file 9.4

7/15/63

USE OF

LEM PROPULSION SYSTEM

AS BACK-UP TO

~~PC~~

SERVICE PROCULSION SYSTEM

Return to Mary file 9.4

~~Return to Carl.~~ This was presented by Lanskron (ASPO-SI) at 7/15 Action Com Meeting

ASSUMED WEIGHTS

USED IN

PERFORMANCE CALCULATIONS

I.	LEM DESCENT (INERT)	3157
	LEM DESCENT PROPELLANT	14213
II.	LEM ASCENT (INERT)	3641
	LEM ASCENT PROPELLANT	4389
III.	SERVICE MODULE (INERT)	9620
	SERVICE MODULE PROPELLANT	37610
IV.	COMMAND MODULE	9170

ADDITIONAL ASSUMPTIONS:

(1) LEM DESCENT I_{sp} = 305 sec

LEM ASCENT I_{sp} = 303 sec

SERVICE MODULE I_{sp} = 313 sec

(2) IMPULSIVE THRUSTING

roughly nominal S/M propellant in lunar orbit

PERFORMANCE CAPABILITY

Amount of SM Propellant On-board	△V CHAR (FPS)			
	(37610)* Full	15000#	10000#	Empty
LEM DESCENT STAGE ONLY	1860	2670	3140	3760
LEM ASCENT STAGE ONLY (Descent Stage Jettisoned)	675	1032	1220	1728
BOTH LEM STAGES	2535	3702	4360	5488

△V Midcourse
Translunar - 300 ft/sec
Transearth - 300 ft/sec

△V Transearth Injection - 3583 ft/sec

POSSIBLE APPLICATIONS OF BACK-UP CAPABILITY

I. Application during lunar operations

SITUATION	RECOMMENDED ACTION
(1) Lunar orbit insertion errors as a result of SPS failure during retro (impulse or gimbal) - could result in collision course with moon.	(1) Use LEM descent stage to obtain clear pericynthion. If SPS failure cannot be corrected in lunar orbit, use remaining LEM propellant for transearth injection.
(2) SPS failure discovered during lunar orbit, but prior to LEM powered descent maneuver.	(2) Use LEM propulsion for transearth injection and subsequent mid-course corrections.
(3) Rescue of LEM from equal period orbit required, but propellant used by SM during rescue was in excess of that budgeted.	(3) For transearth injection, use LEM propulsion, then jettison-use SPS for mid-course corrections.

II. Application during translunar phase

SITUATION	RECOMMENDED ACTION
(1) Failure of SPS to function during mid-course correction maneuver.	(1)(a) Present plan is to use SM RCS to stay on free return, but capacity is marginal - particularly if large corrections are necessary. Use of LEM propulsion is recommended for this purpose. (1)(b) Alternately, the LEM propulsion could be used to abort directly back to earth (e.g. an abort 3 hrs after injection requires 50 hrs to return vs 135 hrs to continue on free return.)
(2) Poor translunar injection requiring mid-course corrections in excess of that budgeted in SM propellant.	(2) Use LEM to make the necessary corrections, conserving SM propellant so that alternate lunar orbit mission could be accomplished in which LEM could be exercised but not landed.
(3) Failure causing decision to abort back to earth.	(3) Supplement SM propulsion with all available LEM propulsion to reduce return time. (e.g. an abort back to earth 20 hrs after injection requires 20 hrs to return using SPS, only 15 if LEM is also used.

III. Application during earth parking orbit

SITUATION		RECOMMENDED ACTION	
(1)	Checkout in earth parking orbit reveals failure in SPS necessitating either alternate earth orbit mission or abort.	(1)(a)	Transpose, jettison S-IVB and continue in earth orbit for alternate mission. When ready to deorbit, jettison SM (and LEM descent stage, if desired), using LEM to deorbit.
		(1)(b)	Use could be made of SM RCS to deorbit but some problems result: Long burning time required, long reentry ranges, large dispersions, heating problems - also precludes extended earth orbit mission since RCS fuel is needed for deorbit maneuver.

IMPLEMENTATION OPTION

1. All operations carried out from CM, using either CM or LEM G&N system to control thrusting. Interface requirement would be similar to CM/S-IVB for Apollo guidance backup of injection.

2. Crew enters LEM and performs maneuver using LEM G&N. One (or two) astronauts remain in CM. Requires minimum interface.

   At present, (2) seems to be adequate to accomplish objectives, but further study required.

IMPLICATIONS

1. Structural - No problem - loads are similar to those encountered during normal mission.

2. G&N -

   a. Essentially none if capability can be exercised from inside LEM using LEM G&N.

   b. Considerably greater implications if required to operate from CM; needs further study.

3. Operational -

   a. LEM must be on "ready" status prior to time - critical situations in which backup capability is to be used (e.g. lunar orbit retro).

   b. If LEM were to be used after initial separation in lunar orbit, then subsequent docking would need to be done at top hatch.

