ATK ALLIANT TECHSYSTEMS
THIOKOL PROPULSION

CRITICAL ITEMS LIST (CIL)

No. 10-05-02-11R/01

SYSTEM:	Space Shuttle RSRM 10	CRITICALITY CATEGORY:	1R
SUBSYSTEM:	Assembly Hardware/Interfaces 10-05	PART NAME:	Case-to-Nozzle Joint, Primary O-ring, Secondary O-ring (2)
ASSEMBLY:	Case-to-Nozzle Interface 10-05-02		
FMEA ITEM NO.:	10-05-02-11R Rev M		
CIL REV NO.:	M (DCN-533)	PART NO.:	(See Section 6.0)
DATE:	10 Apr 2002	PHASE(S):	Boost (BT)
SUPERSEDES PAGE:	356-1ff.	QUANTITY:	(See Section 6.0)
DATED:	31 Jul 2000	EFFECTIVITY:	(See Table 101-6)
CIL ANALYST:	R. E. L. Hamilton	HAZARD REF.:	BC-04
APPROVED BY:		DATE:	

RELIABILITY ENGINEERING: K. G. Sanofsky 10 Apr 2002

ENGINEERING: B. H. Prescott 10 Apr 2002

1.0 FAILURE CONDITION: Failure during operation (D)

2.0 FAILURE MODE: 1.0 Leakage of primary O-ring and secondary O-ring

3.0 FAILURE EFFECTS: Failure of the system would result in hot gasses eroding joint metal components creating a large hole and allowing gas to escape resulting in a motor chamber pressure decrease and expulsion of nozzle. Side thrust, thrust imbalance, or loss of TVC leading to loss of RSRM, SRB, crew, and vehicle

4.0 FAILURE CAUSES (FC):

FC NO.	DESCRIPTION	FAILURE CAUSE KEY
1.1	Nonconforming O-ring dimensions or improper O-ring splice or repair	A
1.2	O-ring gland does not meet dimensional or surface finish requirements	B
1.3	O-ring improperly installed, cut, or damaged	C
1.4	Transportation, handling, or assembly damage	D
1.5	Sealing surfaces contamination or corrosion	E
1.6	Nonconforming O-ring voids, inclusions, or subsurface indications	F
1.7	Age degradation of O-ring	G
1.8	Moisture and/or fungus degradation of O-ring	H
1.9	Nonconforming physical or mechanical properties	I
1.10	Improper preload	J

5.0 REDUNDANCY SCREENS:

SCREEN A: Pass--The leak test procedure verifies the primary O-ring and secondary O-ring seal.
SCREEN B: Fail--No provision is made for failure detection by the crew.
SCREEN C: Pass--The primary and secondary O-ring seal can not be lost due to a single credible cause.

1. The Case-to-Nozzle Joint Primary O-ring and Secondary O-ring, together, form a redundant seal system when the leak check port seals. The secondary O-ring will see no pressure unless the primary O-ring fails. If the primary O-ring fails, the secondary O-ring will be pressurized and will still maintain a seal. If both the primary O-ring and the secondary O-ring fail, a leak path will exist and could result in loss of crew and vehicle.

6.0 ITEM DESCRIPTION:

1. The Case-to-Nozzle Joint includes a primary O-ring and a secondary O-ring as shown by engineering drawing (Figures 1 and 2). Materials are listed in Table 1.

TABLE 1. MATERIALS

Drawing No.	Name	Material	Specification	Quantity
1U75150	Packing, Preformed Fluorocarbon	Black Fluorocarbon Rubber	STW4-3339	1/motor
1U51916	Cartridge Assembly	Heavy-duty Calcium Grease, Filtered and Placed in an Application Cartridge	STW7-3657	A/R
1U52945	Housing, Nozzle-Fixed			1/motor
1U50129	Case Segment, Aft			1/motor
1U75801	Packing, Lubricated	Black Fluorocarbon Rubber O-ring and Lubricant	STW7-2999	1/motor
	Corrosion-Preventive Compound and O-ring Lubricant	Heavy-Duty Calcium Grease	STW5-2942	A/R
1U77640	Segment Assembly, Rocket Motor, Aft			1/motor

6.1 CHARACTERISTICS:

1. The Nozzle-to-Case Joint allows the nozzle assembly to be mounted to the aft case segment. The unit is assembled with O-rings and bolts to assure that there is no leakage after assembly.

