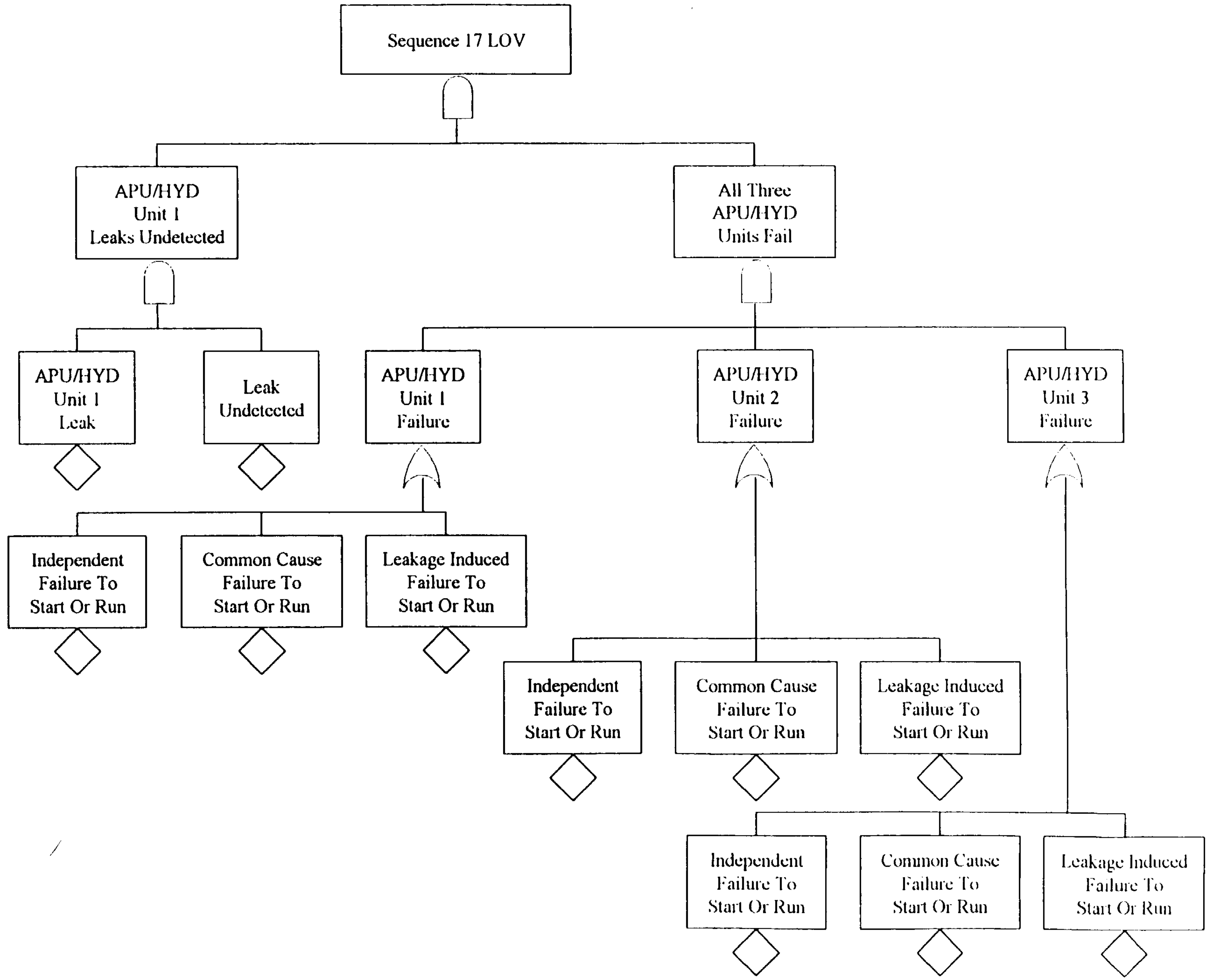
Sequence 16 LOV: One APU/HYD Unit Leaks Undetected, Two APU/HYD Units Fail and Single APU/HYD Unit Reentry, TAEM and Landing is Unsuccessful



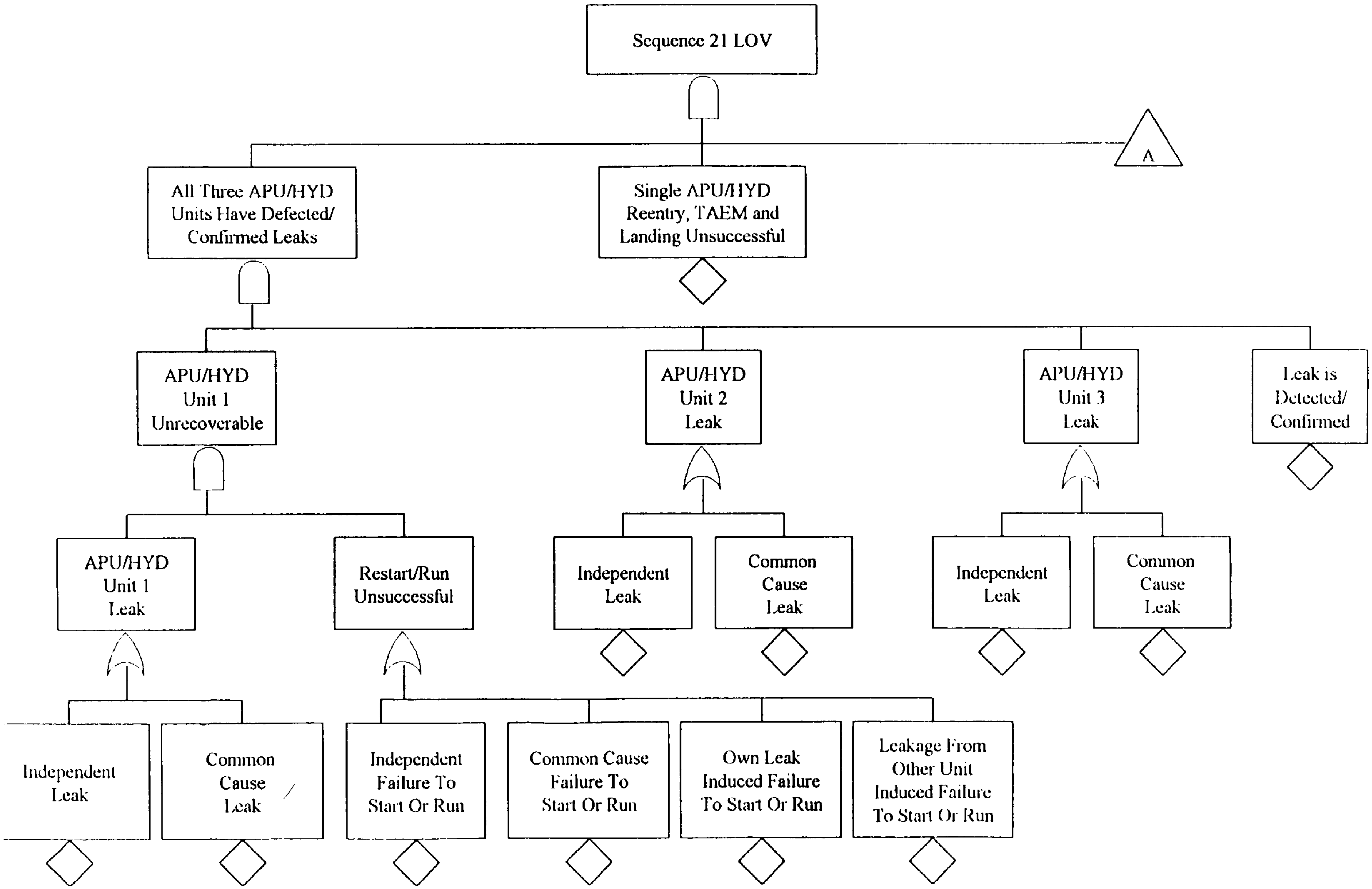
Sequence 16 LOV: One APU/HYD Unit Leaks Undetected, Two APU/HYD Units Fail and Single APU/HYD Unit Reentry, TAEM and Landing is Unsuccessful (Continued)



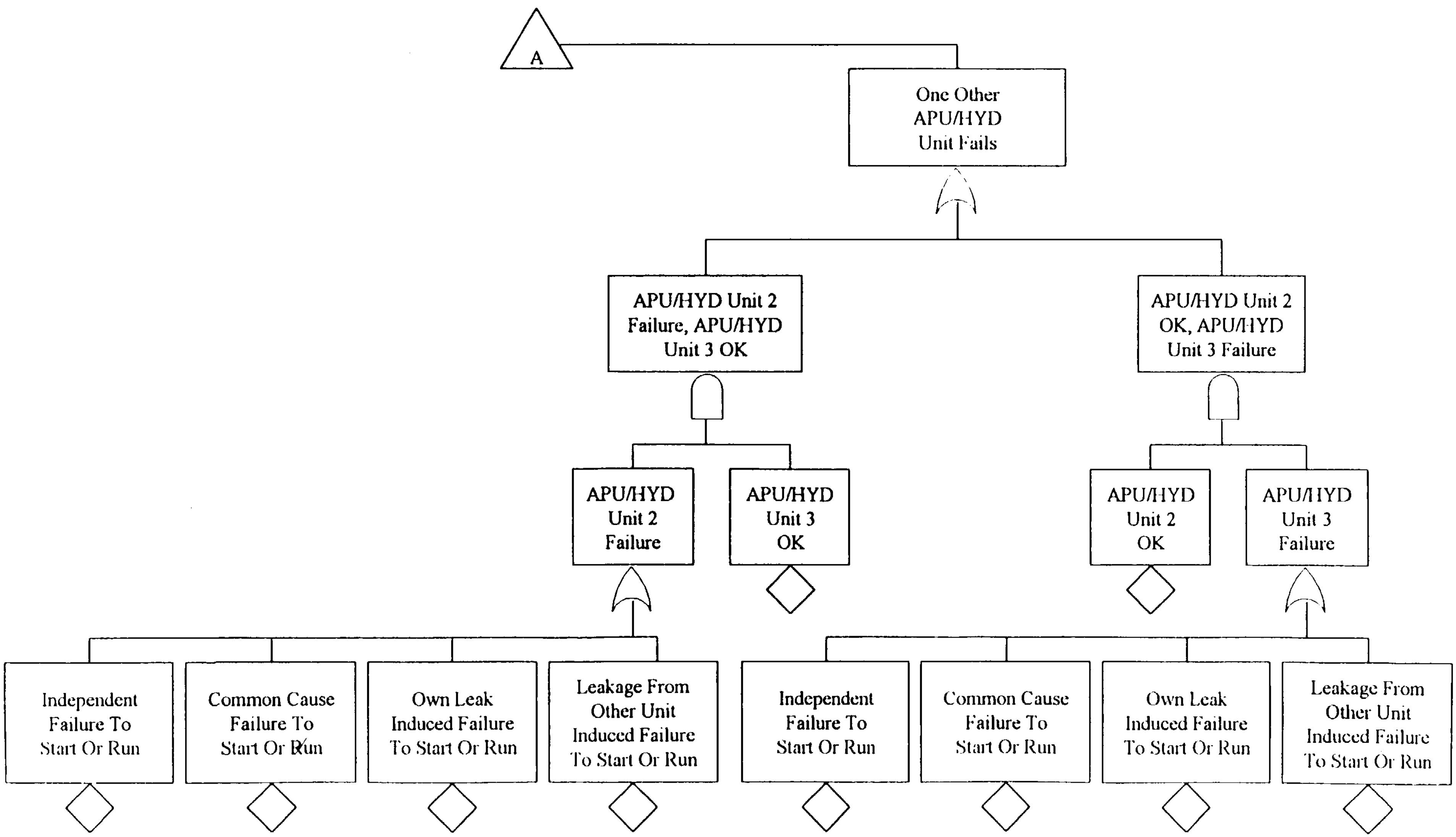
Sequence 17 LOV: One APU/HYD Unit Leaks Undetected and all Three APU/HYD Units Fail



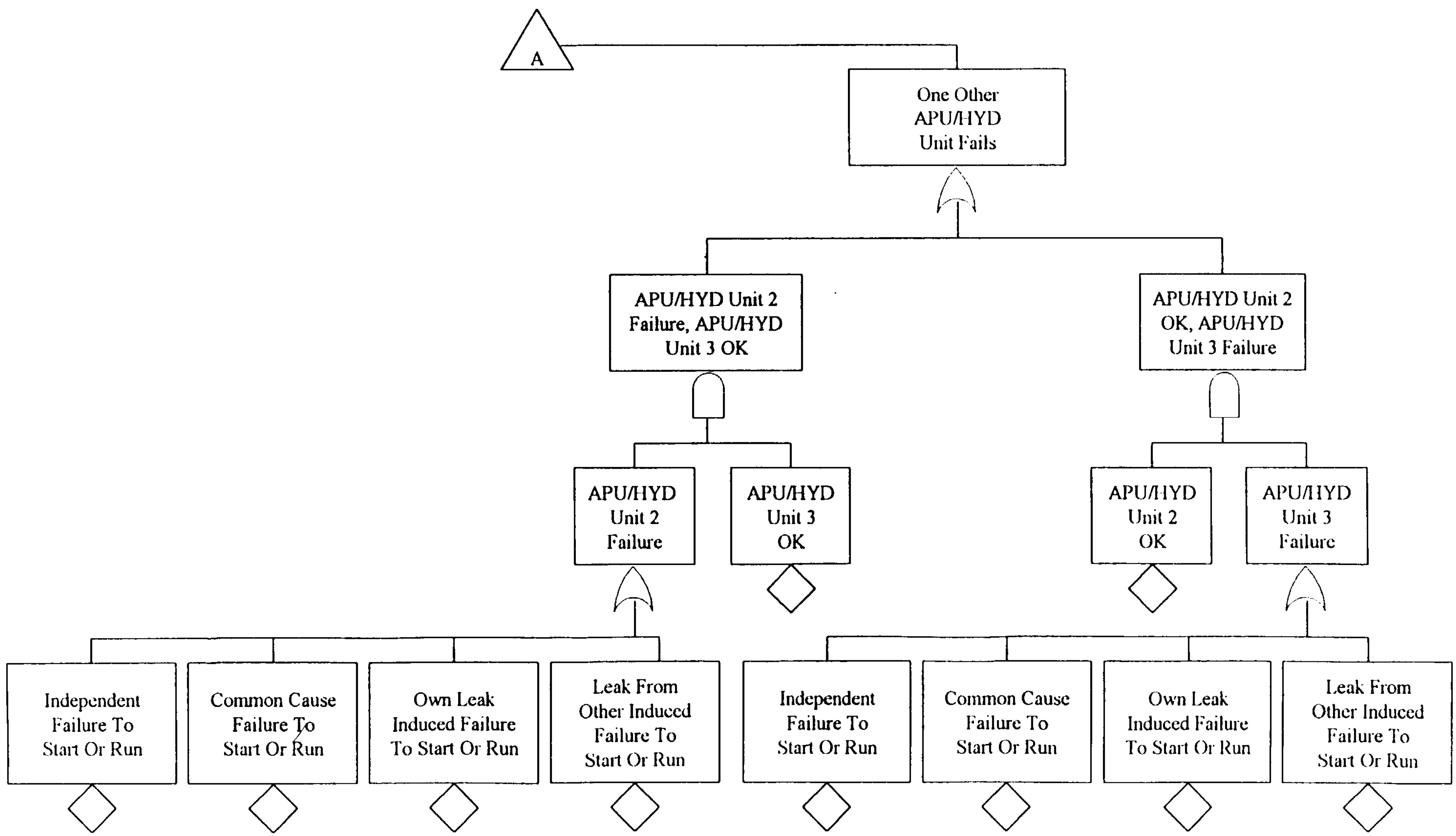
Fault Tree for Sequence 21 LOV: All Three APU/HYD Units Leak, APU/HYD Unit 1 is Shutdown, One Other Unit Fails, Restart of Shutdown Unit is Unsuccessful and Single APU/HYD Unit Loading is Unsuccessful