RECOMMENDATIONS

Contractors (NAA, GAEC, MIT) should be directed to study in further detail the use of LEM propulsion as backup to SPS and report on (1) Recommended means of implementation, (2) Systems implications, if implemented and (3) Effect on crew safety and maximization of mission objectives, if implemented.

F.T. files Rm. 122
O. C.
9.2.6

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON 1, TEXAS

IN REPLY REFER TO: SCE-L423/63-361 (CHP:mh)

AUG 6 1963

THRU: NASA Resident Apollo Spacecraft Project Office
North American Aviation, Inc.
Space and Information Systems Division
Downey, California

TO: North American Aviation, Inc.
Space and Information Systems Division
Downey, California

Attention: Mr. E. E. Sack, Manager, Contracts and Proposals

Subject: LEM Propulsion System as Backup to SM Propulsion System

Gentlemen:

The possibility exists of using the LEM propulsion system for the impulse required to return the crew safely to earth in the event of a malfunction of the Service Module Propulsion System (SPS) up to a certain point in the mission. Preliminary studies of this question have revealed no serious implications and it is generally agreed that this capability should be implemented. Before the decision to implement is made, however, additional study is necessary to develop better definition as to how useful this capability would be and more detail on systems implications.

This study should include the development of sufficient design data to provide a first order approximation of any design or weight changes and schedule implications involved, as well as the development of proposed operational procedures for the more probable contingencies in which LEM propulsion could be used in the backup role. The level of detail which should be included will be limited by the requirement to have completed the study in approximately two months.

It is requested that NAA investigate the operational and systems aspects of this backup mode to determine:

a. Situations during the mission in which such capability could be used to advantage.

AUG 6 1963

North American Aviation, Inc.
Subject: LEM Propulsion System as Backup to SM Propulsion System

b. Implications to CSM systems' interface with LEM systems when LEM propulsion is commanded from LEM.

c. Implications to CSM systems' interface with LEM systems when LEM propulsion is commanded from CM.

d. Improvement in probability of safe return of crew if this backup is added to CSM as presently designed.

e. Effect on CSM system design if this backup capability is added without changing probability of safe return of crew.

f. Effect on C&SM schedules if this capability is implemented in either of the manners described in items (d) and (e).

All calculations should be based on control weights and the following Isp values:

SM Propulsion	313 sec.
LEM Descent	305 sec.
LEM Ascent	303 sec.

Questions regarding this study may be directed to J. Sevier, ASPO-SI. A preliminary oral report on this study is requested four weeks from the receipt of this letter and a final written report four weeks later.

Sincerely,

C. C. Johnson

Robert O. Piland
Acting Manager
Apollo Spacecraft Project Office

SLE10

NASA Manned Spacecraft Center
Houston, Texas
In reply refer to: SLE-10 (OEM:Jr)
August 22, 1963

19/3

MEMORANDUM for Mr. R. O. Piland

Subject: LEM to Provide Propulsion Back-up for the Service Module RCS

Reference: TWX No. MA 21821, dated August 3, 1963, from NAA-S/ID, H. G. Osbon, for Robert O. Piland

The following has been brought to my attention:

"The SM RCS Propellant tanks are sized and being manufactured with no propellent allocation to achieve safe return in the event of SPS failure just after translunar injection. The sizing is based on the requirement that the LEM Propulsion System shall provide any necessary delta velocity corrections to insure proper entry corridor conditions should the SPS fail during translunar flight."

The referenced TWX asks to "Confirm LEM included in all C-5 Missions."

I believe this is a wrong thing to do and would like to discuss it at your convenience.

Owen E. Maynard
Manager
LEM Engineering Office

cc: Mr. J. L. Decker
Mr. C. C. Johnson

SLE-1-63-298

SLE

SLE-1-63-298 (CES:jp)

SEP 5 1963

THRU: NASA Resident Apollo Spacecraft Project Office
Grumman Aircraft Engineering Corp.
Bethpage, N.Y. New York

TO: Grumman Aircraft Engineering Corp.
Bethpage, L.I., New York

Attention: Mr. R. S. Mullaney, Program Manager

Subject: Contract NAS 9-1100, Operating LEM Propulsion While Docked To Command Module (CM)

Gentleman:

There are several reasons which may make it desirable to have the capability to activate the LEM descent propulsion system while attached to the Command Module. Some of the more obvious ones are:

a. To exercise the LEM Propulsion System in demonstration or qualifcation operations in earth orbital missions.

b. To check the Propulsion system in translunar or lunar orbital phases of the mission.

It is therefore appropriate that GAEC consider now the implication on design end analysis of the LEM structure by creating leading conditions Which reflect the above and other similar flight conditions.

