Bendix Aerospace Systems Division

A Trade-Off Study of Various Methods of Releasing the LEAM Dust Covers	NO. ATM - 980	REV. NO.
	PAGE 1 OF 13	
	DATE 2/24/71	

This ATM was written in response to NASA Action Item 3 imposed at the LEAM PDR the week of February 20, 1971.

J. W. Cooper
LEAM Reliability Project Eng.

DISCUSSION:

The Problem. The LEAM has several surfaces which are sensitive to the moon dust that will be stirred up by rocket exhaust when the astronauts leave the moon. To shield the experiment from this dust, the sensitive surfaces are covered with two dust covers, plastic sheets that, upon release, will roll up like a window shade and fall off of the experiment. Currently BxA is considering releasing the covers by cutting their reefing lines with redundant pyrotechnic squibs fired on command from Earth.

At PDR, NASA has asked BxA to re-examine the present reefing line/pyrotechnic squib plans to be sure they are optimized with respect to reliability and other pertinent engineering parameters.

Accordingly, this analysis has been undertaken.

CONCLUSIONS:

Of the 21 methods of reefing line release considered, only six are worthy of deeper consideration. They are:

1. Using the Suns heat to sublimate the reefing line.
2. Using the Suns heat to melt a stud of Woods metal to which the reefing line is attached.
3. Using the Suns heat to ignite a pyrofuse reefing line. (See Attachment A for a vendors description of pyrofuse).
4. Using Central Station electrical power to melt the reefing line.
5. Using Central Station electrical power to ignite squibs which power a reefing line cutter.
6. Using a battery depletion system where the reefing line is held by a solenoid which is powered by a small battery. When the battery is depleted, the solenoid releases the reefing line.

All six have a high Figure of Merit, a composite number reflecting the desirability of their reliability, cost, operations acceptability and availability. Two (4 & 5) are commandable from Earth, the others must be pre-programmed to operate after a set time.

If we feel that we must have a release commandable from Earth, then the best choice would be to select either method 4 or 5. Method 5 is recommended because (1) it has a reliability which is quite adequate and, (2) the functioning and interaction of each component part is well known and (3) it would cause the least program pertibation because it requires no change in program direction.

Additional assurance of dust cover release can be had by using Method 5 in parallel with one of the sun activated methods, 1, 2 or 3. Method 1 and 2 seem particularly attractive with Method 2 being the most controllable. The reliability recommendation is, therefore, to use Method 5 combined with Method 2.

ANALYSIS:

The analysis first identifies all classes of dust cover removal devices and then compares their attributes.

The identification of the classes is shown diagrammatically in Figure 1 and the comparison of attributes is shown in Figure 2.

Looking at Figure 1, Block A is seen to be the desired result, the release of the reefing lines. It was reasoned that if something physical is to be released (i.e., moved) energy must be expended and the energy must be either contained within the LEAM (Box B) or come from outside of the LEAM (Box C).