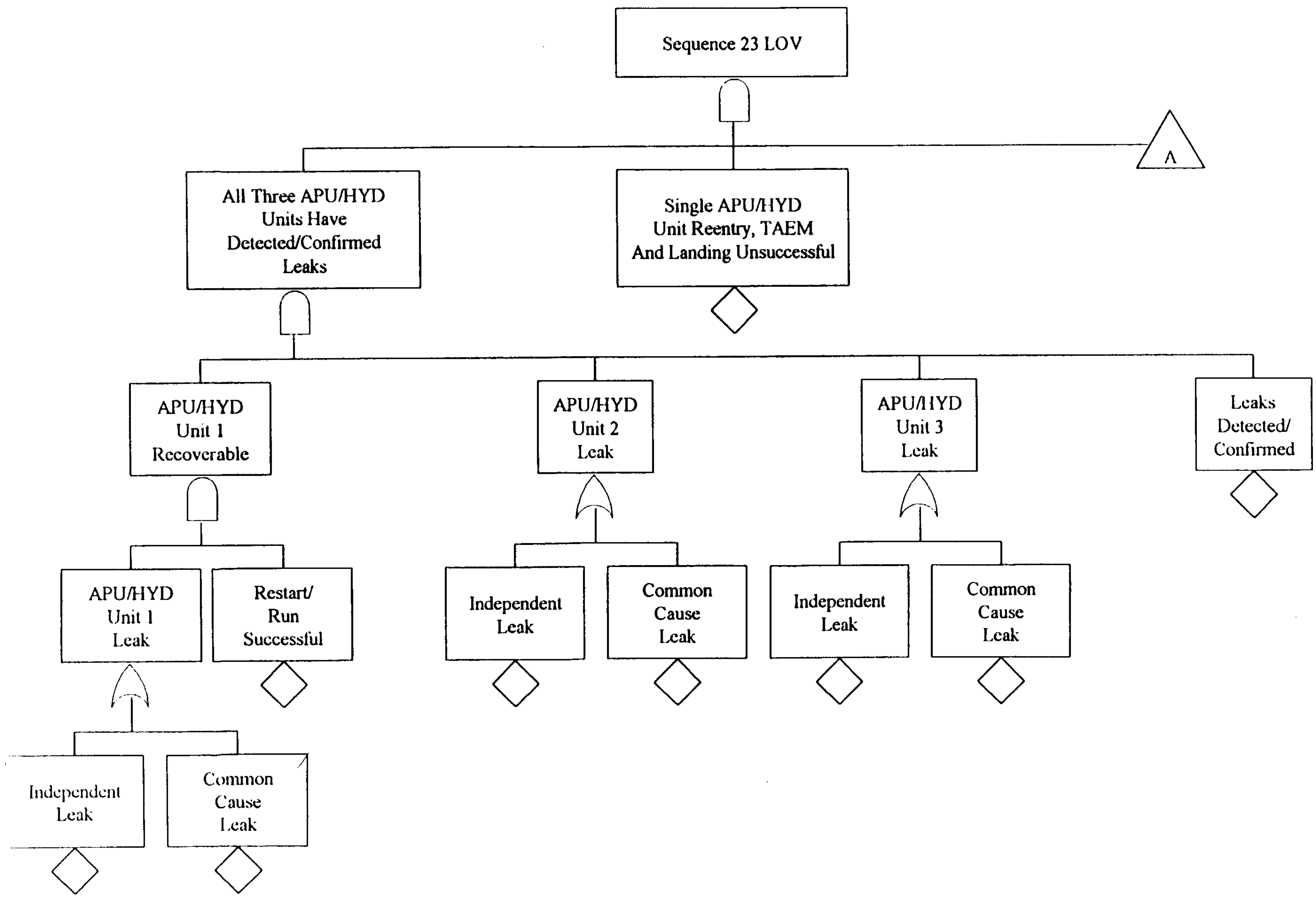
Fault Tree for Sequence 2? LOV: All Three APU/HYD Units Leak, APU/HYD Unit 1 is Shutdown, One Other Unit Fails, Restart of Shutdown Unit is Unsuccessful and Single APU/HYD Unit Loading is Unsuccessful (Continued)



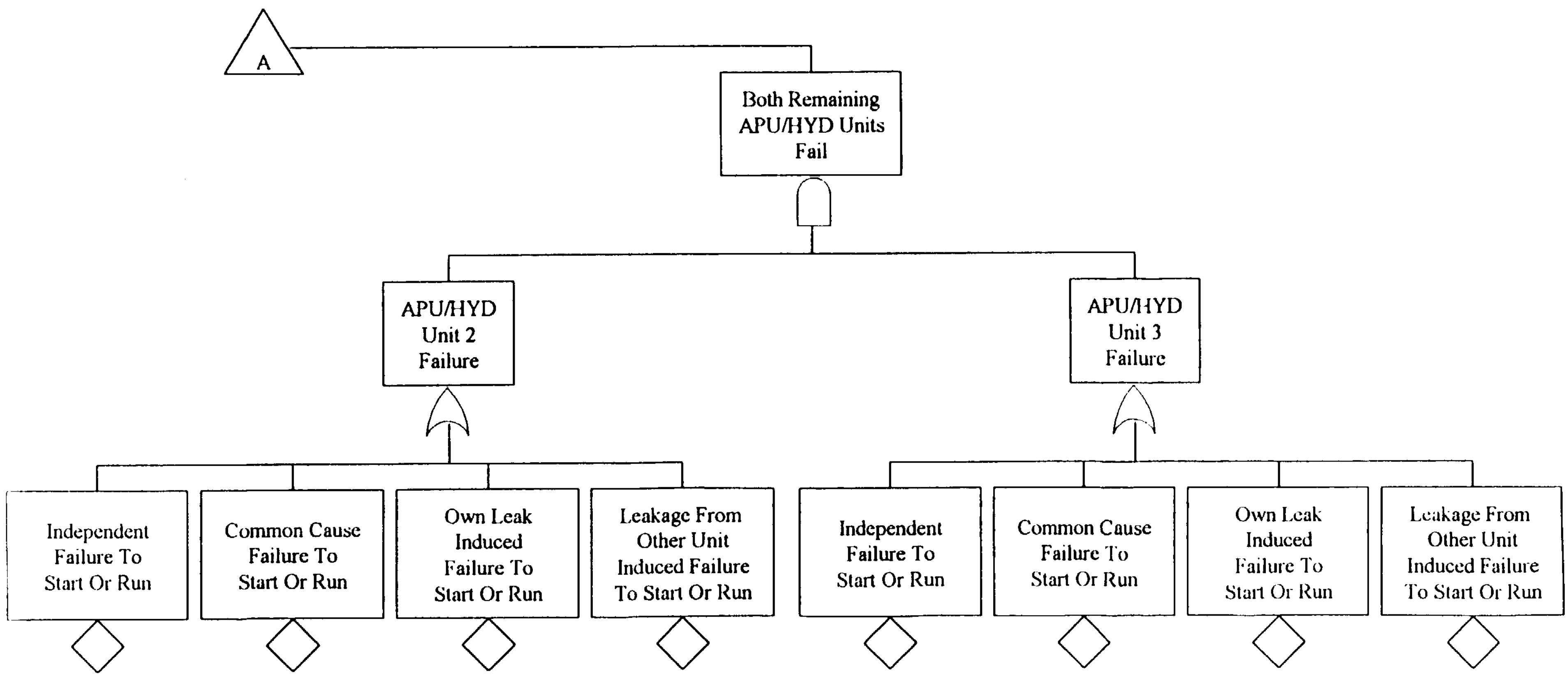
Fault Tree for Sequence 21 LOV: All Three APU/HYD Units Leak, APU/HYD Unit 1 is Shutdown, One Other Unit Fails, Restart of Shutdown Unit is Unsuccessful and Single APU/HYD Unit Loading is Unsuccessful (Continued)



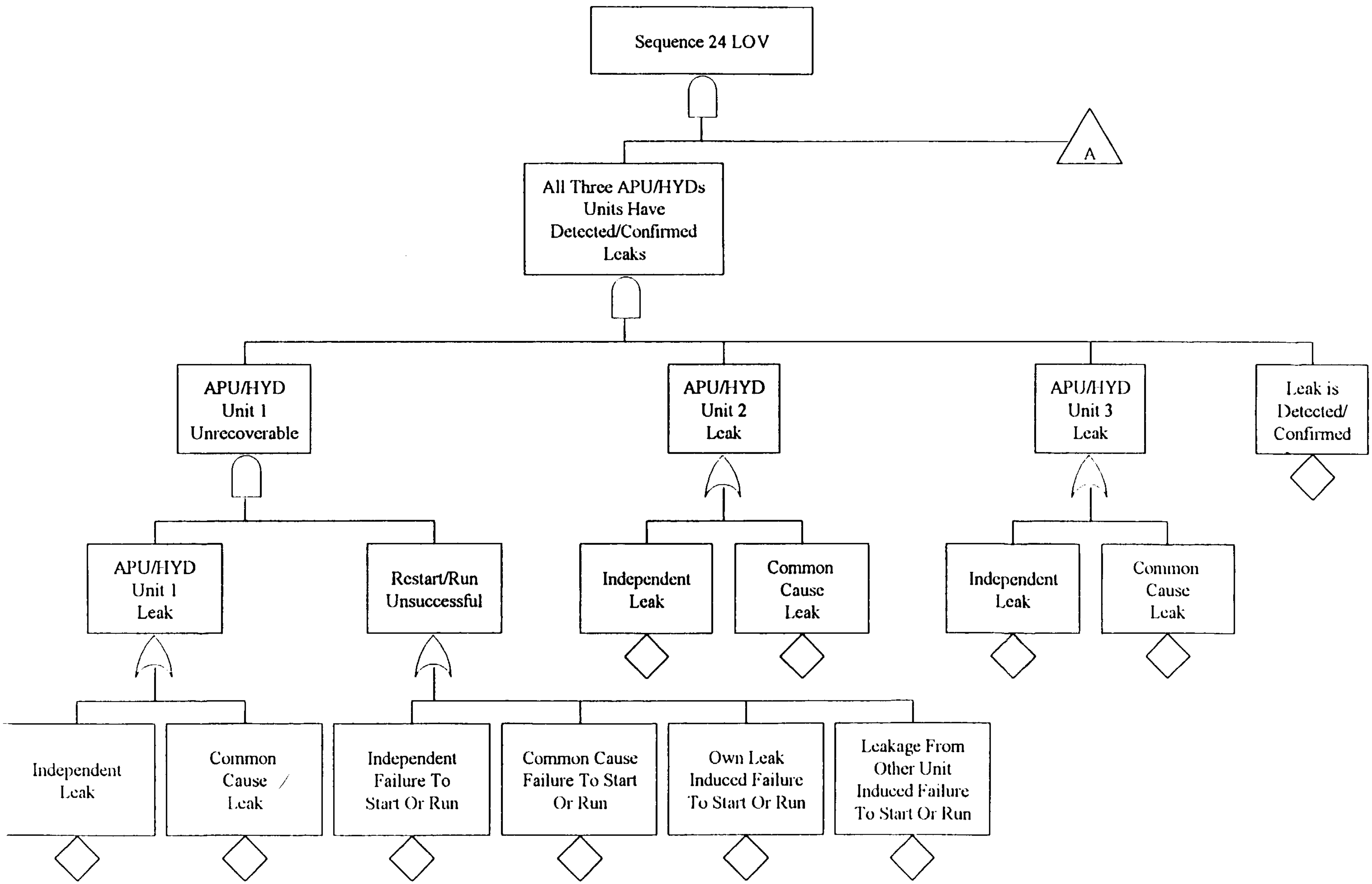
Fault Tree for Sequence 23 LOV: All Three APU/HYD Units Leak, APU/HYD Unit 1 is Shutdown, Both Remaining APU/HYD Units Fail, the Shutdown Unit is Restarted, but the Single APU/HYD Unit Reentry, TAEM and Landing is Unsuccessful



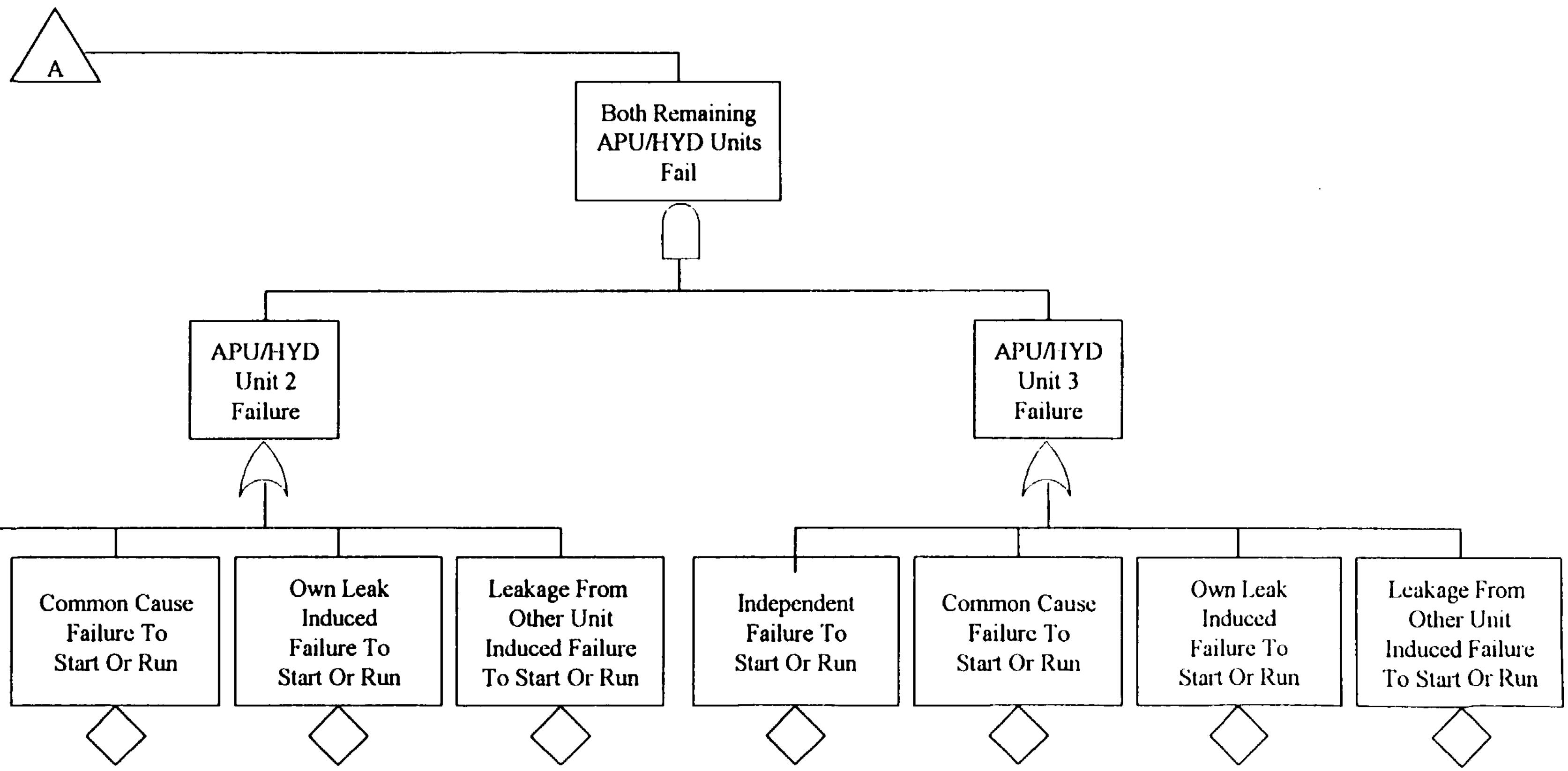
Fault Tree for Sequence 23 LOV: All Three APU/HYD Units Leak, APU/HYD Unit 1 Shutdown, Both Remaining APU/HYD Units Fail and Restart of Shutdown APU/HYD Unit is Unsuccessful (Continued)