2. The seals at the Nozzle-to-Case Joint are designed so that the O-ring maintains constant contact with its cavity at all times. Squeeze, fill, and tracking are taken into account, relating to O-ring groove tolerance.

3. The O-ring is specified as a one-time-use item.

4. The joint and seals are an important part of the assembled rocket motor case. The assembled RSRM is a combustion chamber made up of segments and the nozzle. It is sealed with O-rings, and must contain and direct pressure generated by burning propellant.

7.0 FAILURE HISTORY/RELATED EXPERIENCE:

1. Current data on test failures, flight failures, unexplained failures, and other failures during RSRM ground processing activity can be found in the PRACA database.

8.0 OPERATIONAL USE: N/A

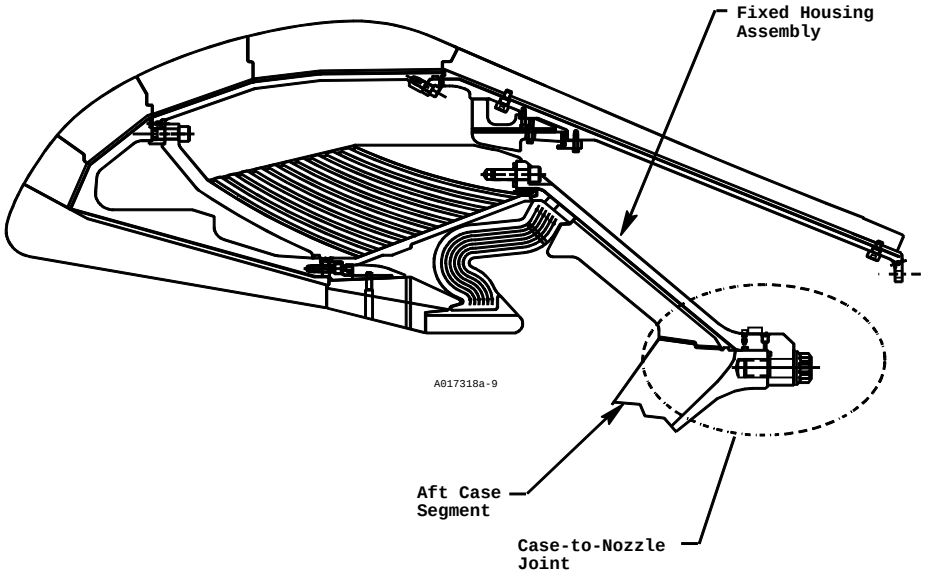

Figure 1. Case-to-Nozzle Joint Location

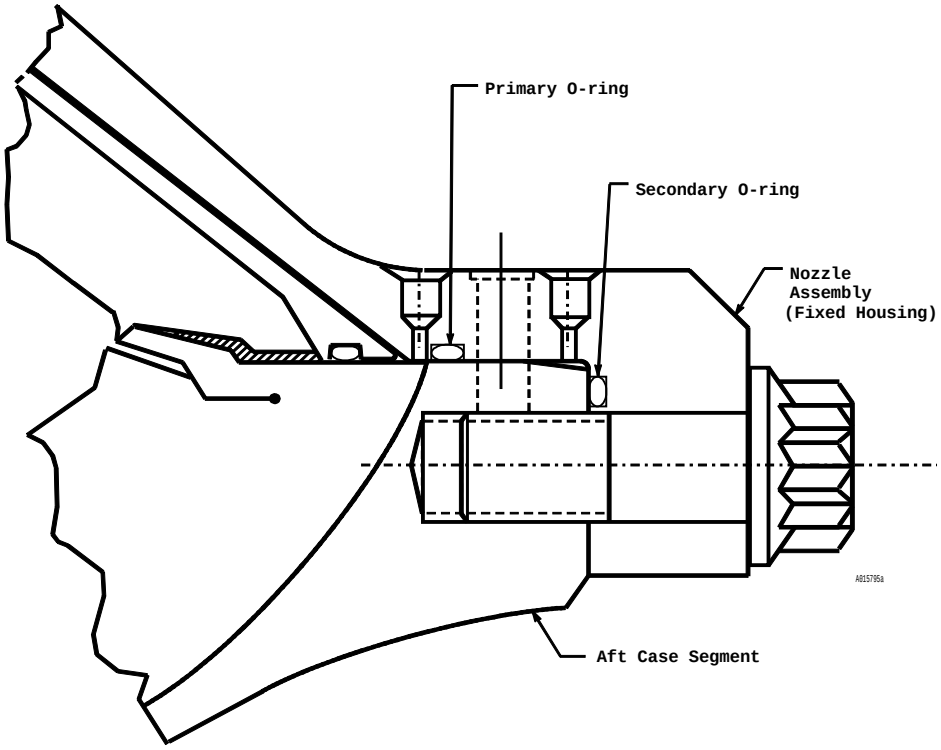

Figure 2. Case-to-Nozzle Joint, Primary and Secondary O-rings

9.0 RATIONALE FOR RETENTION:

9.1 DESIGN:

DCN	FAILURE CAUSES	
A	1.	Criteria determining O-ring dimensions are found in TWR-15771.
A	2.	Both O-ring designs provide a constant contact between the O-ring and mating segment sealing surfaces.
A,F	3.	Large O-rings conform to engineering that establishes geometric dimensions and fabrication details.
A	4.	Large O-rings conform to engineering that covers process controls for fabrication of spliced joints and repairs.
A	5.	Splice joints are cut on a specified angle and bonded together in a mold (using 100 percent of the scarf area) using an adhesive with the same physical and chemical properties as the parent stock.
A,F	6.	O-rings were tested to determine size and types of flaws that could cause sealing problems. Results are published in TWR-17750.
B	7.	Primary and secondary O-ring glands are established per engineering drawings, and conform to Thiokol Design Engineering dimensions and calculations for squeeze, fill, and tracking per TWR-15771.
B	8.	Design verification analysis of data from live firing tests per TWR-16534 and TWR-17563 shows that O-ring sealing surfaces are acceptable for flight use as reported in TWR-18764-02.
B	9.	Sealing surface requirements during refurbishment are established per engineering drawings.
C	10.	Large O-rings are individually packaged. a. Per engineering drawings prior to lubrication. b. Per engineering drawings after lubrication.
C	11.	Both O-ring designs provide a constant contact between the O-ring and mating segment sealing surfaces.