Possibly the subject capability exists as a result of more critical design loads from other loading conditions and the capability may be gained without penalty. Obviously if a penalty is incurred, GAEC is requested to ascertain the status of the subject requirements, or similar requirements, before release of design which would reflect the penalty.

Sincerely,

ORIGINAL SIGNED BY OWEN E. MAYNARD

J. L Decker
Deputy Manager
Apollo Spacecraft Project Office (LEM)

CM
JN

Cc: NASA Hq. - MD(P) - Mr. G. Low

OEM

~~P2~~
~~AP-5~~ PE6
~~Title C-2~~
19/3 NAG

[illegible] 22 [illegible]

JAN 27 1964

THRU: NASA Resident Apollo Spacecraft Program Office
Grumman Aircraft Engineering Corp.
Bethpage, N.Y., New York

TO: Grumman Aircraft Engineering Corp.
Bethpage, L.I., New York

Attention: Mr. R. S. Mullaney, Program Manager

Subject: Contract NAS 9-1100, Request for Study of LEM Capability to Stabilize the Command and Service Module in Lunar Orbit

Gentleman:

In order to aquire an operational LEM guidance and navigation system prior to separation from the Command Module in Lunar Orbit, it is necessary to align the LEM inertial measurement unit while docked. The use of the LEM telescope for the LEM IMU fine alignment requires stabilization by the LEM stabization and control system during the alignment procedure.

GAEC is required to study the ability of the LEM RCS to produce acceptable limit cycle rates when controlling the command and service modules and evaluate the reaction control system fuel requirements for a five minute alignment period during which two star sightings are made. Maximum vehicle rotation should be assumed for the star sightings. The minimum dead band should be assumed during attitude hold.

GAEC is also requested to determine reaction control system fuel requirements for a second LEM IMU fine alignment during the LEM descent coasting period. The second alignment is necessary to provide the required landing accuracy for a Hohmann descent orbit.

Completion of the studies is requested by March 1, 1964

Sincerely,

[illegible]
W. F. Rector III
Project Officer, LEM
Apollo Spacecraft Project Office

cc: NASA Hq. - MA - Apollo Program Office

OPTIONAL FORM NO. 10
5010-106

UNITED STATES GOVERNMENT

Memorandum

PL2

TO : See list below

DATE: August 13, 1964

FROM : PL/Chief, Operations Planning Division

In reply refer to:
PL2-64-8-5 (JRS:cws)

19/3 FLO Gen.

SUBJECT: Review of AMPTF recommendation on LEM propulsion backup of SPS

As a part of the Apollo Mission Planning Task Force (AMPTF) efforts, a study has been performed as to the desirability of providing partial backup of the Service Propulsion System (SPS) through the use of the LEM descent engine. The results of this study are summarized in the attached report. Briefly, the results indicate that significant backup capability can be provided (up to some point early in the LEM powered descent phase) with only minor changes in hardware; the AMPTF recommendation is that the concept be implemented.

It is requested that your office review the attached report and provide comments to PL by August 24, 1964. Concurrent with this review, the contractors have been requested to assess the impact on the Program if directed to implement the potential concept. The decision as to whether to proceed with implementation will be made when all results are available.

William A. Lee

Enclosure

Addressees:
FG
FF5 (w/o enc)
FF6 (w/o enc) — for info only — no action required
FR
FS (3)
FT
CB
CF
EA2
EG3 (2)
EP (2)
EG (2)
ET (2)
FA
FF
FM

PL Lee
2.3.4.18

APOLLO
ACTION COPY TO
SUSPENSE DATE
AUG 20 10 00 AM '64
PREPARED REPLY FOR SIGNATURE OF
INFO COPY SENT TO

PL2-64-324

AUG 19 1964

THROUGH: NASA Resident Apollo Spacecraft Program Office
Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge 42, Massachusetts

TO : Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge 42, Massachusetts
Attention: M. B. Trageser, Director, Apollo G&N Program

FROM : Project Officer, Guidance and Navigation
Apollo Spacecraft Program Office

SUBJECT: Contract NAS 9-153, Impact of LEM Propulsion Backup to Service Propulsion System

As a part of the Apollo Mission Task Force (AMPTF) efforts, a study has been performed as to the desirability of providing partial backup of the Service Propulsion System (SPS) through the use of the LEM descent engine. The results of this study are summarized in the enclosed report. Briefly, the results indicate that significant backup capability can be provided (up to some point early in the LEM powered descent phase) with only minor changes in LEM hardware.

The AMPTF recommendation to implement this concept is currently under consideration by the Manned Spacecraft Center (MSC). MIT is requested to assess the impact on the Apollo Program of the implementation of this concept. A reply should be furnished MSC within two weeks after receipt of this letter.