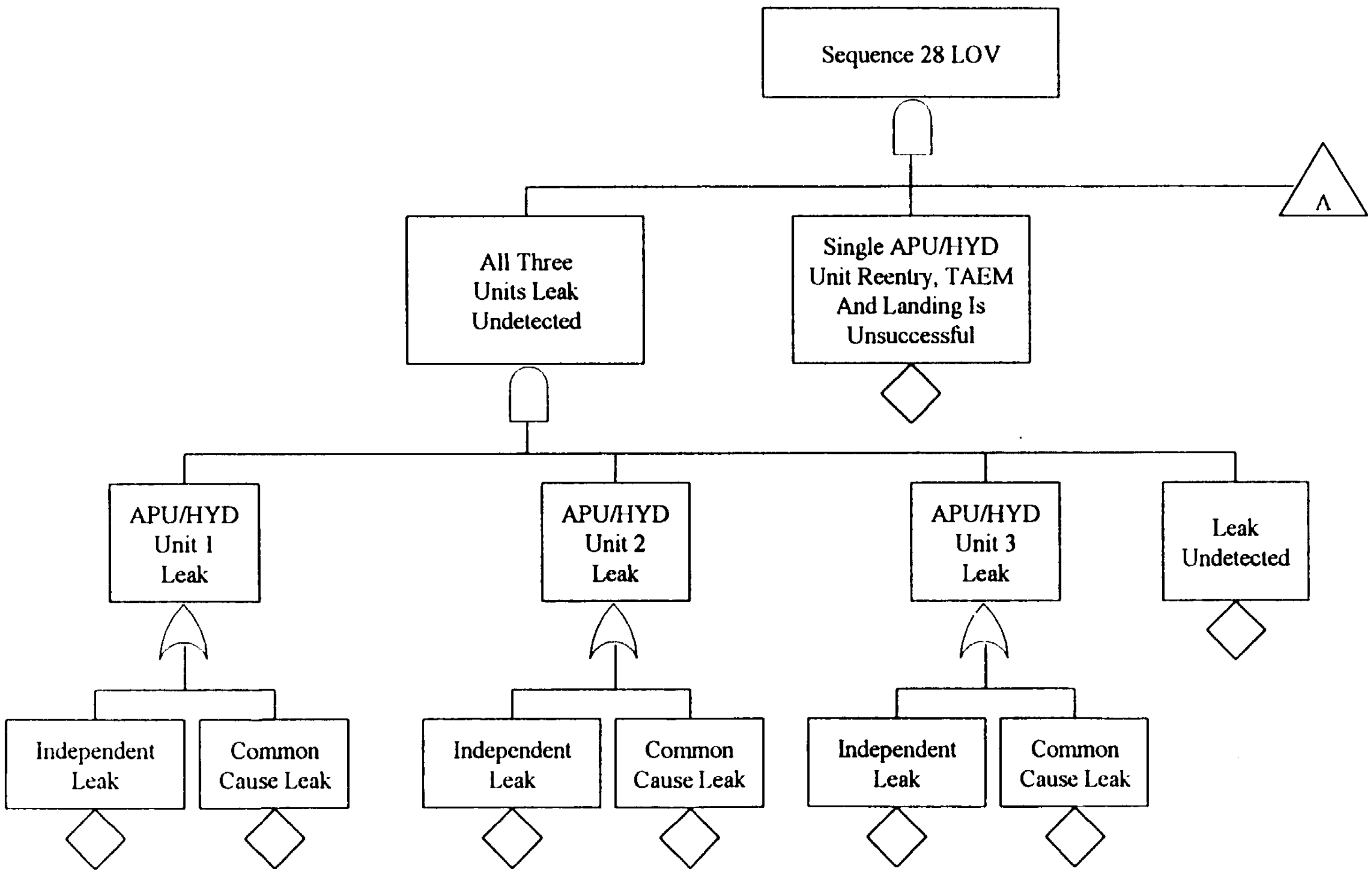
Fault Tree for Sequence 24 LOV: All Three APU/HYD Units Leak, APU/HYD Unit 1 is Shutdown, Both Remaining APU/HYD Units Fail and Restart of Shutdown APU/HYD Unit is Unsuccessful



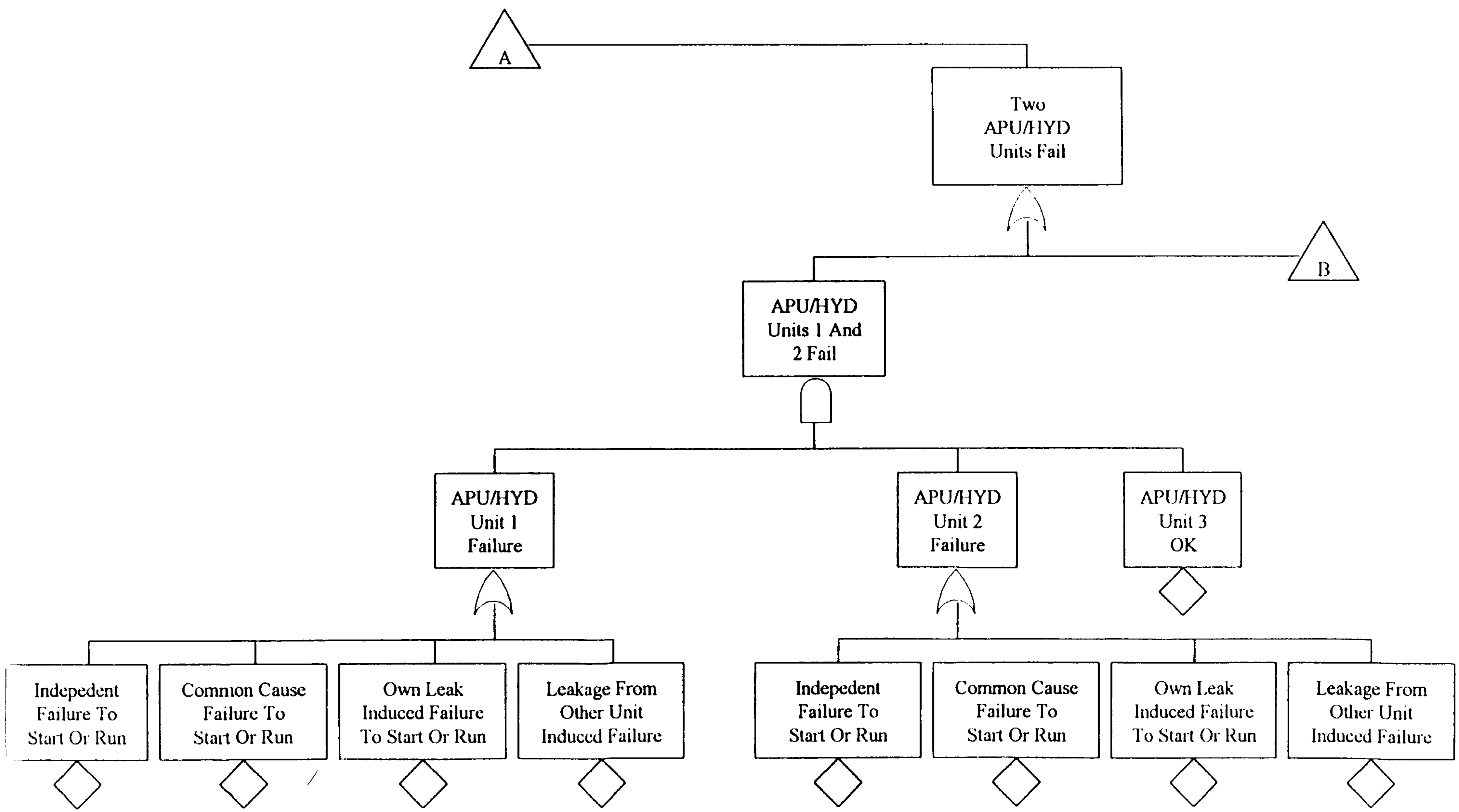
Fault Tree for Sequence 24 LOV: All Three APU/HYD Units Leak, APU/HYD Unit 1 is Shutdown, Both Remaining APU/HYD Units Fail and Restart of Shutdown APU/HYD Unit is Unsuccessful (Continued)



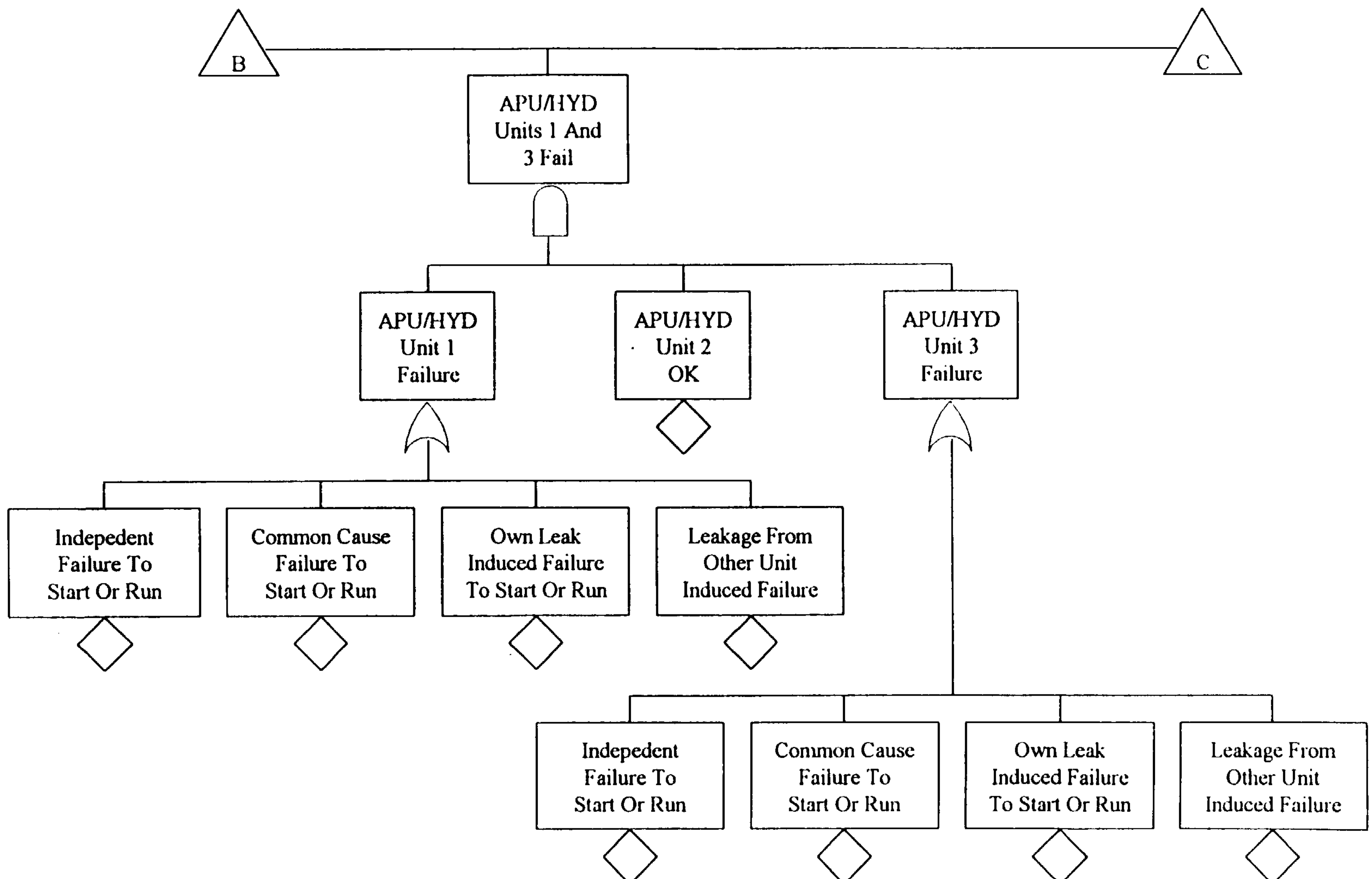
Fault Tree for Sequence 28 LOV: All Three APU/HYD Units Leak Undetected, Two APU/HYD Units Fail, Single APU/HYD Unit Landing Unsuccessful