C	12.	Material selection was based in part on resistance to damage as documented in TWR-17082.
C	13.	Design development testing regarding O-ring twisting and its effect on performance was performed per ETP-0153, with the results documented in TWR-17991.
D	14.	Transportation and handling of nozzle assembly items by Thiokol is detailed per IHM 29.
D	15.	The RSRM and its component parts, when protected per TWR-10299 and TWR-11325, are capable of being handled and transported by rail or other suitable means to and from fabrication, test, operational launch, recovery, retrieval, and refurbishment sites.
D	16.	Positive cradling or support devices and tie downs that conform to shape, size,

weight, and contour of components to be transported are provided to support RSRM segments and other components. Shock mounting and other protective devices are used on trucks and dollies to move sensitive loads per TWR-13880.

D 17. Support equipment used to test, handle, transport, and assemble or disassemble the RSRM is certified and verified per TWR-15723.

D 18. Analysis is conducted by Thiokol engineering to assess vibration and shock load response of the RSRM nozzle during transportation and handling to assembly and launch sites per TWR-16975.

D 19. The nozzle assembly is shipped in the aft segment. Railcar transportation shock and vibration levels are monitored per engineering and applicable loads are derived by analysis. Monitoring records are evaluated by Thiokol to verify shock and vibration levels per MSFC specification SE-019-049-2H were not exceeded. TWR-16975 documents compliance of the nozzle with environments per MSFC specifications.

D,E,H 20. Protection of leak check vent port threads from damage and contamination during handling is provided by installed protective plugs. The protective plugs are removed when leak tests are performed and flight plugs are installed. Inspections are performed to verify no transportation or handling damage.

E 21. Corrosion preventative compound is applied to all sealing surfaces per engineering.

E 22. Filtered grease is applied to all sealing surfaces per engineering.

E 23. Filtered grease filtering is per engineering to control contamination.

E 24. Removal of surface contamination and corrosion is a standard shop practice used whenever contamination and corrosion is noted.

E 25. Contamination control requirements and procedures are described in TWR-16564.

