Bendix
Aerospace Systems Division

Failure Modes and Effects Analysis
ALSEP Cask Assembly

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INTRODUCTION

The intent of this report is to evaluate the design features of the ALSEP Cask Assembly; identify potential failure modes; and to establish and/or define an acceptable contingency operational procedure designed to circumvent a failure occurance. This ATM in combination with ATM-852, entitled, "Failure Modes and Effects Analysis, Fuel Handling Tool, and Fuel Capsule/ Cask Assembly Interface," covers all aspects of the transportation and deployment of the RTG Fuel Capsule for lunar application.

The attached table summarizes the critical failure modes of the cask assembly. In most instances, the documented failure modes, if not circumvented, would result in the abort of the ALSEP mission. However, the inherent design features of the cask assembly minimizes the likelihood of failure. This aspect, in combination with the contingency procedures documented under the "Comments" column, provide a high degree of confidence the flight configuration cask assembly will accomplish its intended mission.

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Cask Assembly Failure Mode Analysis Summary

Failure Mode		Failure Effect		Comment	
1.0	Rotation of Cask Assembly				
1.1	Lanyard breaks or is functionally inoperative such that it separates from the cam lever. The two most likely failure points are the ferrulet(s) and the bolt assembly which are part of the cam lever assembly.	1.1	Upper trunnion(s) will not be released. The cask cannot be rotated forward to permit access to the cask dome. The astronaut cannot remove the fuel capsule unless the cask is rotated to a near horizontal position	1.1	An operational contingency procedure has been established to use the MESA tools hammer/extension as a hook to pull the cam lever to release the upper trunnion pin(s).
1.2	Malfunction of the Trunnion Release Mechanism. A failure can occur in one of the following ways.	1.2	Cask cannot be rotated forward until both upper trunnion pins are sheared.		
1.2.1	Cutter fails to shear trunnion pin(s) with prescribed amount of torque.	1.2.1	Cam level fails to release the upper trunnion pin(s). If cask assembly cannot be rotated forward, the mission will be aborted.	1.2.1	An operational contingency procedure has been established to use the hammer/extension as a hook on the astronaut guard to apply additional force to break the cask free at the trunnions.
1.2.2	Cam level or shear retainer pin breaks during ascent or descent vibration.	1.2.2	Cam lever will be loose, however, vibration will not shear the trunnion pins.	1.2.2	Failure will have no adverse affect on the mission.

Failure Mode	Failure Effect	Comment
1.3 Malfunction of the Gear Box Tilt Assembly.	1.3 The failure of this assembly has a direct bearing of the ability of the astronaut to rotate the cask assembly forward.	1.3 Removal of the Fuel Capsule requires the cast assembly be rotated forward. Failure to accomplish this function would result in the abort of the ALSEP mission.
1.3.1 Lanyard and Sprocket chain become disengaged. Bracket assembly disassembles itself via vibration, etc.	1.3.1 Sprocket chain cannot be pulled through sprocket wheel which in turn drives the worm gear to rotate the cask forward.	1.3.1 The operational contingency procedure designed to circumvent this problem is as follows: a) Use hammer/extension as hook on Astronaut Guard. b) Assure the cask is free of the upper trunnions. c) Apply downward force on guard. Increasing this force will eventually shear the worm shaft key. The cask will then free - fall forward.

Failure Mode	Failure Effect	Comment
1.3.2 The sprocket chain binds in the sprocket housing assembly, thus preventing proper rotation of the sprocket wheel.	1.3.2 Sprocket chain cannot be pulled through sprocket wheel which in turn drives the worm gear to rotate the cask forward.	1.3.2 The operational contingency procedure designed to circumvent this problem is as follows: a) Use hammer/extension as hook on astronaut guard. b) Assure the cask is free of the upper trunnions. c) Apply downward force on guard. Increasing this force will eventually shear the worm shaft key. The cask will then free - fall forward.
1.3.3 The Worm Shaft bearings are damaged or functionally degraded.	1.3.3 Worm gear rotation becomes stiff and more difficult to rotate.	1.3.3 Cask assembly rotation becomes more difficult but can successfully be accomplished.
1.3.4 Dowel pin that holds worm gear to worm shaft shears off.	1.3.4 The gear tilt assembly becomes inoperative. Worm gear will not rotate. Cask assembly cannot be lowered by lanyard.	1.3.4 The strength of the Dowel Pin makes this failure mode very unlikely. However, rotation of the cask assembly can be accomplished by pulling on the astronaut guard as outlined above.