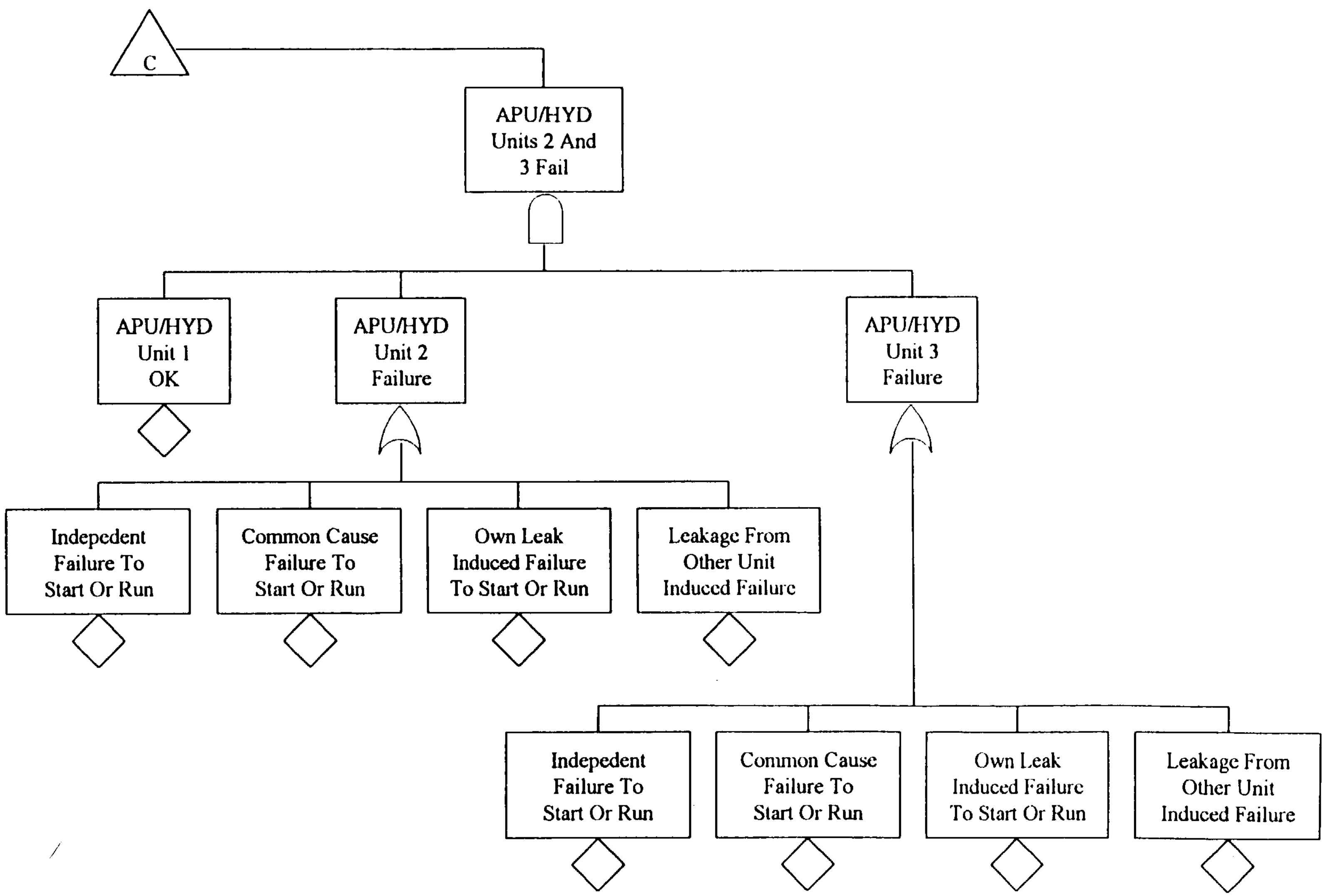
Fault Tree for Sequence 28 LOV: All Three APU/HYD Units Leak Undetected, Two APU/HYD Units Fail, Single APU/HYD Unit Landing Unsuccessful (Continued)



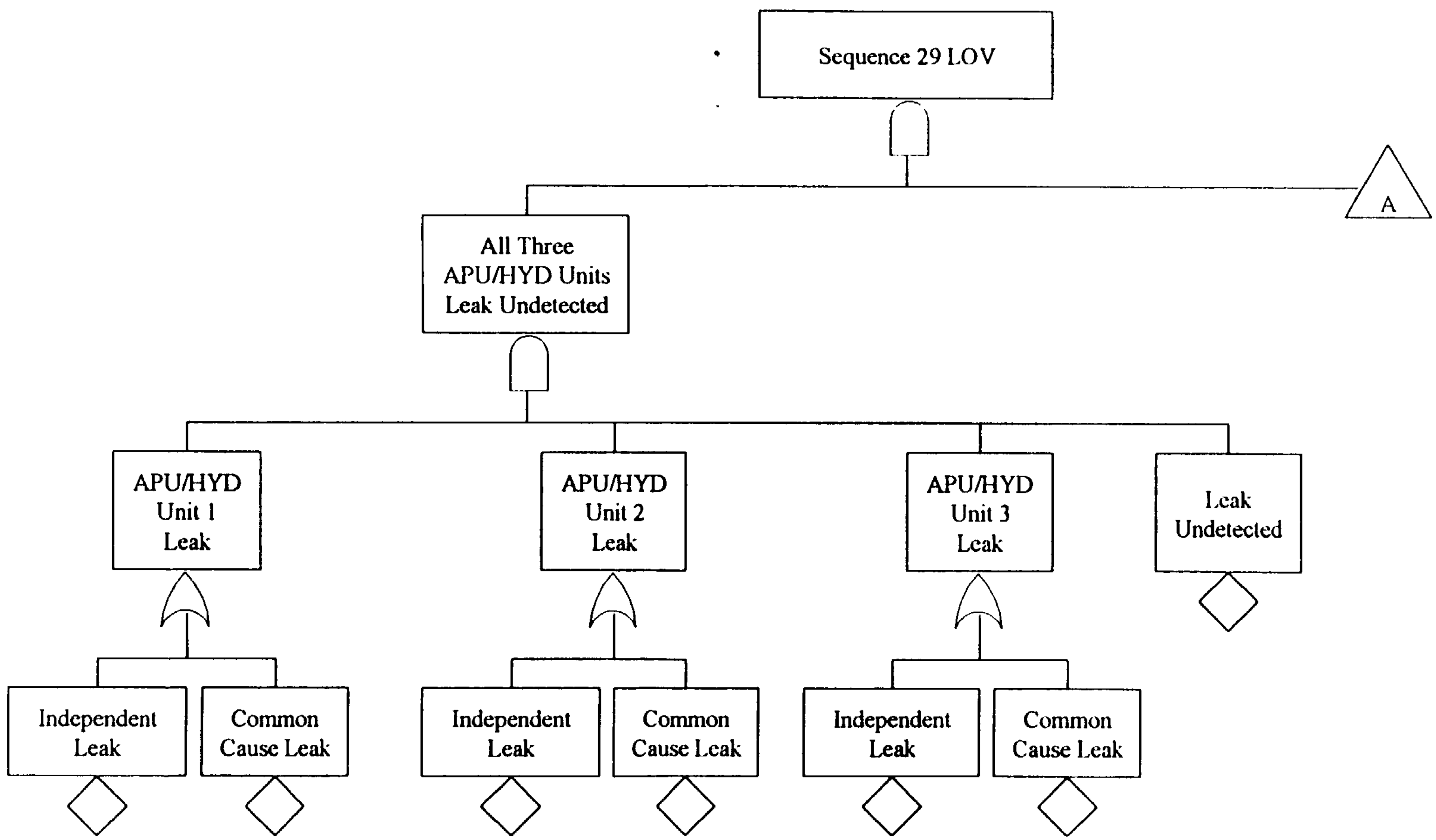
Fault Tree for Sequence 28 LOV: All Three APU/HYD Units Leak Undetected, Two APU/HYD Units Fail, Single APU/HYD Unit Landing Unsuccessful (Continued)



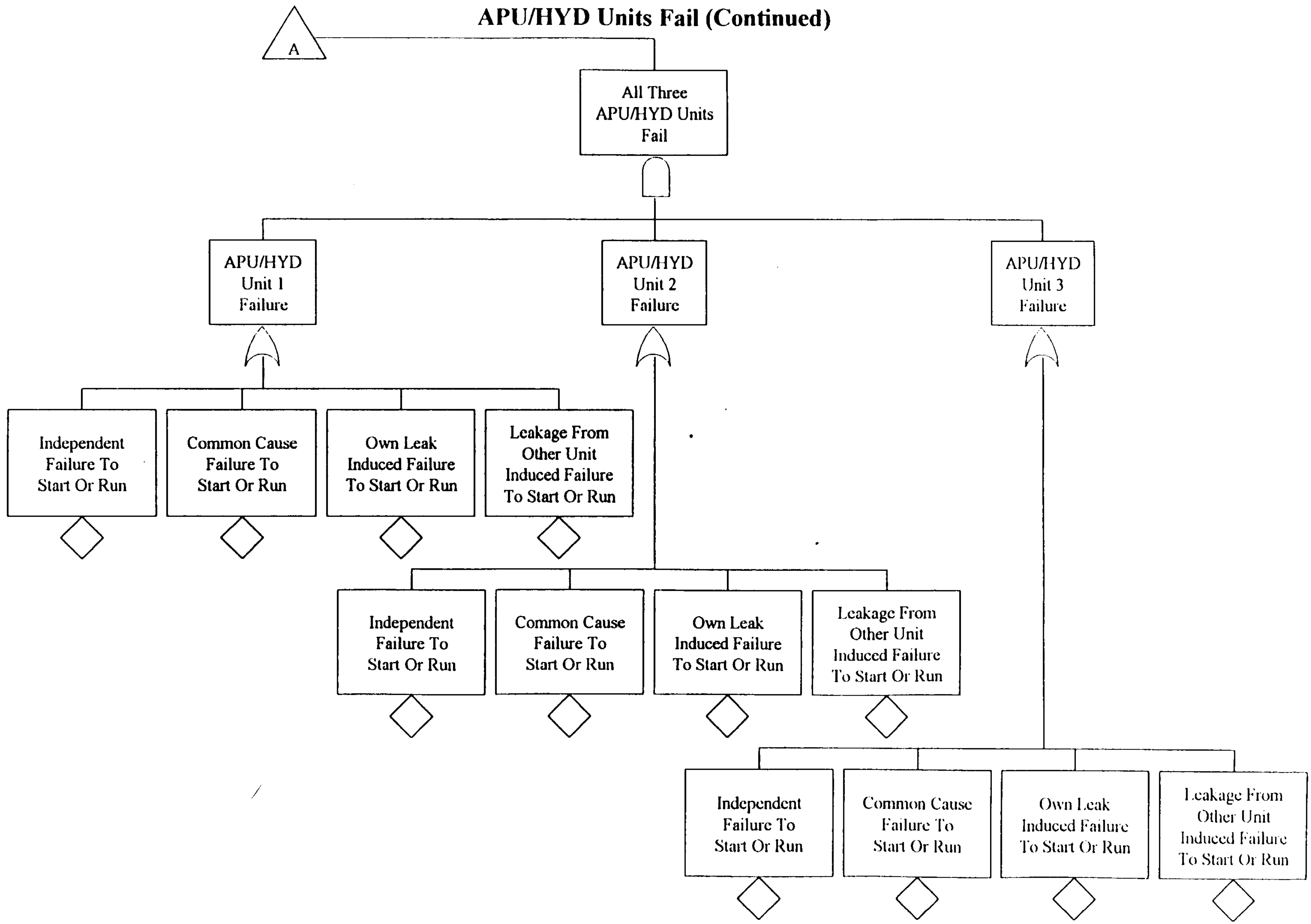
Fault Tree for Sequence 28 LOV: All Three APU/HYD Units Leak Undetected, Two APU/HYD Units Fail, Single APU/HYD Unit Landing Unsuccessful (Continued)



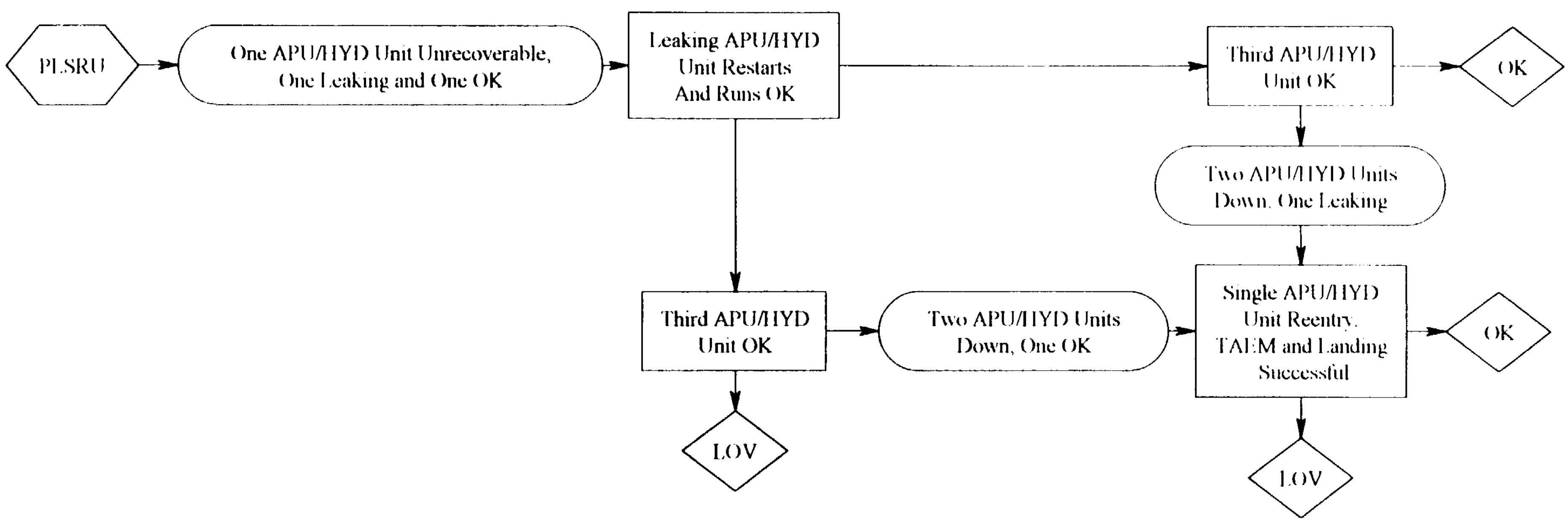
Fault Tree for Sequence 29 LOV: All Three APU/HYD Units Leak Undetected and all Three APU/HYD Units Fail



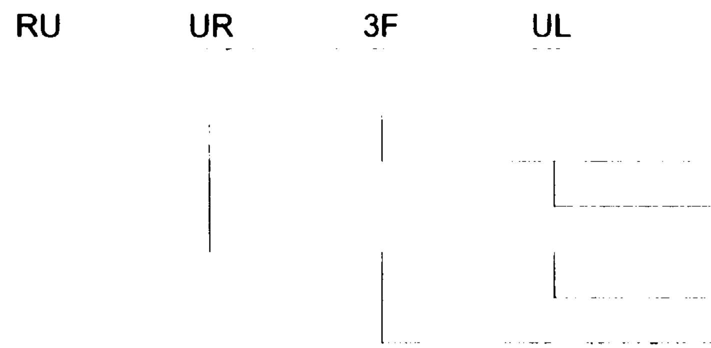
Fault Tree for Sequence 29 LOV: All Three APU/HYD Units Leak Undetected and all Three APU/HYD Units Fail (Continued)