Orig. signed by
R. Wayne Young
R. Wayne Young

Enclosure

bcc:
NASA Hqs., MA (w/o enc - cy of enc fwd with NASA Hqs' cy of ltr to NAA)

PL:JRSevier:cws/August 18, 1964

CONCURRENCES: MSC Form 192 (Mar 64) OFFICIAL FILE COPY

OFFICE CODE ▶	PL2/RVBattey	PL/WALee				
SIGNATURE ▶		Original signed by WILLIAM A. LEE				
DATE ▶		8-18-64				

PL2

AUG 18 1964

19/3 PR53 N

PI2-64-534

AUG 20 1964

THROUGH: NASA Resident Apollo Spacecraft Program Office
North American Aviation, Inc.
Space and Information Systems Division
Downey, California

TO : North American Aviation, Inc.
Space and Information Systems Division
Downey, California
Attention: E. E. Sack, Manager, Contracts and Proposals

FROM : Project Officer, C and SM
Apollo Spacecraft Program Office

SUBJECT: Contract NAS 9-150, Impact of LEM Propulsion Backup to Service Propulsion System

As a part of the Apollo Mission Task Force (AMTF) efforts, a study has been performed as to the desirability of providing partial backup of the Service Propulsion System (SPS) through the use of the LEM descent engine. The results of this study are summarized in the enclosed report. Briefly, the results indicate that significant backup capability can be provided (up to some point early in the LEM powered descent phase) with only minor changes in LEM hardware.

The AMTF recommendation to implement this concept is currently under consideration by the Manned Spacecraft Center (MSC). NAA is requested to assess the impact on the Apollo Program of the implementation of this concept. A reply should be furnished MSC within two weeks after receipt of this letter.

Original Signed by C. L. Taylor
C. L. Taylor

Enclosure

bcc:
NASA Hqs, MA

PI2/JRSevier/cws/August 18, 1964

CONCURRENCES:

MSC Form 192 (Mar 64) OFFICIAL FILE COPY

OFFICE CODE ▶	PI2/RVBattey	PL/WALee				
SIGNATURE ▶						
DATE ▶	8/18/64	8/18/64				

AUG 21 1964

PL2-Line Item 9-64- 427

THROUGH: NASA Resident Apollo Spacecraft Program Office
Grumman Aircraft Engineering Corporation
Bethpage, L. I., New York

TO : Grumman Aircraft Engineering Corporation
Bethpage, L. I., New York
Attention: R. S. Mullaney, Program Manager

FROM : Project Officer, LEM
Apollo Spacecraft Program Office

SUBJECT: Contract NAS 9-1100, Impact of LEM Propulsion Backup to Service Propulsion System

As a part of the Apollo Mission Task Force (AMPTF) efforts, a study has been performed as to the desirability of providing partial backup of the Service Propulsion System (SPS) through the use of the LEM descent engine. The results of this study are summarized in the enclosed report. Briefly, the results indicate that significant backup capability can be provided (up to some point early in the LEM powered descent phase) with only minor changes in LEM hardware.

The AMPTF recommendation to implement this concept is currently under consideration by the Manned Spacecraft Center (MSC). GAEC is requested to assess the impact on the Apollo Program of the implementation of this concept. A reply should be furnished MSC within two weeks after receipt of this letter.

Jesse D. Goree, Jr.

W. F. Rector, III

Enclosure

bcc:
NASA Hqs., MA (w/o enc - cy of enc fwd with NASA Hqs cy of ltr to NAA)

PL2/JRSevier/cws/August 18, 1964

CONCURRENCES:

MSC Form 192 (Mar 64) OFFICIAL FILE COPY

OFFICE CODE ▶	PL2/RVBattey	PL/WALee				
SIGNATURE ▶		Original Signed by WILLIAM A. LEE				
DATE ▶		8-18-64				

J. F. Shea
PA-114-82

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA GEN. REG. NO. 27
5010-107

UNITED STATES GOVERNMENT

Memorandum

APOLLO
ACTION COPY TO
SUSPENSE DATE
OCT 23 8 47 AM '64
PREPARED REPLY FOR SIGNATURE OF
INFO COPY SENT TO

TO : PL/Chief, Operations Planning Division

DATE: 21 OCT 1964

FROM : FM/Chief, Mission Planning and Analysis Division

In reply refer to: FM3(THS:jh/4286)

SUBJECT: Review of AMPTF recommendation on use of LEM propulsion as backup to the SPS

1. The subject report was reviewed by various Mission Planning and Analysis Division personnel for the past month. The purpose of this memorandum is to submit the overdue Mission Planning and Analysis Division comments to your office, but in time for final assessment as to whether to proceed with the implementation of the backup mode.