G 26. Fluorocarbon rubber O-rings are suitable for periods of storage of up to 20 years (O-ring Handbook, ORD 5700, Copyright 1982, by Parker Seal Group, Lexington, KY). Environment and age is significant to useful seal life, both in storage and actual service.

a. O-rings are packaged and stored to preclude deterioration caused by ozone, grease, ultraviolet light, and excessive temperature.

G 27. Large O-ring time duration of supplier storage and total shelf life prior to installation is limited per engineering.

G 28 Aging studies of O-rings after 5 years installation life were performed. Test results are applicable to all RSRM fluorocarbon seals. Fluorocarbon maintained its tracking ability and resiliency. Fluorocarbon was certified to maintain its sealing capability over 5 years per TWR-65546.

G 29. The O-ring is specified as one-time-use.

G 30. Grease is stored at warehouse-ambient condition that is any condition of temperature and relative humidity experienced by the material when stored in an enclosed warehouse, in unopened containers, or containers that were resealed after each use. Storage life under these conditions is per engineering.

G 31. Aging studies to demonstrate characteristics of grease after 5 years installation life

were performed on TEM-9. Results showed that grease provided adequate corrosion protection for D6AC steel, and that all chemical properties of grease remained intact per TWR-61408 and TWR-64397.

G	32.	Large O-rings and filtered grease are included in the aft segment life verification.
H	33.	O-ring swell is negligible unless the O-ring undergoes a long period of water immersion (O-ring Handbook, ORD 5700, Copyright 1982, by Parker Seal Group, Lexington, KY).
H	34.	Fluorocarbon rubber is a non-nutrient to fungus growth (O-ring Handbook, ORD 5700, Copyright 1982, by Parker Seal Group, Lexington, KY).
H	35.	Large O-rings are kept dry and clean prior to packaging.
H,I	36.	Large O-rings are high-temperature, low-compression set, fluid-resistant, black fluorocarbon rubber.
I	37.	Filtered grease material requirements are per engineering.
I	38.	Temperature prior to launch is monitored for the nozzle flexible bearing and case-to-nozzle joint and is maintained to requirements established per TWR-15832. Joint thermal analysis (o-ring resiliency testing) is documented in TWR-16818.
J	39.	Snug torque values, installation sequence, and angle of rotation for the axial and radial bolts of the nozzle-to-case joint are per engineering. The bolt loading method was qualified per TWR-66211 and TWR-66738.
J	40.	Nozzle-to-case joint radial and axial bolts are refurbished per engineering.
J	41.	Structural analyses per TWR-16975 show that all metal components of the joint have a positive margin of safety based on factors of safety of 1.4 on ultimate and 1.1 on yield.
J	42.	The nozzle-to-case joint axial bolt is heat treated Inconel 718. Requirements are for tensile and yield strength.
J	43.	Radial bolt Material is heat treated MP35N alloy steel per AMS specifications.
J	44.	Aft Dome internal threads at the case-to-nozzle joint must satisfy thread requirements for new and refurbished Aft Domes per engineering. Threads will have no damage or defects greater than that called out in engineering. Threads are inspected after proof testing.
J	45.	New and refurbished Aft Domes are proof tested per engineering. Aft Dome threads are loaded in this test.
J	46.	Thread damage repair requires Discrepancy Report and Material Review Board action per engineering. Helical inserts may be used per engineering.
J	47.	Nozzle-to-Case bolt preload controls the joint gap opening when dimensions and allowable surface defects are within limits per engineering. Thermal analysis per TWR-17016, TWR-73594 and testing demonstrates that controlled gap opening (less then 0.004 inch) reduces the temperature of motor gas to the primary O-ring and greatly reduces gas temperature at the secondary O-ring.
A,B,D	48.	Analysis of carbon-cloth phenolic ply angle changes for the nozzle was performed. Results show that redesigned nozzle phenolic components have a reduced in-

plane fiber strain and wedge-out potential per TWR-16975. New loads that were driven by the Performance Enhancement (PE) Program were addressed in TWR-73984. No significant effects on the performance of the RSRM nozzle were identified due to PE.

533 A,B,D 49. Thermal analysis per TWR-17219 shows the nozzle phenolic meets the new performance factor equation based on the remaining virgin material after boost phase is complete. This performance factor will be equal to or greater than a safety factor of 1.4 for the fixed housing assembly per TWR-74238 and TWR-75135. (Carbon phenolic-to-glass interface, bondline temperature and metal housing temperatures were all taken into consideration). The new performance factor will insure that the CEI requirements will be met which requires that the bond between carbon and glass will not exceed 600 degree F, bondline of glass-to-metal remains at ambient temperature during boost phase, and the metal will not be heat affected at splashdown.