Event Sequence Diagram for a PLSRU State During Reentry, TAEM and Landing

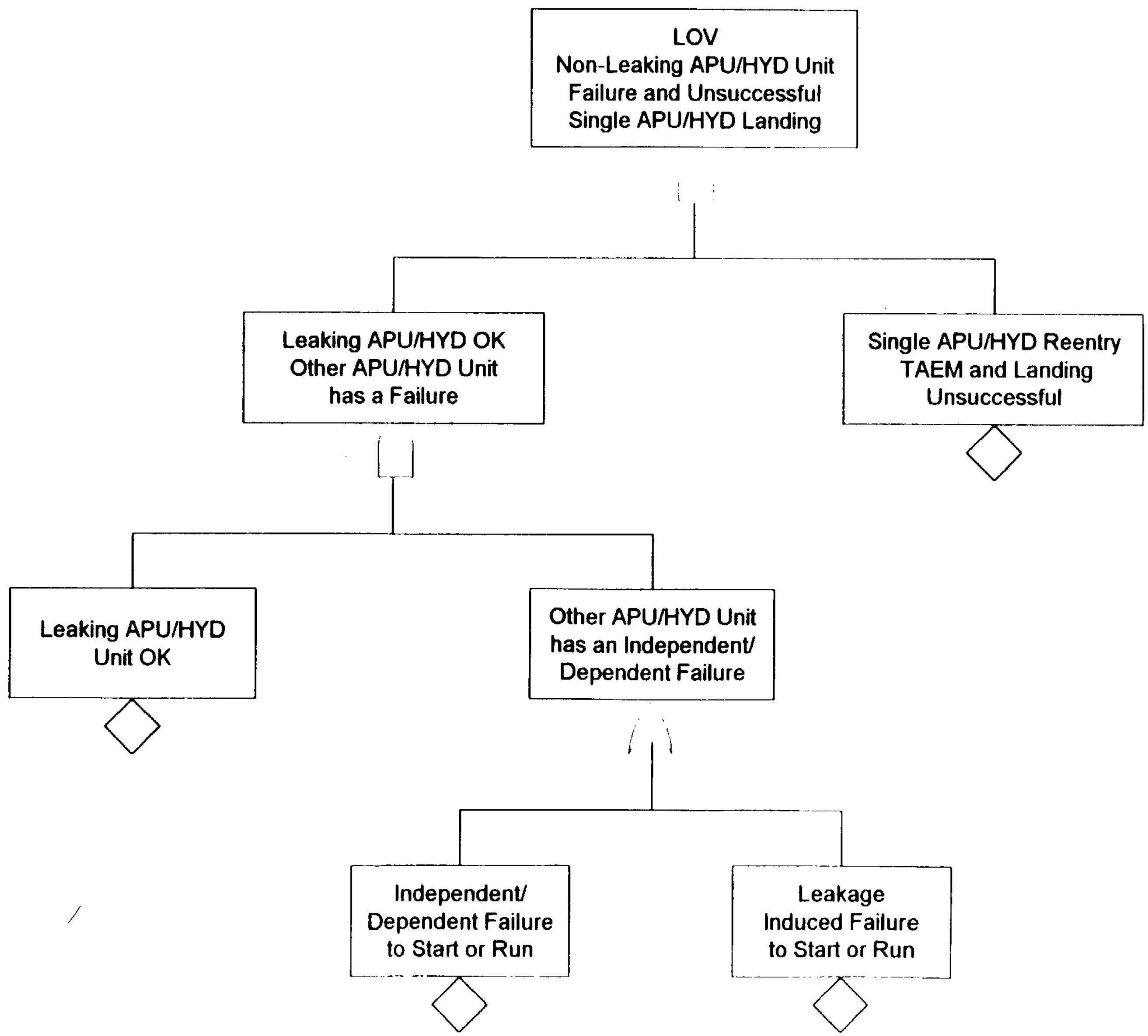


EVENT TREE OF A PLSRU INITIATING EVENT DURING REENTRY, TAEM AND LANDING

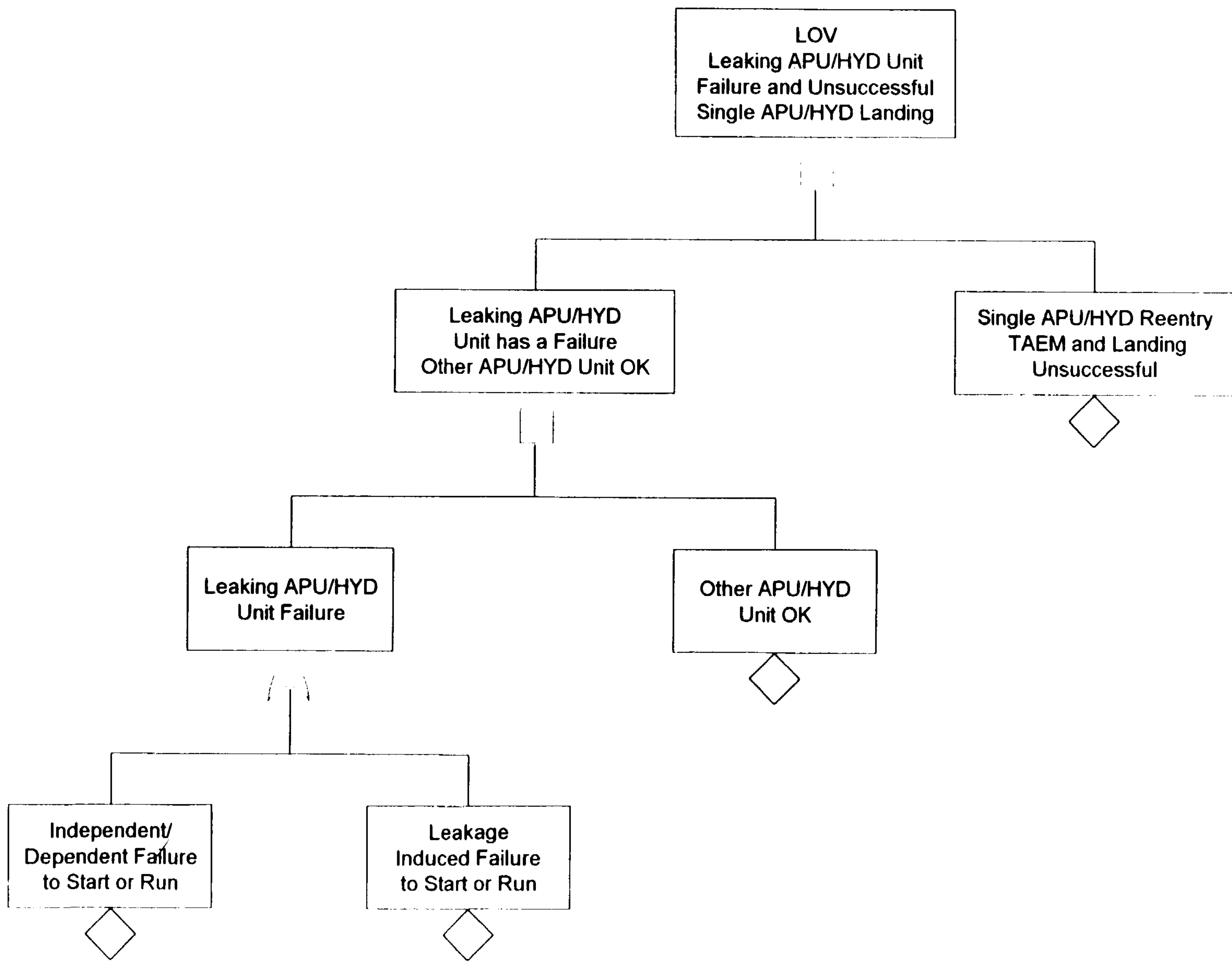


SEQUENCE NUMBER	SEQUENCE DESCRIPTION	STATE
1	RU	OK
2	RU3F	OK
3	RU3FUL	LOV
4	RUUR	OK
5	RUURUL	LOV
6	RUUR3F	LOV

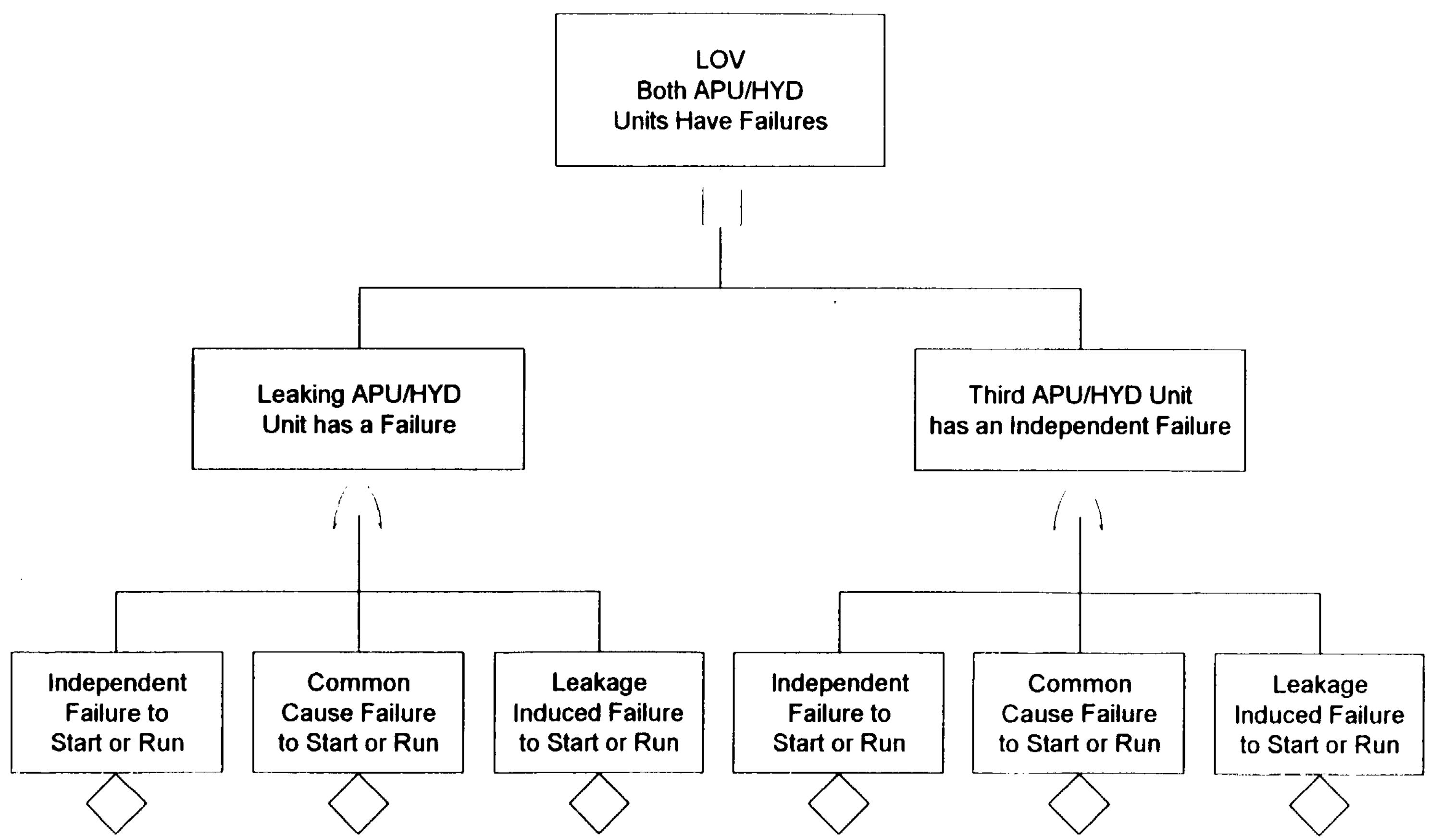
Fault Tree For Sequence 3 LOV State With PLSRU Initiating Event During Reentry, TAEM and Landing



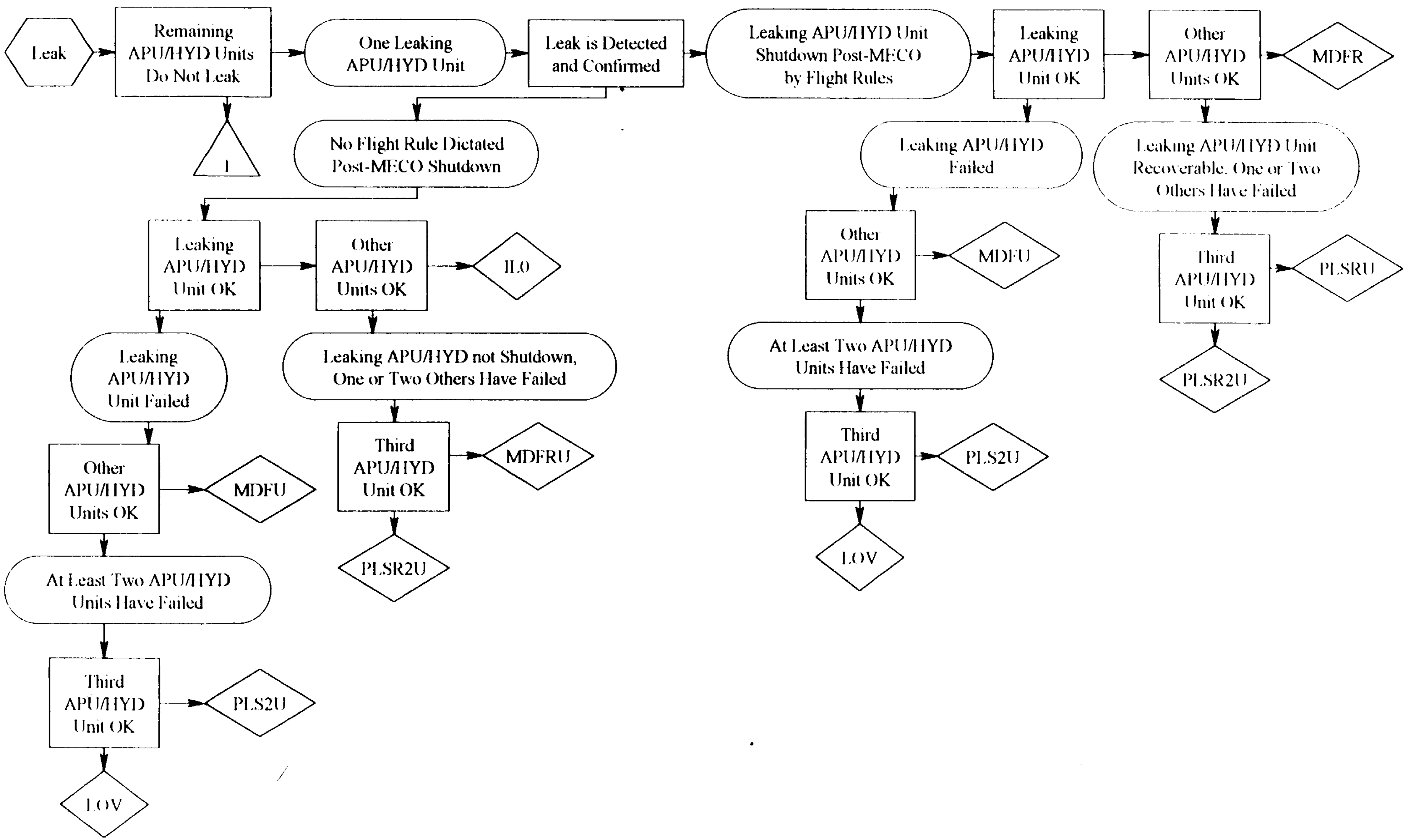
Fault Tree For Sequence 5 LOV State With PLSRU Initiating Event During Reentry, TAEM and Landing