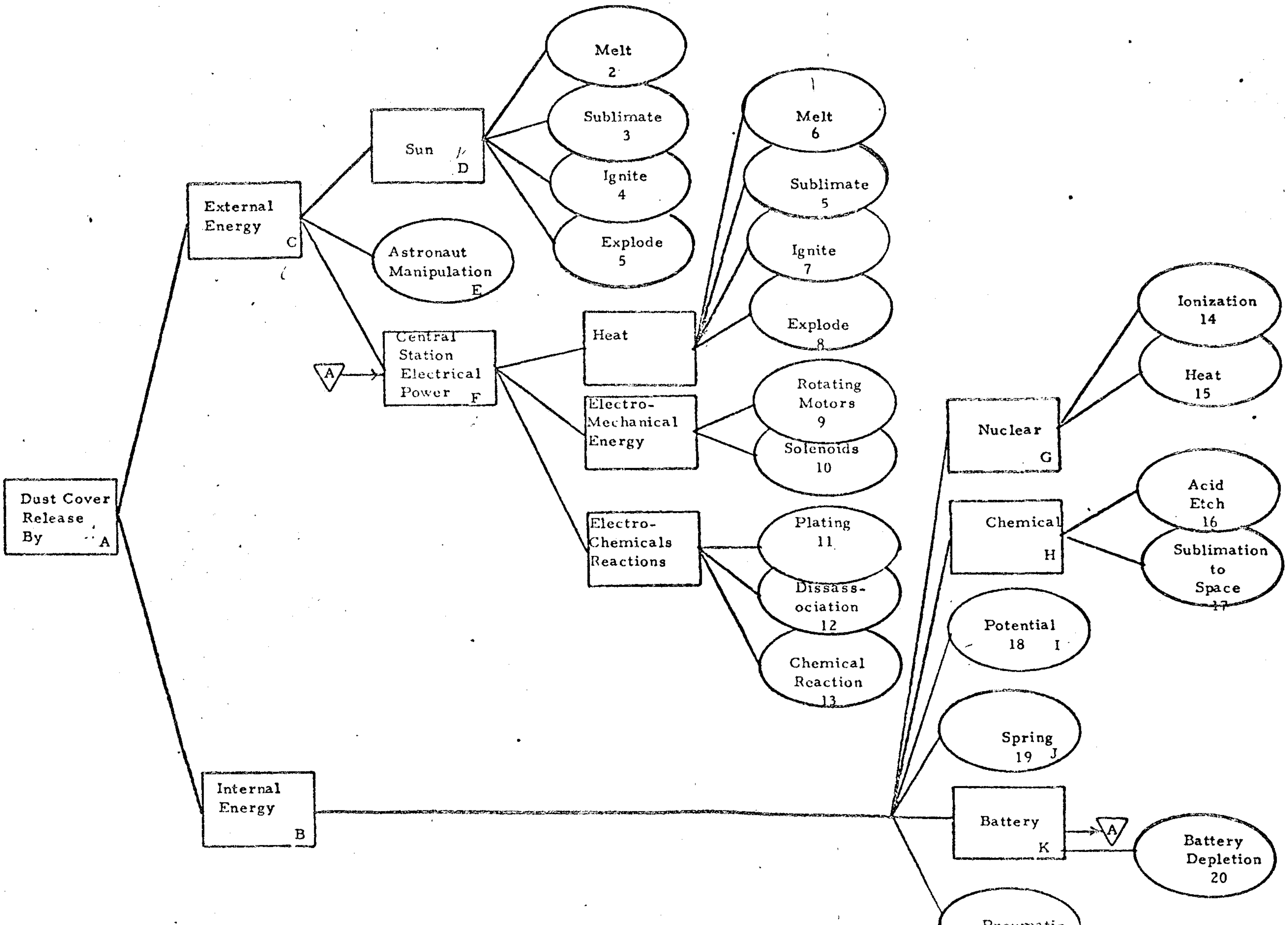

FIGURE 1

Various Methods of LEAM Dust Cover Release

Looking at Box C "External Energy" we see that three sources of energy have been considered, the Sun (D), the astronaut (E), and Central Station Power (F).

In a like manner Box B "Internal Energy" has been considered to be composed of Nuclear Energy (G), Chemical Energy (H), Potential Energy (I), Spring Energy (J), Battery Energy (K), and Pneumatic Energy (L).

In the subsequent tiers of boxes each energy source is considered to be applied to a task; melt, ignite, explode, rotate, etc. Because each task is limited in scope to one action, the embodiment of the machine to apply the energy can be readily visualized and described, and, given a description of a machine, engineering judgment can be made as to the suitability of various attributes of the machine.

These engineering judgments are shown in Table 2 and are based on a 5 point scale:

- 5 - Most desirable
- 4 - Desirable
- 3 - Acceptable
- 2 - Not desired
- UA - Unacceptable. A machine could be given a UA for, typically, safety, unavailability or unnecessary complexity which was equated with unreliability.

The four engineering judgments; cost, availability, operations and reliability were added to make, for each approach, a Figure of Merit which is proportionately to the desirability of the approach.

If so desired, this Figure of Merit could be expanded to include such attributes as weight, power consumption, or desirability of command vs. pre-programmed release.