2. The use of the LEM backup of the SPS has been studied by NAA/GAEC/MIT and MSC for about a year to obtain the S/C system design implications and the implementation impact on the program schedule. Of the three possible applications of backup capability namely during: (a) earth parking orbit, (b) lunar operations and (c) midcourse phases, the subject AMPTF report published by GAEC considered the abort from lunar orbit or TEI to be the most critical from a ΔV standpoint, and therefore, was the prime object of their study. The study assumed that the CSM/LEM configuration was in an 80 nautical mile circular orbit and quoted some required TEI ΔV's for selected launch dates. This is a very rare case where an SPS failure is somehow discovered during the lunar orbit coast prior to the LEM powered descent maneuver. A more realistic case to examine from a performance aspect would be an SPS failure during the lunar orbit insertion powered phase which either put the S/C on a collision course with the moon or on an odd elliptic orbit around the moon with a ΔV budget being a function of where the TEI point has to occur for a selected earth landing area. The point to be made here is that the feasibility of having the LEM descent stage as a backup to the SPS does not come from the TEI phase. GAEC very conveniently selected a point in the LOR mission which has the least effect on their 48 hour system design and reliability numbers.

3. The feasibility of having the LEM propulsion system as a backup to the SPS depends primarily on the midcourse phases where major impulses might be needed to correct for injection errors and to assure hitting the entry corridor for the free return trajectory or to initiate an abort for immediate earth return. The present LEM reliability numbers are based on the LEM being sealed until the crew enters the LEM in lunar orbit for system checkout prior to separation for the LEM transfer orbit. Reliability numbers based on systems analysis for the use of the LEM as backup to the SPS during the midcourse phases should determine the feasibility of the LEM backup of the SPS. Use of the LEM descent engine to either realize a free return trajectory or perform an abort near where the first SPS midcourse maneuver would occur, results in times to entry in excess of 48 hours. Introducing other concepts like an auxiliary

propulsion system which uses the S/M fuel, resizing the S/M RCS system or jettisoning the SPS fuel are all interesting but they should not be substituted for SPS backup in the midcourse phases and then only implementing the LEM as backup for the SPS in lunar operations.

4. More realistic abort situations should be examined during the lunar operations phase to determine the abort limits for the backup system from performance and operational considerations. This along with the LEM system reliability numbers for systems operations during the translunar and transearth midcourse phases will better determine the feasibility of implementing the backup capability.

5. The MPAD is of the opinion that LEM thrust vector control can provide in many instances mission saving capability prior to lunar landing in instances of SPS failure. To insure mission success the capability appears highly desirable, in that the project would no longer be dependent on reliability estimates of the SPS.

6. Of course, detailed studies of the structural and stability problems must yield assurances of solution before implementation can proceed.

J. P. Mayer

Enclosure (w/o enc.)
Subject report

cc:
PA/J. F. Shea
FA/C. C. Kraft, Jr.
FM/H. W. Tindall, Jr.
MPAD Branch Chiefs
ATSO

OPTIONAL FORM NO. 10
5010-104

UNITED STATES GOVERNMENT

Memorandum

TO : PA/Manager, Apollo Spacecraft Program Office

DATE: NOV 2 1964

FROM : PL/Chief, Operations Planning Division

In reply refer to: PL2-64-10-50

NOV 3 1964

SUBJECT: Memorandum from FM, Chief, Mission Planning and Analysis Division, relative to the use of LEM propulsion as backup to SPS, FM3 (THS:jh:4286)

Clarification of the subject memorandum with FM indicates that they are definitely in favor of the concept, but felt that we had missed the boat in the AMPTF study. Their memorandum suggested that the study had selected a backup situation (performing transearth injection with LEM propulsion) which was so unlikely to occur as to only be of academic interest; and further, that the study failed to explore the backup cases during translunar coast and lunar orbit insertion where it is more likely that such backup capability might be called for. The implication was that the transearth injection case was selected by GAEC because it represents the shortest time home, hence places the least strain on the LEM 48 hour design capability. I will attempt to clarify these points.

First of all, the AMPTF assumed that we are not going to accept any significant penalties in LEM to provide this backup capability. For example, we would not expect to load more propellant on LEM for the backup function than was absolutely required to perform its nominal mission. Hence, the problem becomes one of how we can best manage with the available capability; if this capability covers the desired range of situations, then we are probably willing to go ahead and make the minor changes necessary to actually implement the capability.

The study actually considered the static and dynamic situations for LEM thrusting with a range of SM propellant loadings from full to empty. From some aspects, it was more stringent to have the SM full (as in the translunar phase), and from other aspects it was worse to have a partially filled SM (as would be the case after it had deboosted into lunar orbit). For example, the partially filled SM presents the worst static stability problem; and, in fact, eliminates the non-gimbalable LEM ascent engine from consideration. On the other hand, the full SM presents some of the worst dynamic stability problems. The AMPTF, in making the recommendation to implement the backup capability, felt that all the backup situations were investigated in sufficient depth to justify their recommendation. The report, to which the FM memorandum refers, presented only the summary of these

findings, and perhaps does place undue emphasis on the transearth injection case, which was considered to be the one which fully exercised the LEM ΔV capability.