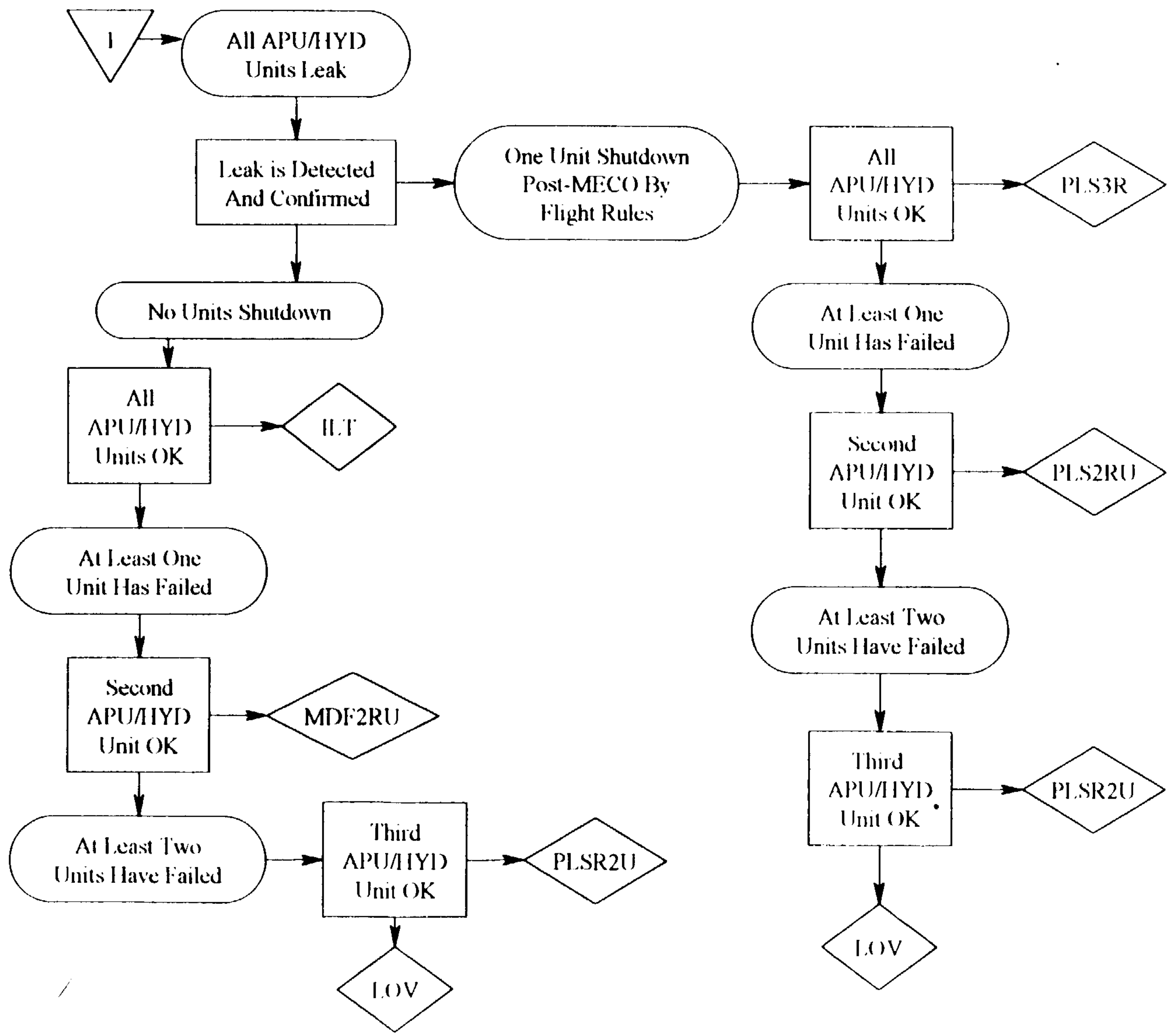
Fault Tree For Sequence 6 LOV State With PLSRU Initiating Event During Reentry, TAEM and Landing



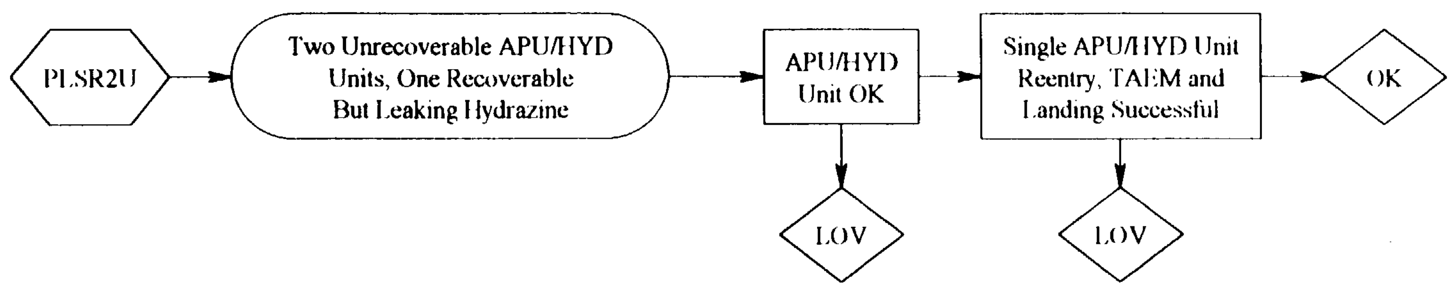
Event Sequence Diagram of APU/HYD Hydrazine Leaks During Ascent



Event Sequence Diagram of APU/HYD Hydrazine Leaks During Ascent (Continued)



Event Sequence Diagram for a PLSR2U State During Reentry, TAEM and Landing

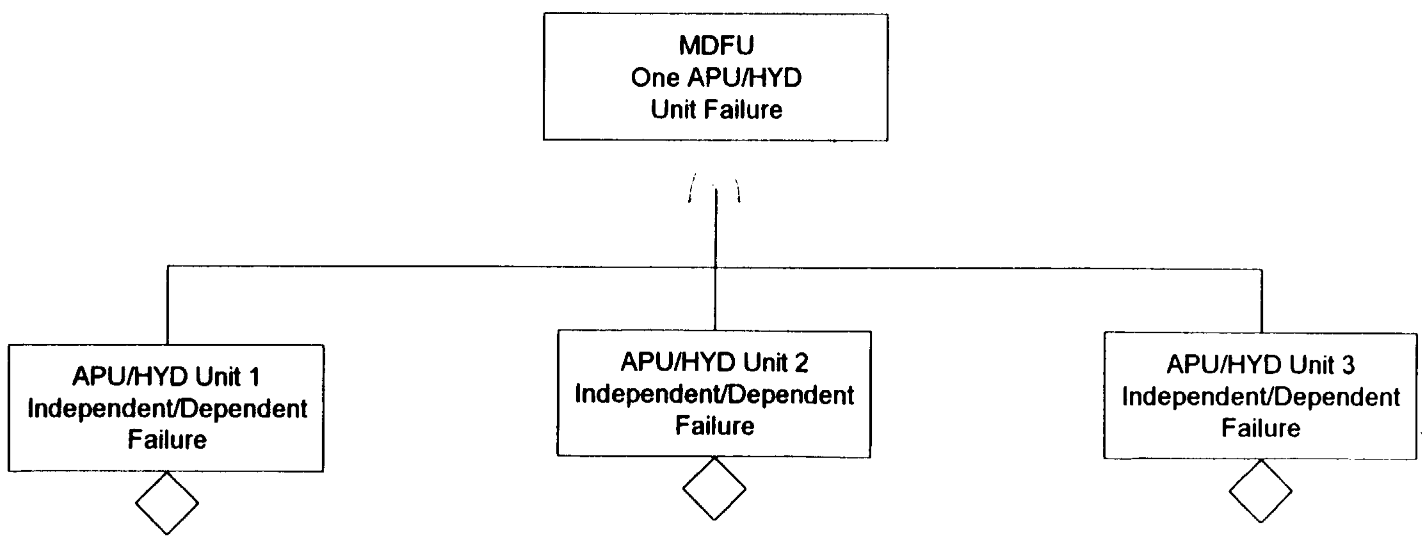


<u>Assumption</u>
Assuming remaining APU/HYD unit restarted before reentry.

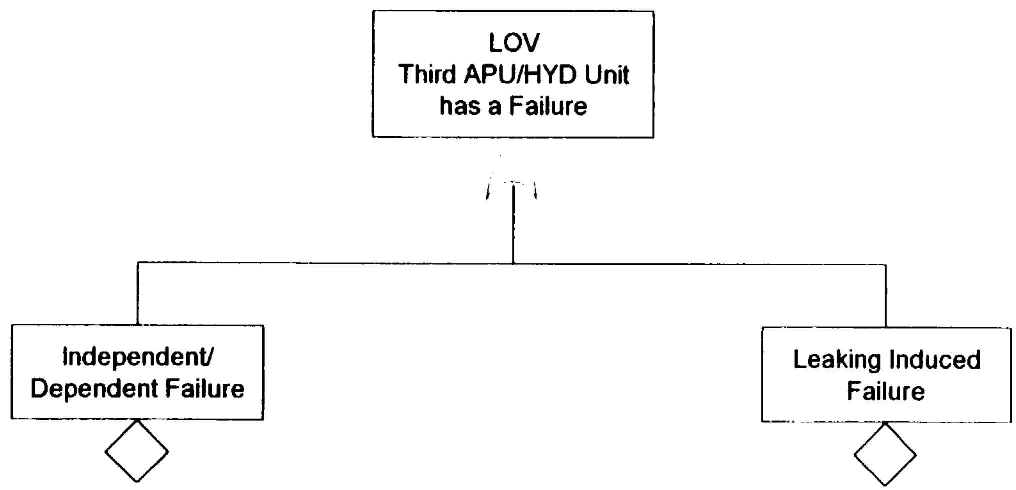
EVENT TREE OF A PLSR2U INITIATING EVENT DURING REENTRY, TAEM AND LANDING

2U	3F	UL	SEQUENCE NUMBER	SEQUENCE DESCRIPTION	STATE
			1	2U	OK
			2	2UUL	LOV
			3	2U3F	LOV

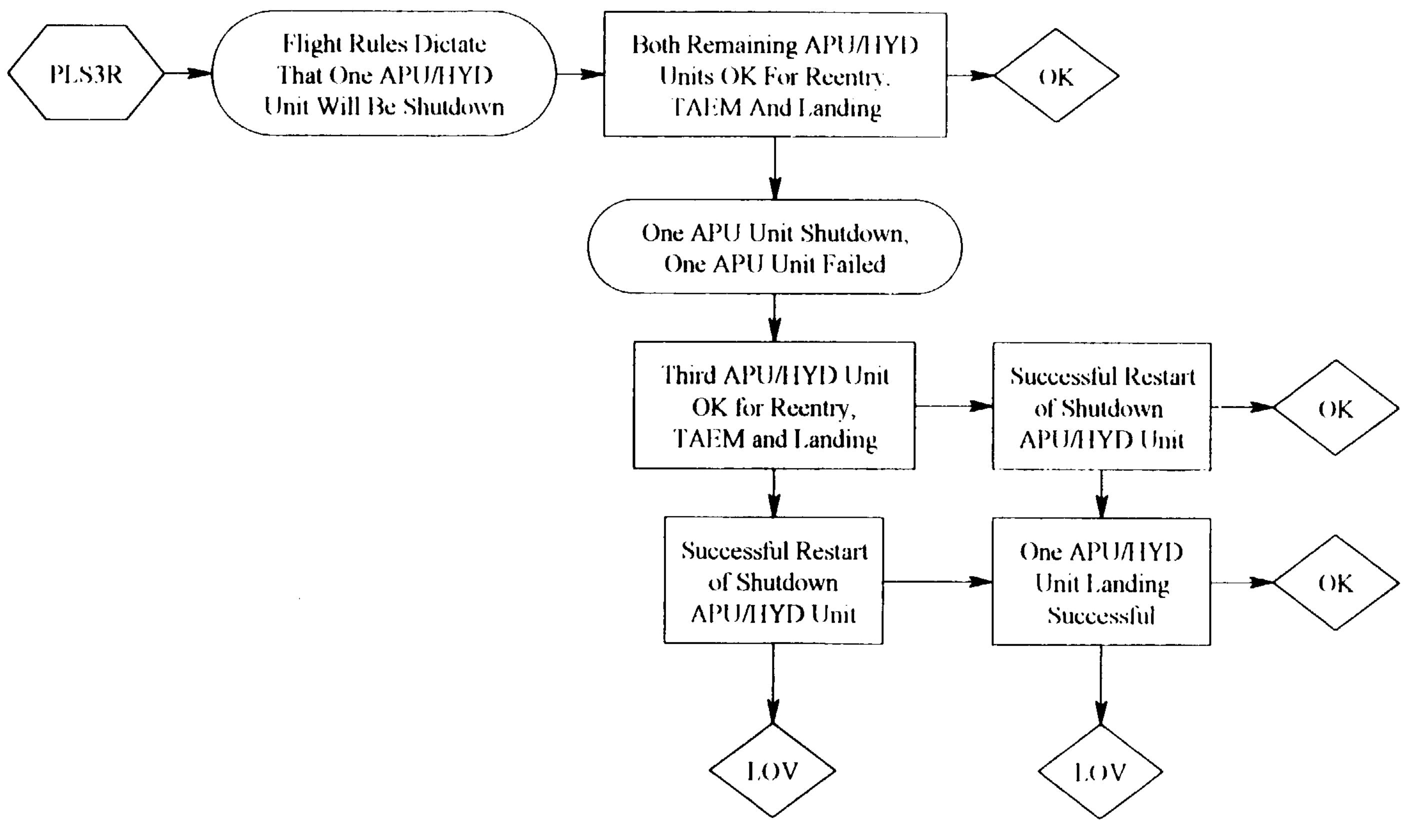
Fault Tree For Sequence 2 MDFU State From OK Start Without A Hydrazine Leak During Ascent



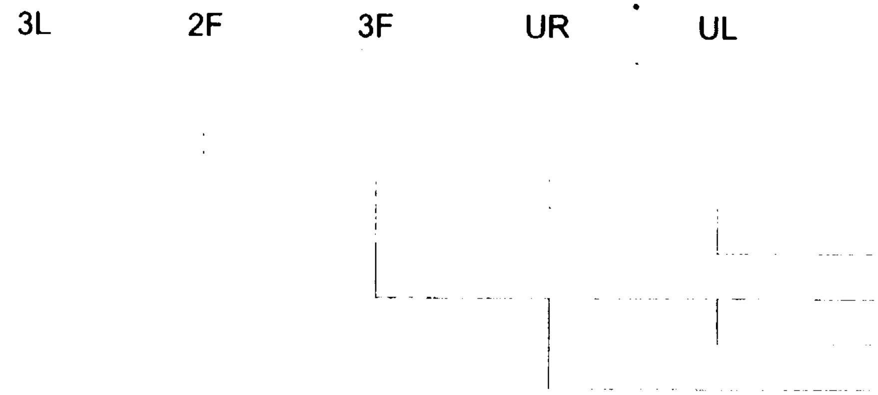
Fault Tree For Sequence 3 LOV State With PLSR2U Initiating Event During Reentry, TAEM and Landing