Failure Mode	Failure Effect	Comment
1.3.5 Worm Shaft Key between Worm Wheel and Tilt Shaft breaks from shearing force.	1.3.5 The Cask assembly can free-fall forward once the upper trunnion pins are sheared. Once tilted forward, the cask assembly may become unstable, making fuel removal task more difficult.	1.3.5 Astronaut can rotate the cask assembly forward per paragraph 1.3.1 above.
2.0 Removal of Cask Dome		
2.1 The Spline Lock Pin cannot be extracted from the cask assembly.	2.1 Cask Dome cannot be removed. ALSEP Mission will be aborted.	
2.1.1 Spline Lock Pin and Lanyard become disengaged. Bracket disassembles itself due to vibration, etc.	2.1.1 Cask Dome cannot be rotated so as to disengage spline.	2.1.1 The bracket assembly utilizes a self-locking nut to minimize the probability of this failure. Availability of an extension tool, for the Astronaut, small enough to hook the spline pin loop will permit its removal.

Failure Mode	Failure Effect	Comment
2.1.2 Spline pin shears off, leaving ceramic beaded portion in cask assembly. This failure would be attributed to a binding action caused by excessive thermal expansion.	2.1.2 Cask Dome cannot be rotated so as to disengage spline.	2.1.2 The ceramic bead material and the cask graphite material has minimal thermal expansion properties thus minimizing the probability of this failure.
2.2 The Dome Removal Tool fails to engage the Dome Lock Nut properly.	2.2 Cask Dome remains in place. The ALSEP mission would be aborted.	2.2 For operational contingency procedure: Astronaut should a) Apply added forward pressure and rotating action with side loading on DRT. b) Attempt removal of dome with MESA tools, e.g., Hammer and Tongs, Second astronaut assisting.
2.2.1 The Norco lock mechanism binds, thus preventing proper mating of the Tool to the Dome lock nut.	2.2.1 DRT cannot engage and rotate the dome lock nut the required 90° to release the upper radial axial bands.	2.2.1 Same as 2.2b

Failure Mode		Failure Effect		Comment	
2.3	The Spring Release mechanism of the Dome Lock Nut binds, thus failing to depress sufficiently to permit rotation of the Lock nut.	2.3	The lock nut cannot be rotated to release the upper radial axial bands. The ALSEP mission is aborted.	2.3	For contingency procedure: attempt to free release mechanism with hammer.
2.3.1	The Dome Removal Tool is properly engaged, but dome lock nut fails to rotate due to binding action.	2.3.1	The lock nut cannot be rotated to release the upper radial axial bands. The ALSEP mission is aborted.	2.3.1	For contingency procedure generate additional torqueing force by hammering on DRT handle.
2.4	The DRT and dome are properly engaged, the axial tension bands are released, but dome will not rotate the required 60° to release the dome/cask splines. The binding action is caused by thermal expansion.	2.4	The final operation for cask dome removal cannot be accomplished.	2.4	The graphite material and loose tolerance fit minimizes this failure mode. However, in the event of this failure the hammering procedure of paragraph 2.3.1 will free the dome.
3.0	Cold Welding				
3.1	Any of the identified functional parts where metal to metal contact exists, cold welding could effect a binding failure mode.	3.1	The effect of failure would be the same as that detailed in the appropriate section.	3.1	To preclude the possibility of a cold welding failure, all metal to metal surfaces are dry lubricated with Molykote Z or Microseal.