The FM memorandum raises the question of the necessity of extending the LEM 48 hour lifetime to provide backup to the SPS from very early in the translunar coast. The assumption implicit in this reasoning is that the LEM will be retained during the long trip home to make subsequent midcourse corrections. As your note points out, the preferred mode would be to jettison the LEM after the major burn (or possibly after the first correction) and make the subsequent corrections with the SM RCS. This might not always be possible depending on how accurately the major burn had been accomplished and how much SM RCS propellant was available for corrections. At any rate, the present LEM design should furnish ample capability to support the longest return times under consideration, provided LEM systems were shut down during those periods when not in use.

Consider the case where the failure occurred early in the translunar coast, and we selected the abort mode which continues on a circumlunar course. Taking the LEM electrical energy capability of 120 kwt. hours as a measure, we could provide standby power of 300 w. for a 200 hour period and have sufficient energy remaining to supply the LEM for 24 hours at a full 2500 w. level. This would certainly be adequate for several trips into the LEM to activate systems preparatory for a midcourse correction. The systems would subsequently be deactivated except for those requiring standby power.

William A. Lee

PL2/JRSevier/cws/10-29-64

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : See attached list

DATE: APR 27 1970

In reply refer to:
PD4/M30-70

FROM : PD/Acting Chief, Systems Engineering Division

SUBJECT: Enhancement of abort capabilities after multiple failures in the CSM

The experience with Apollo 13 indicates that it is of interest to consider means of improving the capability of the spacecraft to accommodate multiple failures in the CSM. The successful abort on Apollo 13 shows that such a capability exists, but relatively simple spacecraft modifications should be investigated to see if this capability cannot be improved upon.

Specifically, Systems Engineering Division plans to consider the following areas:

(a) Modification to the LM/CM umbilical to provide additional capability of powering CSM systems from the LM electrical power

(b) Means of transferring CSM water to LM

(c) Means of dumping SPS propellant to increase delta V capability of LM DPS

(d) Means of insulating the critical components in the CM to eliminate thermal problems after early jettison of the service module

(e) Provisions for using PLSS batteries or a new auxilliary battery for entry power

(f) Improved capability to use command module LiOH cannisters in the LM and vice versa

(g) Transfer of PLSS water to the LM ascent tanks

(h) Capability to tee in two OPS's to three crewmen in case of loss of pressure and oxygen in the command module

Most of these items were considered during the Apollo 13 mission but did not have to be used. Perhaps improved means of making use of these capabilities, considering modest hardware modifications, can be worked out now without the pressures which were present during the mission. It is understood that this list is not all inclusive, but merely represents some of the ideas that come to mind in view of the specific Apollo 13 situation. We solicit your inputs as to similar hardware items that might be considered or additional analyses which might be performed to improve present capability.

Please address such ~~inputs~~ inputs to J. Sevier who will coordinate this effort for the Systems Engineering Division.

C. H. Perrine

Calvin H. Perrine

cc:
PA/J. McDivitt
PA/R. Johnston
PD5/R. Colonna
PD7/R. Kohrs
PD9/J. Craig

PD4:JSevier:sas 4-27-70

Mission Planning and Analysis Division
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

IN REPLY REFER TO: 70-FM36-81

MAY 4 1970

MEMORANDUM TO: FM/Chief, Mission Planning and Analysis Division

FROM : FM3/Head, Contingency Analysis Section
Flight Analysis Branch

SUBJECT : Preflight abort work used for the Apollo 13 emergency

References

1. Memorandum 67-FM36-195, "Mission Planning and Analysis Division abort procedures meeting on June 1, 1967," dated June 8, 1967.

2. Memorandum 67-FM36-275, "Thirteenth Apollo Abort Working Group Meeting," dated July 25, 1967.

3. Memorandum 67-FM13-346, "Discussion with GAEC about return-to-earth aborts that involve the LM," dated September 11, 1967.

4. Memorandum 68-FM36-66, "Open action items resulting from the Apollo Abort Working Group (AAWG) meetings pertaining to the LLM," dated February 15, 1968.

5. TRW Letter 3423.6-353, "Summary of Manual Onboard Techniques for Determination of Orbit and Attitude and Manual Abort Maneuvers," dated June 25, 1968.

6. Internal Note 68-FM-288, "Onboard Midcourse Correction Targeting During the Transearth Coast Phase of a Lunar Mission," dated December 3, 1968.

7. TRW Letter 3423.2-22, "Crew Verification of Inertial Measurement Unit (IMU) Gimbal Angles for Aborts at 90 Minutes After the Translunar Injection (TLI) Burn," dated August 15, 1968.