Event Sequence Diagram of a PLS3R State During Reentry, TAEM and Landing

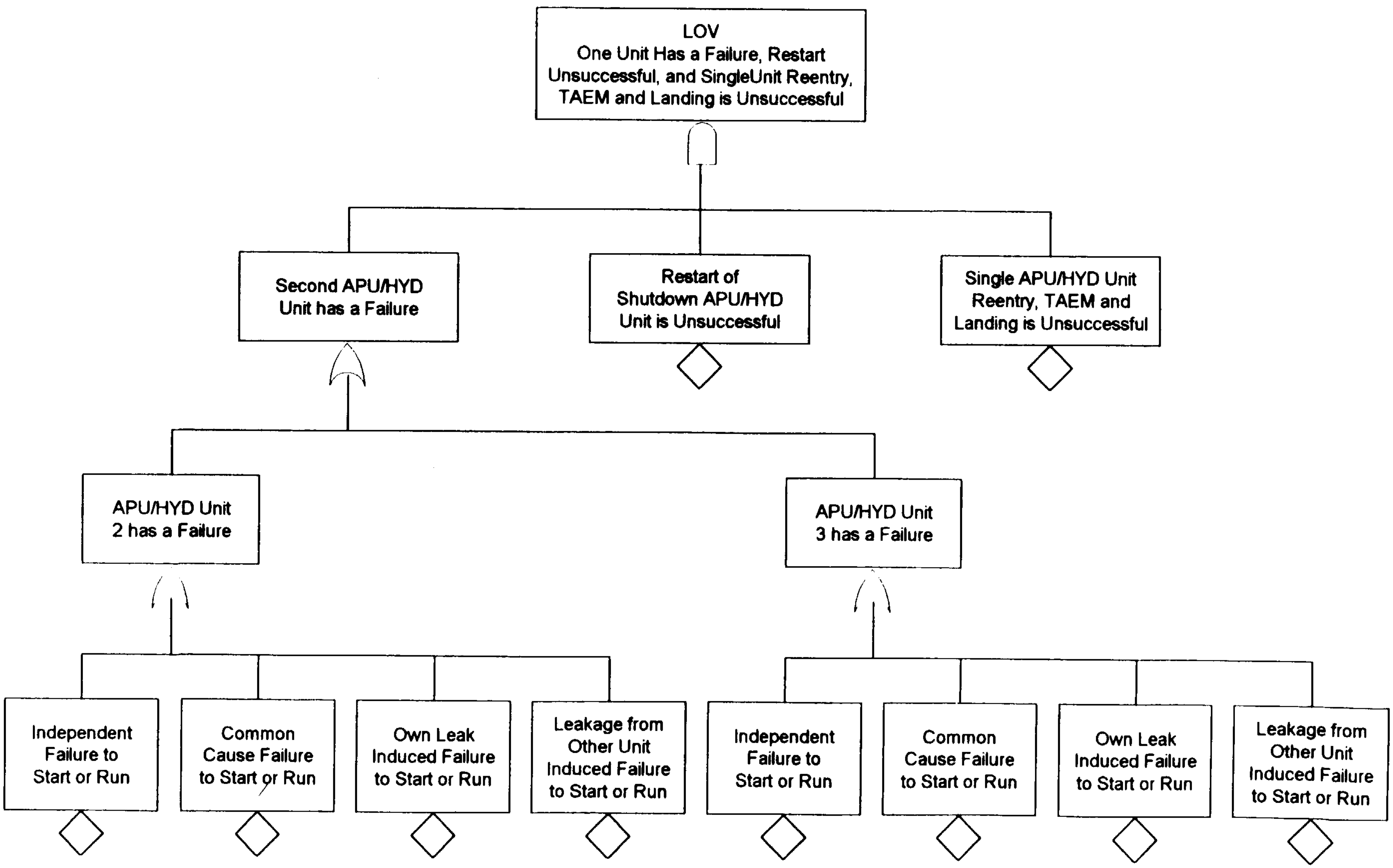


EVENT TREE OF A PLS3R INITIATING EVENT DURING REENTRY, TAEM AND LANDING

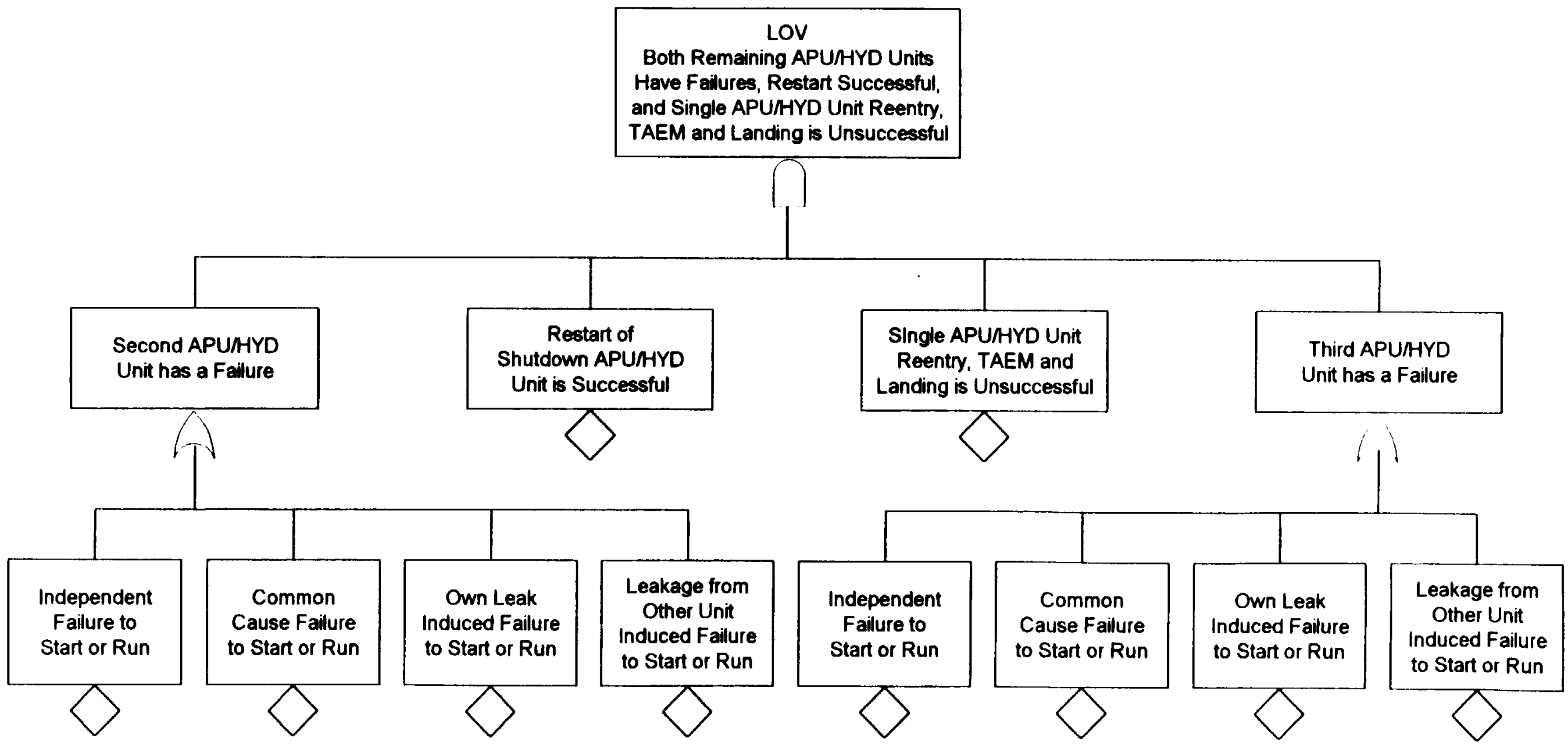


SEQUENCE NUMBER	SEQUENCE DESCRIPTION	STATE
1	3L	OK
2	3L2F	OK
3	3L2FUR	OK
4	3L2FURUL	LOV
5	3L2F3F	OK
6	3L2F3FUL	LOV
7	3L2F3FUR	LOV

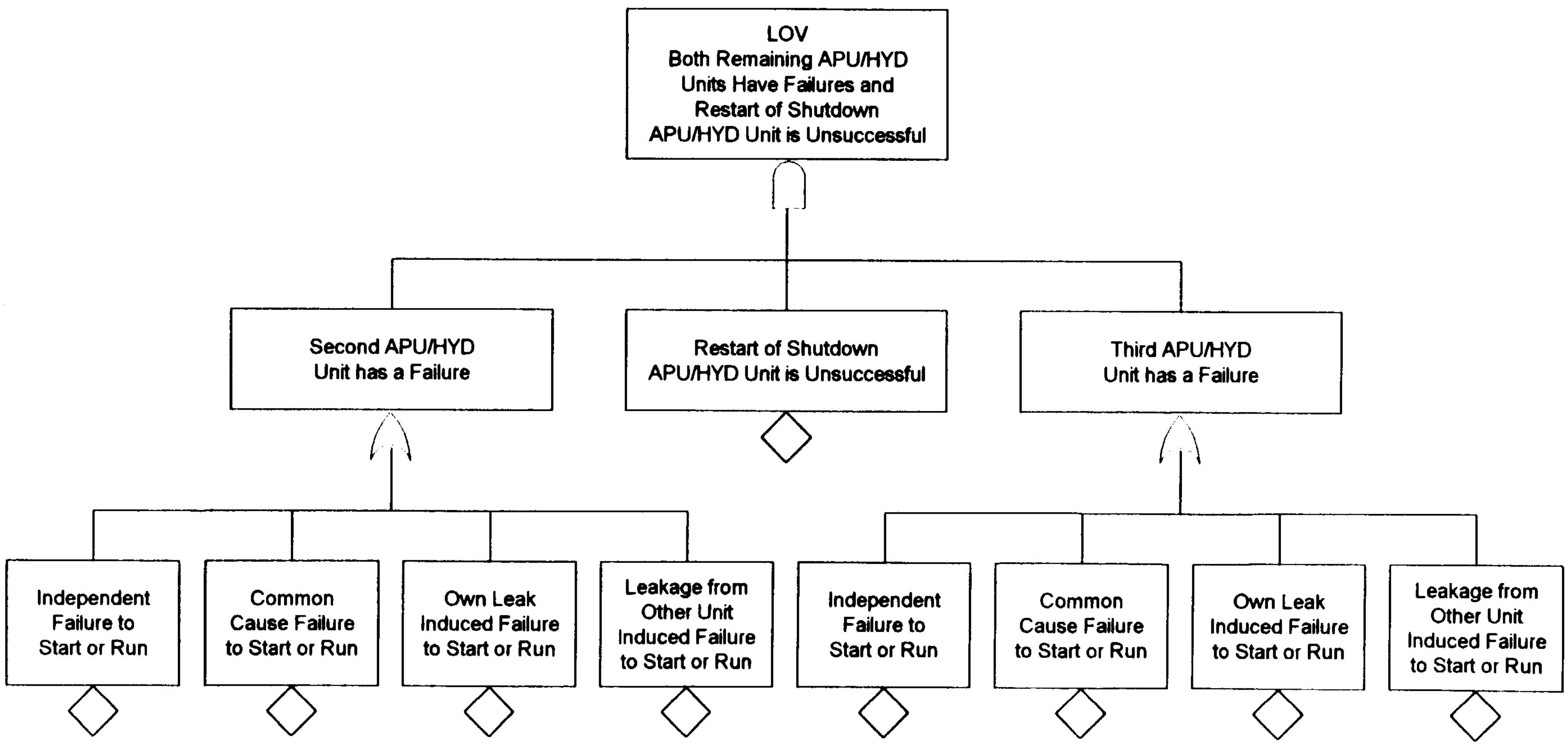
Fault Tree For Sequence 4 LOV State With A PLS3R Initiating Event During Reentry, TAEM and Landing



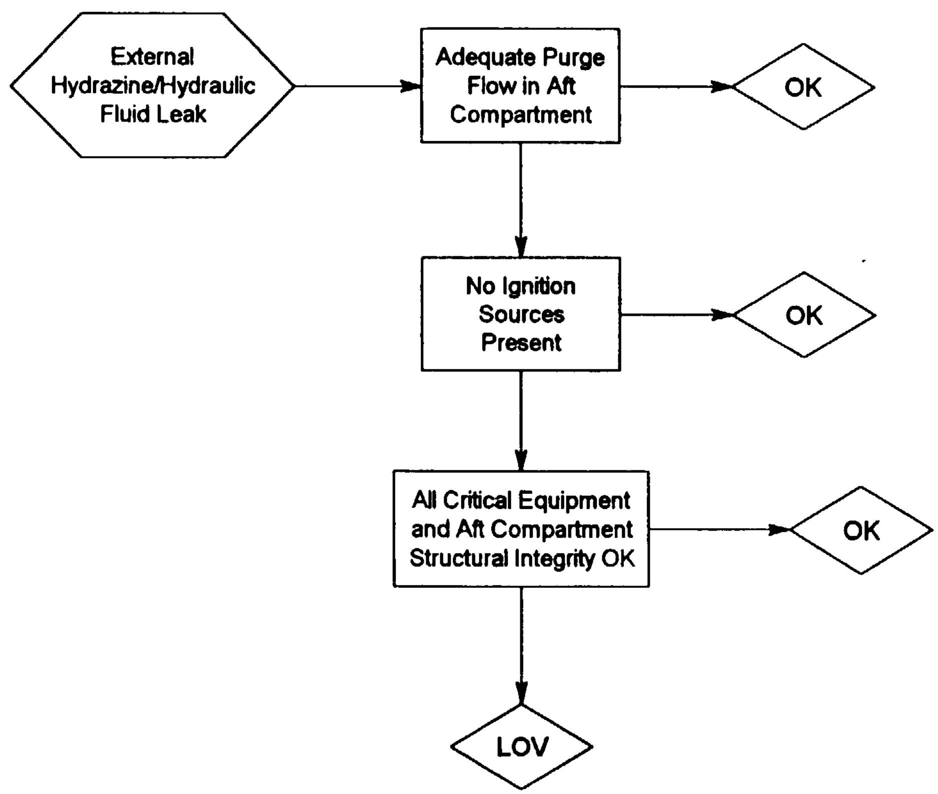
Fault Tree For Sequence 6 LOV State With A PLS3R Initiating Event During Reentry, TAEM and Landing



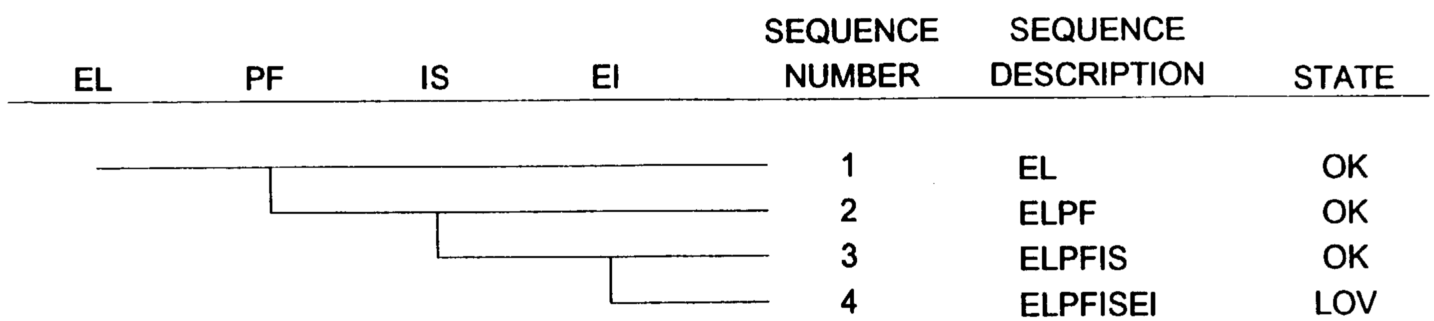
Fault Tree For Sequence 7 LOV State With A PLS3R Initiating Event During Reentry, TAEM and Landing



Event Sequence Diagram for an External Hydrazine or Hydraulic Fluid Leak



EVENT TREE OF AN EXTERNAL HYDRAZINE OR HYDRAULIC FLUID LEAK



B.4. Electrical Power System

ORBITER ELECTRIC POWER SYSTEM:
EVALUATION OF FAILURE MODES AND SEQUENCES POTENTIALLY SIGNIFICANT TO LOSS OF VEHICLE.
*See last page for key assumptions and risk classifications.