Space Experience

Referring to Figure 2, several of the methods shown have either been used on BxA space projects in the past or are planned for future use. These items are listed below:

Item 1 of Figure 2 details the removal of the LMS breakseal on the analyzer chamber. This method, while approaching the ultimate in reliability is unacceptable for LEAM covers because it would expose the sensors to the dust raised by the blast-off from the Moon.

Item Item 6 of Figure 2 shows a method for removal of the LMS dust cover, the melting of the reefing line by a hot Nichrome wire. This method has a high Figure of Merit, however, a change over at circuit rework, with possibly some slippage in schedule. In addition, the evergy requirements for activation would be higher than the presently planned system, Item 7.

Item 7, a squib-driven reefing line cutter, is the presently planned method of dust cover removal for LEAM. It has much to recommend it; a vast body of experience, a high reliability, a low activation energy requirement, and a quick, positive low vibration release.

The BxA experience with identical hardware was with the CPLEE, Charged Partical Lunar Experiment flown on APOLLO 14 and successfully deployed on the Moon.

The high reliability comes from having the two squibs in parallel for firing. The calculated reliability for this method is about 0.9999, which makes the presently planned LEAM dust cover removal subsystem the most reliable subsystem on the experiment.

F .E 2

A TRADE-OFF STUDY OF METHODS OF DUST COVER RELEASE

Name 1	Figure** of Merit 2	Description 3	Release Time 4	Reli-ability 5	Opera-tions 6	Avail-ability 7	Cost 8	Failure Modes 9	Examples 10	Notes 11
1. Astronaut manipulation	UA*	Astronaut Re-moves dust cover before leaving moon	Prepro-grammed	5	UA	3	3	Astronaut error, for-gets to re-move cover	LMS break-seal on analyzer chamber	Dust cover must be re-moved be-fore blastoff from moon (UA)
2. Sun melts stud or plastic line.	17	Reefing line is attached to stud of SN/Pb metal. Sun shade blocks sun from stud until predetermined time. Stud melts about @ 200°F	Prepro-grammed	5	3	4	5	Astronaut error, mis-positions sun shade and gets early or late release		
3. Sun's heat causes sub-limation	18	Reefing line is attached to stud of sub-limating material (cadmium or sublimating plastic)	Prepro-grammed	5	3	5 (mono-filament)	5	Astronaut error, mis-positions sun shade and gets early or late release		Vaporized Cd may be unacceptable to LMS ex-periment. 3 days to moon with sublimate in vacuum may weaken it. Fail Safe

* UA = Unacceptable

** Column 5 + 6 + 7 + 8

Name 1	Figure of Merit 2	Description 3	Release Time 4	Reliability 5	Operations 6	Availability 7	Cost 8	Failure Modes 9	Examples 10	Notes 11
4. Sun's heat causes ignition	17	Reefing line is made of "Pyrofuze". Magnifying glass ignites Pyrofuze	Preprogrammed	5	4	4	4	Astronaut error, mispositions sun shade and gets early or late release	Military uses	Pyrofuze is made of palladium aluminum which deflagrates when heated
5. Sun's heat causes explosion	UA	Magnifying glass concentrates sun on heat sensitive squib of reefing line cutter	Preprogrammed	4	TBD	UA	TBD	Astronaut error, mispositions sun shade and gets early or late release		Squibs will probably have to be designed. Procurement would be unacceptable
6. C.S.* electrical power melts	15	Reefing line is wrapped with nichrome wire. Wire is heated and melts line	Command	4	3	4	4	Nichrome wire breaks or command link fails - either give no removal	LMS dust cover removal	
7. C.S. electrical power ignites squib	15	Squib drives reefing line cutter	Command	4	4	4	3	Command link fails or both LEAM squibs fail. Total loss of experiment	Presently planned on LEAM	