8. Internal Note 68-FM-294, "Apollo 8 Maneuver Attitudes Relative to the Celestial Sphere as Viewed From the Spacecraft," dated December 9, 1968.

9. Memorandum 69-FM36-1, "Mission F contingency techniques - use of the LM systems to backup CSM," dated January 2, 1969.

10. Memorandum 69-FM36-20, "Contingency techniques for Apollo 10 - translunar phase," dated January 24, 1969.

11. Memorandum 69-FM36-173, "Proposed abort techniques for SPS failure during LOI burn of Hybrid Lunar Mission," dated April 17, 1969.

12. Internal Note 69-FM-178, "Hybrid Mission Effects on the LOI Phase of the Apollo 11 (Mission G) Abort Plan," dated June 30, 1969.

13. GAEC Letter LLR-540-478, "Preferred Abort Technique for SPS Failure During LOI Burn of Hybrid Lunar Mission," dated June 17, 1969 (cover for LM Engineering Memorandum LMO-540-1474 dated June 4, 1969).

14. Internal Note 69-FM-220, "Recommended LOI Procedures for Hybrid Lunar Missions," dated August 4, 1969.

Summary

Specific preflight efforts by the Contingency Analysis Section utilized during the Apollo 13 emergency include the following:

- Quick LM activation procedures
- Docked DPS abort at perilune + 2 hours
- Docked DPS abort without SM
- Use of celestial sphere window views for attitude determination during powered maneuvers
- LM consumables for CSM backup during lunar abort

Introduction

Recognizing that there are many versions of the "truth", it is felt that the members of the Contingency Analysis Section contributed in many ways - directly and indirectly - to the fact that the Apollo 13 crew returned safely to earth.

Discussion

The following paragraphs identify in chronological order several Contingency Analysis Section efforts that were utilized or applied during the Apollo 13 contingency.

June 1967

MPAD abort philosophy meetings such as the one mentioned in reference 1 resulted in identifying pertinent decisions required to support translunar coast aborts.

July 1967

Another series of meetings by the Apollo Abort Working Group (AAWG) considered the problems associated with aborts during lunar flights. Reference 2 summarized the meetings and provided the basis for a preliminary lunar abort procedures presentation at an AS-504 FOP meeting. Reference 2 also documented several unanswered questions about the capability of the LM to backup CSM systems failures in an abort situation, particularly in the region of the translunar coast prior to perilune in the lunar sphere of influence. A discussion of the crossover region from direct to circumlunar aborts was included.

August 1967

Personnel from FAB and GPB discussed with GAEC the current abort plans for using the LM to backup CSM problems on August 25, 1967 (reference 3). The purpose of the discussion was to identify any LM problems associated with these plans and to answer some outstanding questions about LM systems that arose during previous AAWG meetings. In general, the questions pertained to consumables usage of the LM by three crewmen, the minimum activation time for a DPS burn, and control problems related to docked DPS burn.

February 1968

A formal request for LM and SM jettison studies and procedures following LM DPS aborts was included in reference 4.

June - December 1968

Several studies exploring the concept of terminator use for abort were provided by references 5 and 6. The first practical applications adopted for actual crew procedures were described in references 7 and 8.

January 1969

A request for management decisions regarding use of the LM for translunar abort based on alternatives studied by the Contingency Analysis Section and the resulting set of approved techniques for actual implementation on Apollo 10 are described in references 9 and 10.

April 1969

New abort procedures for SPS failures during a hybrid lunar mission were proposed in reference 11. The procedures included APS docked burns which had previously not been considered (APS abort procedures were subsequently developed for Apollo 12) and SM jettison prior to a DPS burn. Comments on the LM consumables capability for three crewmen on the transearth coast were requested.

June 1969

Hybrid Mission Effects on the Apollo 11 Abort Plan (reference 12, Appendix B) considered a DPS abort burn following SM jettison and indicated uncertainties of LM consumables backup to three crewmen.

July 1969

GAEC responded to reference 11 with a description of possible LM consumable capabilities for three crewmen in the event CSM systems were not available (reference 13).

August 1969

New abort procedures for hybrid missions were recommended in reference 14. The need for a shorter DPS burn activation procedure was discussed. Cmdr. Pete Conrad later confirmed that a short LM activation procedure was possible and was being implemented.

Although some of the above efforts were informally documented, formal approval of specific techniques was obtained through Data Priority meetings and documentation in addition to the Apollo Documentation List. In addition, management and contractor awareness of abort planning was maintained through formal briefings (i.e., Mission Review meetings and plant visits).

Conclusions

With the recent deemphasis on abort and contingency work (due in part to budget cuts and successful flights), it is indeed fortunate that we had addressed the above issues prior to Apollo 13. It is noted, however, that much of the effort was accomplished in spite of the reluctance of many to be concerned with operations outside design specifications.