System failure	Failure sequence	Initiator or cause	Estimated sequence and state conditional probability /mission	Basis of screening conditional probability estimate	Risk class*	Comments
ELECTRIC POWER SYSTEM FUNCTIONAL FAILURE SEQUENCES:						
1. No or insufficient dc power to critical systems.	1.1.1. Shrapnel, jet impingement, or pipe whip causes either reactant manifold rupture or multiple reactant system ruptures and suddenly depletes one or both reactants for 2 fuel cells.	1.1. Violent rupture of reactant tank, piping, or valve.	2E-06	1.1.1. [1e-6/hr for violent rupture]*[168hrs for typical mission]*[1e-2 for severe consequential damage] = 1.7e-6/mission	Low	
Same	1.1.2. Shrapnel, jet impingement, or pipe whip disables 2 of 3 main distribution or mid power controller assemblies.	Same	2E-07	1.1.2 [1e-6/hr for violent rupture]*[168hrs for typical mission]*[1e-3 for severe consequential damage] = 1.7e-7/mission	Very low	
Same	1.2. 2 out of 3 fuel cells fail suddenly and concurrently (complete outage or insufficient voltage).	1.2.1. Undetected pre-flight fuel cell processing error.	1E-07	1.2.1. [1e-2 for processing error]*[1e-3 for failure to detect before launch]*[1e-2 for failure progressing too fast for recovery or abort] = 1e-7/mission.	Very low	Low P(failure to detect) because FCs run under load and voltage is monitored for considerable period before launch.
Same	Same	1.2.2. Concurrent unrecoverable loss of ECLSS freon loops 1 and 2 (disables fuel cell cooling).	2E-06	2.1.2. See note 2.	Low	See note 2.
Same	1.3. Severe sustained overload fails one fuel cell; crew transfers load to another cell, which also fails on overload.	1.3. Severe sustained electrical overload.	1E-08	1.3. [1e-3 for severe sustained overload]*[1e-2 for crew transferring overload to second cell]*[1e-3 for failing to notice and correct in time] = 1e-8/mission.	Negligible	Low P(failure to detect ov-erload) because overload this severe would cause symptoms obvious to crew.
Same	1.4. One (or both) fuel cell reactants is depleted before detection and isolation.	1.4.1. Severe spontaneous external leak or rupture of reactant manifold or associated valves, etc.	1E-08	1.4.1. [1e-6/hr for severe leak or rupture]* [168hrs for typical mission]* [1e-2 for failure to detect and isolate in time] = 1e-8/mission.	Negligible	
Same	Same	1.4.2. Relief valve on isolated re-actant manifold section spontan-eously fails closed, causing over-pressure and undetected rupture; isolation valve is then opened.	8E-07	1.4.2. [2e-6/hr for relief valve failure]*[168hrs for typical mission]*[0.5 for leak or rupture on overpressure]*[1e-2 for failure to detect]*[0.5 for opening isolation valve] = 8e-7/mission.	Very low	

ORBITER ELECTRIC POWER SYSTEM:
EVALUATION OF FAILURE MODES AND SEQUENCES POTENTIALLY SIGNIFICANT TO LOSS OF VEHICLE.
*See last page for key assumptions and risk classifications.

System failure	Failure sequence	Initiator or cause	Estimated sequence and state conditional probability /mission	Basis of screening conditional probability estimate	Risk class*	Comments
Same	Same	1.4.3. Multiple reactant tank relief valves fail open due to undetected pre-flight processing or pressure set-point error.	1E-05	1.4.3. [1e-3 for processing or set-point error]*[1e-2 for failure to detect before launch] = 1e-5/mission.	Moderate	
Same	Same	1.4.4. Severe sustained electrical overload depletes reactants before detection of overload or low reactant level.	1E-10	1.4.4. [1e-3 for severe overload]*[1e-4 for failure to detect overload before reactant depletion]*[1e-3 for failure to detect depletion in time] = 1e-10/mission	Negligible	Low P(failure to detect overload) because overload this severe would cause symptoms obvious to crew.
Same	1.5. 2 of 3 fuel cells or main busses turned off and not restored.	1.5. Crew error.	1E-09	1.5. [1e-5 for turning off FCs, main busses, or essential busses]*[1e-4 for failing to notice and correct] = 1e-9/mission.	Negligible	
Same	1.6. 2 of 3 dc distribution trains fail open.	1.6.1. Undetected, unrecoverable pre-flight processing error (e.g. failure to restore after testing, RPC setpoint error) in 2	1E-06	1.6.1. [1e-3 for unrecoverable processing error]*[1e-3 for failure to detect open before launch] = 1e-6/mission	Low	
Same	Same	1.6.2. Short circuit in one train propagates to second before interruption.	1E-11	1.6.2. [4e-4 for short circuit]*[1e-2 for vulnerable components of another train being close enough to allow propagation]*[5e-6 for failure to trip in time to prevent propagation] = 1e-11/mission	Negligible	See note 3 for basis of estimate of short circuit probability. P(failure to trip)=P(CB f.t. open on command)+P(prot. relay f.t. close)
Same	Same	1.6.3. Concurrent unrelated spontaneous failures of 2 trains.	6E-07	1.6.3. [8e-4 for failure of 1st train]*[8e-4 for failure of 2nd train] = 6e-7/mission.	Very low	Same basis of estimate as 1.5.2 except all failure modes considered.
2. No or insufficient ac power to critical systems.	2.1. 2 of 3 inverter sets fail suddenly (complete outage or unacceptable voltage, frequency, or waveform).	2.1.1. Undetected pre-flight processing error.	1E-06	2.1.1. [1e-2 for processing error]*[1e-4 for failure to detect before launch] = 1e-6/mission.	Low	

ORBITER ELECTRIC POWER SYSTEM:
EVALUATION OF FAILURE MODES AND SEQUENCES POTENTIALLY SIGNIFICANT TO LOSS OF VEHICLE.
*See last page for key assumptions and risk classifications.

System failure	Failure sequence	Initiator or cause	Estimated sequence end state conditional probability /mission	Basis of screening conditional probability estimate	Risk class*	Comments
Same	Same	2.1.2. Concurrent unrevoverable loss of ECLSS H2O cooling loops 1 and 2 disables inverter cooling.	2E-06	2.1.2. See note 2.	Low	See note 2.
Same	2.2. Mid-deck power components of 2 or 3 trains overheat and fail.	2.2. Concurrent unrecoverable loss of ECLSS freon cooling loops 1 and 2 disables mid-deck power component cooling.	2E-06	2.1.2. See note 2.	Low	See note 2.
Same	2.3. 2 of 3 inverters or ac busses turned off and not restored.	2.3. Crew error.	1E-09	2.3. [1e-5 for turning off inverters or busses]*[1e-4 for failing to notice and correct] = 1e-9/mission.	Negligible	
Same	2.4. Shrapnel, jet impingement, or pipe whip disables 2 or 3 trains of mid-deck power components.	2.4. Violent rupture of reactant tank, piping, or valve.	2E-07	2.4. [1e-6/hr for violent rupture]*[168hrs for typical mission]*[1e-3 for severe consequential damage] = 1.7e-7/mission	Very low	
Same	2.5. 2 of 3 ac distribution trains fail open.	2.5.1-2.5.3. Analogous to 1.6.1-1.6.3 above.	2E-07	2.5.1-2.5.3. 1.6e-7/mission.	Very low	Estimated by analogy to 1.6.1-1.6.3 above. Note: short circuit propagation is impossible because inverters lack necessary short circuit capacity.

ORBITER ELECTRIC POWER SYSTEM:
EVALUATION OF FAILURE MODES AND SEQUENCES POTENTIALLY SIGNIFICANT TO LOSS OF VEHICLE.

*See last page for key assumptions and risk classifications.

System failure	Failure sequence	Initiator or cause	Estimated sequence end state conditional probability /mission	Basis of screening conditional probability estimate	Risk class*	Comments
SEQUENCES INITIATED BY ELECTRIC POWER SYSTEM						
3. Electrical fire damage to other systems.	3. Electrical short circuit or component overheating initiates uncontrolled fire that unrecoverably disables other critical system(s).	3.1. Undetected pre-flight processing error.	5E-12	3.1. [1e-2 for fire-initiating processing error]*[1e-2 for failure to detect before launch]*[1e-3 for failure to trip]*[1e-3 for presence of nearby combustibles when O2 is available]*[0.5 for ignition]*[0.1 for failure of fire suppression] = 5e-12/mission	Negligible	
Same	Same	3.2. Spontaneous component failure.	5E-11	3.2. [1e-3 for fire-initiating component failure]*[1e-3 for failure to trip]*[1e-3 for presence of nearby combustibles when O2 is available]*[0.5 for ignition]*[0.1 for failure of fire suppression] = 5e-11/mission	Negligible	
4. Crew is disabled by fire suppression system response to electrical fire.	4. Electrical short circuit or component overheating initiates Halon flood of crew compartment; Halon exposure disables crew.	4.1. Undetected pre-flight processing error.	1E-12	4.1. [1e-2 for fire-initiating processing error]*[1e-2 for failure to detect before launch]*[1e-3 for failure to trip]*[1e-3 for crew susceptibility to Halon]*[1e-2 for failure to don breathing apparatus in time] = 1e-12/mission	Negligible	
Same	Same	4.2. Spontaneous component failure.	1E-11	4.2. [1e-3 for fire-initiating component failure]*[1e-3 for failure to trip]*[1e-3 for crew susceptibility to Halon]*[1e-2 for failure to don breathing apparatus in time] = 1e-11/mission	Negligible	
5. Critical systems are disabled by fire suppression system response to electrical fire.	5. Electrical short circuit or component overheating initiates Halon flood of affected compartment; presence of Halon or its decomposition products damages critical components or disables equipment cooling.	5.1. Undetected pre-flight processing error.	1E-12	5.1. [1e-2 for fire-initiating processing error]*[1e-2 for failure to detect before launch]*[1e-3 for failure to trip]*[1e-3 for crew susceptibility to low Halon concentration]*[1e-2 for failure to don breathing apparatus in time] = 1e-12/mission	Negligible	

ORBITER ELECTRIC POWER SYSTEM:
EVALUATION OF FAILURE MODES AND SEQUENCES POTENTIALLY SIGNIFICANT TO LOSS OF VEHICLE.
*See last page for key assumptions and risk classifications.

System failure	Failure sequence	Initiator or cause	Estimated sequence end state conditional probability /mission	Basis of screening conditional probability estimate	Risk class*	Comments
Same	Same	5.2. Spontaneous component failure.	1E-11	5.2. [1e-3 for fire-initiating component failure]*[1e-3 for failure to trip]*[1e-3 for crew susceptibility to Halon]*[1e-2 for failure to don breathing apparatus in time] = 1e-11/mission	Negligible	
6. Orbiter structural failure.	6. Severe leak or rupture of fuel cell reactant tanks or associated piping and valves overpressurizes confined space leading to structural failure.	6. Rupture or severe external leak of tank, piping, or valve.	2E-06	6. [1e-6/hr for violent rupture]*[168hrs for typical mission]*[1e-2 for severe consequential damage] = 1.7e-6/mission	Low	
7. Mechanical damage to other systems.	7. Shrapnel, jet impingement, or pipe whip unrecoverably disables other nearby critical system(s).	7. Rupture or severe external leak of tank, piping, or valve.	2E-06	7. [1e-6/hr for violent rupture]*[168hrs for typical mission]*[1e-2 for severe consequential damage] = 1.7e-6/mission	Low	
	Total end-state conditional probabilities of all sequences listed		3E-05			

NOTES:

1. Key assumptions: (1) probability estimates are based on IEEE Std 500-1984, IEEE Std 493-1990, and conservative (high) SAIC engineering estimates; (2) typical exposure is one-week (168-hour) mission time; (3) per PRA ground rules, only catastrophic failures leading to loss of vehicle (not abort) are considered; (4) loss of 2 of 3 power trains causes LoV.

2. Concurrent ECLSS freon loop failures: zero failures in 55 flights implies mean failure frequency is 3.03e-3 per flight per loop (using 1/3 failure approximation to zero). Assume 50% of failures are common cause/common mode. Double concurrent failure frequency is therefore 4.6e-6 per flight. Assuming 50% are recoverable, unrecoverable rate is 2.3e-6.

3. Estimate of probability of short circuit in distribution system: Assume each train comprises 6 equivalent circuit breakers, 1000 circuit feet of wire with 30 connections and splices, bare bars equivalent to 50 CB units. IEEE 493 App. A mean failure rates per unit/year: LV fixed CB=0.0035, LV cable=0.00141/1000ft, LV cable connection=0.000127, LV bus=0.00034 per equiv. CB unit. Assume 50% of failures are short circuits. P(short circuit)=0.50*[(168hrs/mission)/(8766hrs/yr)]*[6*0.0035+1*0.00141+30*0.000127+50*0.00034]≈4e-4 per mission.

DEFINITIONS OF RISK CLASSES:	P(sequence end state equivalent to LoV)
Severe	P>=1e-2
Very high	1e-3<=P<1e-2
High	1e-4<=P<1e-3
Moderate	1e-5<=P<1e-4
Low	1e-6<=P<1e-5
Very low	1e-7<=P<1e-6
Negligible	P<1e-7