A,B,D 50. TWR-61410 was updated to include boundary conditions created by the Performance Enhancement (PE) Program. This report analyzed temperature conditions created from flight loads. PE temperatures are equal to current generic temperatures for all locations for the critical time of liftoff. For a few locations at the factory joints and case acreage during flight, temperatures rise, but only slightly, and maximum case temperatures are lower than current generic certification. For flight load events, PE temperatures are not significantly different from current generic temperatures. There is no impact on previous analyses or margins of safety for case membranes, factory joints, and field joints per TWR-61410.

9.2 TEST AND INSPECTION:

DCN	FAILURE CAUSES and TESTS (T)			CIL CODES
		1.	For New Large O-ring verify:	
A		a.	Diameter	AEB014,AEB015,AEB018,AEB023,AEB026,AEB027
A		b.	Correct identification	AEB087,AEB100
A		c.	Splice is bonded over 100 percent of the scarf area	AEB133,AEB134
A		d.	No more than five splices	AEB167,AEB169
A		e.	Repairs	AEB265,AEB266
A		f.	Adhesive is made from fluorocarbon rubber	AEB308,AEB311
A		g.	Splice bond integrity	AEB317,AEB319
A,F	(T)	h.	Subsurface indications	AEB354
A,C,F,H		i.	Surface quality	AEB388,AEB389
A,I	(T)	j.	Tensile strength	AEB401,AEB402
A,I	(T)	k.	Ultimate elongation	AEB442,AEB443
G,H		l.	Packaging for damage or violation	AEB179
G,H,I		m.	Material is fluorocarbon rubber	AEB151,AEB141
C,G,H		n.	Packaging is free of staples or other objects	LAA054
H		o.	Clean and dry when packaged	AEB031,AEB034
I	(T)	p.	Shore A hardness	AGM304,AGM312
I	(T)	q.	Compression set	AKW006,AKW011
		2.	For New Segment, Rocket Motor, Aft verify:	
A,B,C, D,E,F	(T)	a.	Joint seals leak test results	AGJ157
C		b.	Installation and fit of O-rings	AGJ123,AGJ124
C		c.	All O-ring installation clips are removed just prior to seating nozzle assembly with Aft Case Segment	AGJ213
C,E		d.	Application of lubricant to Fixed Housing aft end O-ring grooves	AGJ060
C,E		e.	Application of lubricant to O-rings	AGJ056,AGJ056A
C		f.	Primary and secondary O-rings are unpackaged, processed, and installed one at a time	AGJ181
C		g.	O-rings are free from damage	AGJ183,AGJ189
C		h.	No visible damage of O-ring after installation into O-ring groove	AGJ188,AGJ221
D		i.	O-ring grooves in Fixed Housing aft end are free from damage	AGJ175
D		j.	Aft end sealing surfaces on case segment are free from damage	LAA083
E		k.	Aft boss sealing surfaces on case segment are free from contamination and corrosion	AGJ006
E		l.	O-ring grooves in Fixed Housing aft end are free from contamination and corrosion	AGJ174
G		m.	Shelf life of the lubricant	LAA088
G		n.	O-ring storage life	AGJ222,AGJ223
G		o.	O-ring packaging was not damaged or violated	AGJ195,AGJ195A
H		p.	O-ring grooves in the Fixed Housing aft end are free from fungus and moisture	AGJ192,AGJ194
H		q.	O-rings are free from fungus and moisture	LAA106,LAA107,
J		r.	Aft Segment Boss and Fixed Housing aft end holes are clean and free from debris and foreign matter prior to assembly	AGJ007
J		s.	Aft Segment Boss and Fixed Housing Aft end holes are free from damage including scratches, pits, galls, and burrs prior to assembly	AGJ104
J		t.	Proper location of all bolts	AGJ205
J		u.	Axial and Radial bolts are tightened with a snug torque and angle-of-twist	AGJ238
J		v.	Axial bolts are coated with lubricant on grips and under heads	AGJ075