* C.S. = Central Station

Name 1	Figure of Merit 2	Description 3	Release Time 4	Reliability 5	Operations 6	Availability 7	Cost 8	Failure Modes 9	Examples 10	Notes 11
8. C.S. electrical power explodes squib	UA	Squib breaks mechanical joint	Command	2	UA	4	4	Command link fails, squib fails or explosion is too violent and damages experiment	Shaped charge used in many military and aerospace applications	UA because of brisance of action
9. C.S. electrical power drives motor	10	Electrical motor rotates cam or pulls pin releasing reefing line	Command	2	3	2	3	Motor or command link fails	Many commercial and aircraft examples	Use is fine where device can be repaired/ replaced or environments are not extreme
10. C.S. electrical power activates solenoid	13	Solenoid pulls pin releasing reefing line	Command	2	3	4	4	Solenoid or command link fails	Many commercial and aircraft examples	Use is fine where device can be repaired/ replaced or environments are not extreme

Name 1	F[illegible] of Merit 2	Description 3	Release Time 4	Reliability 5	Operations 6	Availability 7	Cost 8	Failure Modes 9	Examples 10	Notes 11
11. C.S. electrical power destroys stud by plating	UA	Stud is electrolite solution. Reefing line is fastened to stud	Command	3	2	UA	2	Rate of ion migration on moon gravity is unknown. Design must have wet seal for electrolite/stud	Several small elapsed time meters	A device to go through a stud of adequate size must be designed. UA for long procurement
12. C.S. electrical power dissociates water	8	Electrolysis of water produces pressure which drives piston releasing line	Command	2	2	2	2	Needs wet seal and command link	None known	Freezing of water may be a problem
13. C.S. electrical power starts chemical reaction	-	Subset of 7 and 8	Command	-	-	-	-			
14. Nuclear source ionizes plastic link	UA	Nuclear source bombards plastic link until it is weakened allowing reefing line to run free	Preprogrammed	3	UA	2	2	Many unknowns in system may result in late or no release	None known	Must be designed from "scratch". UA because of radiation hazard

Name 1	Figure of Merit 2	Description 3	Release Time 4	Reliability 5	Operations 6	Availability 7	Cost 8	Failure Modes 9	Examples 10	Notes 11
15. Nuclear source heats and melts plastic stud	UA	Nuclear source combined with sun's radiation raises heat of stud to failure point	Preprogrammed	2	UA	2	2	Many unknowns in system may result in late or no release	None known	Must be designed from "scratch". UA because of radiation hazard
16. Acid etch	UA	Astronaut breaks glass vial, releasing acid which dissolves link in reefing line	Preprogrammed	3	UA	2	2	Acid seal is faulty and acid gets onto astronaut	None known	UA because of acid hazard
17. Sublimation into space	-	Subset of 3	-	-	-	-	-			
18. Potential energy	UA	Pendulum drives clock which releases reefing line	Preprogrammed	UA	TBD	UA	2	Device would be a complex clockwork mechanism with many failure modes depending on the clearances of gears	Pendulum Clock	Device must be designed from "scratch". Longish lead time procurement UA

Name 1	Figure of Merit 2	Description 3	Release Time 4	Reliability 5	Operations 6	Availability 7	Cost 8	Failure Modes 9	Examples 10	Notes 11
19. Spring drive	UA	Spring drives clockwork which pulls pin and releases reefing line	Preprogrammed	2	2	UA	2	Device would be a complex clockwork mechanism with many failure modes depending on the clearances of gears		Exact design is probably unavailable and unproven, therefore UA
20. Battery depletion	15	Solenoid is in series with battery and switch. Astronaut toggles switch when battery runs down, solenoid releases reefing line	Preprogrammed	4	5	3	3	Premature release due to battery failure	Experimental submarines to release iron ballast	Fail Safe

Name 1	Figure of Merit 2	Description 3	Release Time 4	Reli-ability 5	Opera-tions 6	Avail-ability 7	Cost 8	Failure Modes 9	Examples 10	Notes 11
21. Pneumatic leak	13	Astronaut opens controlled leak in pressure bottle. When pressure is gone spring pulls pin	Prepro-grammed	4	3	3	3	Slow release due to plugged orifice		

NOTES: In columns 5, 6, 7 and 8

5 = Most desirable
4 = Desirable
3 = Acceptable
2 = Not desired
UA = Not acceptable
CS = Central Station