J		w.	Radial bolts are coated with lubricant on grips and under heads	AGJ209
J		x.	Molykote spray lubricant is applied to the threads of the axial bolts and air dried before installation per the process specification	LHA047
J		y.	Molykote spray lubricant is applied to the threads of the radial bolts and air dried before installation per the process specification	LHA048
H		z.	Secondary O-ring is free from moisture prior to installation	LAA142
H		aa.	Secondary O-ring is free from fungus prior to installation	LAA156
H		ab.	Secondary O-ring is free from contamination prior to installation	LHA204

3. For New Case Segment, Aft, verify:

B		a.	Surface finish of aft boss O-ring sealing surfaces	AAJ072
J		b.	Flatness of Datum -G-	AAJ062,AAJ063
J	(T)	c.	Axial and radial threaded bolt holes are eddy-current inspected after hydroproof, and all non-conforming conditions are dispositioned	AAJ051
J		d.	Depth of threads in aft boss threaded holes	AAJ038,AAJ039
J		e.	Tap drill depth of aft boss threaded holes	AAJ036,AAJ167
J		f.	Axial and radial threaded holes with Go-No-Go gauge after hydroproof	AAJ010

4. For Refurbished Case Segment, Aft, verify:

B		a.	Surface finish of aft boss O-ring sealing surfaces	AAJ157
J		b.	Axial and radial threaded holes with Go-No-Go gauge after hydroproof	AAJ011
J	(T)	c.	Axial and radial threaded bolt holes are eddy-current inspected after hydroproof, and all non-conforming conditions are dispositioned	RAA208

5. For New Housing, Nozzle-Fixed verify:

B		a.	Surface finish	ADV002A,ADV144A,ADV164,ADV167
B		b.	Diameter	ADV048,ADV049
B		c.	O-ring groove depth	ADV139,ADV139A,ADV140,ADV140A
B		d.	O-ring groove diametric location	ADV141A,ADV142A
B		e.	O-ring groove width	ADV145,ADV145A,ADV146,ADV146A
J	(T)	f.	Ultimate tensile strength	ADV213
J	(T)	g.	Yield strength	ADV229
J		h.	Flatness	ADV039,ADV040,ADV042,ADV043

6. For Refurbished Housing, Nozzle Fixed verify:

B		a.	Surface finish	ADV192

7. For New O-ring, Lubricated verify:

C,G,H		a.	O-ring packaging is not damaged or violated	LAA103
C		b.	O-ring is cleaned and lubricated per drawing requirements	LAA104
C		c.	O-ring is packaged per drawing requirements	LAA105

8. For New Filtered Grease verify:

E,G,H,I,J		a.	Grease is received from storage unopened or resealed	ACP015
E,G,H,I		b.	Shelf life of the grease, prior to filtering	AMB018L
E,G,H,I		c.	Contamination	ANO064
E,G,H,I		d.	Grease conforms to specification	LAA044

E,G,H,I		e.	Cartridge conforms to drawing	LAA046
E,G,H,I,J		f.	Filtered grease is capped and sealed after filling	LAA047
E,G,H,I,J		g.	Filtered grease is sent to storage capped and sealed (recapped and resealed)	LAA063
		9.	For New Grease verify:	
E,G,H		a.	Material received in closed containers	ANO015
G,H,I		b.	Type	ANO050
G		c.	No shipping or handling damage	ANO058
I	(T)	d.	Penetration	LAA037
I	(T)	e.	Dropping point	ANO042
I	(T)	f.	Zinc concentration	LAA038
		10.	For New Bolt, Case/Nozzle verify:	
J		a.	Chemical composition	AGE003
J		b.	Mechanical properties after heat treat	AGE010
J		c.	Material is Inconel 718	AGE020
		11.	For Refurbished Bolt, Case/Nozzle verify:	
J		a.	Threads	AGE017
J		b.	Surface defects	AGE006
J		c.	Part is acceptable	AGE034
		12.	For New Bolt, Machine verify:	
J	(T)	a.	Ultimate tensile strength	AEI040
J	(T)	b.	Material and chemical composition	AEI018
J		c.	Threads	AEI016,AEI017
		13.	For Refurbished Bolt, Machine verify:	
J		a.	Threads	AEI015
J		b.	Surface defects	AEI004A
J		c.	Part is acceptable	AEI501
		14.	KSC verifies:	
G		a.	Life requirements for the expected launch schedule are met per OMRSD File II, Vol III, C00CA0.030.	OMD019