Charles T. Hyle

APPROVED BY:

Robert H. Brown
Acting Chief, Flight Analysis Branch

cc:
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FM3:CTHyle:dcb

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

MAY 6 1970

IN REPLY REFER TO: 70-FC22-135

MEMORANDUM TO: FA/Director of Flight Operations

FROM : FC/Chief, Flight Control Division

SUBJECT : Consumables updates on the Apollo 13 mission

1. The first enclosure to this memorandum is a time correlated transcript of air-to-ground conversations related to consumables status between MCC and the Apollo 13 crew.

2. Enclosure 2 is a graphic representation of this data on an individual consumables basis and distinguishes between general comments and specific consumables updates. This enclosure indicates that the first complete consumables update after the cryogenics incident occurred 23 hours later at a GET of approximately 81 hours. Subsequent total updates occurred at 25, 9, and 18 hour intervals with the last total update occurring approximately 10 hours prior to entry.

3. In addition to the updates mentioned above the crew was advised of the status of their most critical consumable, water, approximately every 10 hours.

4. In summary, the enclosures indicate that the Apollo 13 crew was adequately briefed of their total consumables status on a daily basis with more frequent updates on their limiting consumable, water.

Eugene F. Kranz

Enclosures 2

cc:
AC/G. W. Abbey
FL/J. B. Hammack
FM/J. P. Mayer
FS/L. C. Dunseith

FC221:HMDraughon:ad

GET

58:07 SC: Got just about 80 spec 82 hours out of the two primary cartridges. That's two guys. 24 is what LC8 got for the 88 hours. We got a secondary. You're right. Over.

CAPCOM: Odyssey, Houston.

SC: Take. Go ahead.

60:21 CAPCOM: Okay. We'd like to brief you on what the plan is. We're, at this time, water critical in the LM. We'd like to use as little as possible.

61:50 CAPCOM: We're looking real close at water usage profiles and right now things are kind of swinging toward leaving the IMU powered up and powering down the LGC, but we'll have more word for you shortly. And we recommend for sleeping that you leave one guy on watch. We recommend you don't make any urine dumps if you can help it because it'll make the debris problem worse than it is now. And we have some items that you might want to transfer to the LM - some towels, some penlights, some fecal bags, UTS. And do you have any more items that we can help you out with at the moment?

62:42 CAPCOM: And Aquarius, just to get you thinking in that direction, we've run a very thorough analysis and we've found out that it's going to be cheaper to keep the LGC and the disky up and turn the inverter and the ball off. It's going to save us 1 amp, and also some water. So it looks like what we're going to do.

69:23 SC: Go ahead Houston.

CAPCOM: Okay, the time of transfer to LM power was 57 hours 11 minutes. For your information we seem to be reasonably fat on power. In fact, we are looking at a procedure that we might recommend to you later on after the burn and so forth of powering up one of the command module main buses via the LM umbilical. This would enable us possibly to charge up the command module batteries. Over.

71:06 CAPCOM: We'll see Fred. You're almost up with us; we are looking real hard at getting water from the command module waste tank into the PLSS, (garble) dump from the PLSS into the LM ascent stage. We think it is feasible, but we are checking it out to make sure.

Enc 1

GET

80:16 CAPCOM: Okay, just some info. We're working up a procedure for you to use command module LiOH canisters to connect to your hoses, the outlet hoses in the LM so as time passes in the mission, you can continue scrubbing the LM atmosphere. And this whole thing requires that a modifying a kit so that you can attach the hose, you're modifying a LiOH canister so you can attach the hose to it. So, some time in the future we will be coming up to you with that procedure. Second point. Second point is we're standing by to watch your maneuver for the PTC procedure.

SC: Okay. I'm in process now, Vance, of maneuvering to 0 yaw, 90 degree pitch using the LM mode.

CAPCOM: Okay.

SC: And Vance, I assume it has also been though of that we got two extra secondary cartridges. One in each PLSS.

CAPCOM: Roger.

SC: We better start working on that mod right now.

81:42 CAPCOM: Okay. The first midcourse correction will probably be at GET 104 hours and all we look for is a 4 to 6 feet per second DELTA V. Okay, that's the first item. Now, I will give you a rundown on consumables. Okay, in the LM, you have 1498 - that is 1 4 9 8 amp-hours remaining. That means over 61 hours you - that would average out to 24.5 amps. We expect that after power down, that you will use 1 4 or 14 amps per hour, and that would leave a reserve of 500 amp-hours at the end of the mission. Are you with me?

SC: Roger. We're with you. That's what my number was yesterday.

81:48 CAPCOM: Okay. And after you power down, we expect that you will be using water at the rate of 3.2 to 2.7 pounds - that's at 14 amps per hour electrical usage rate. One note, this does not - when we speak here of water available - this does not include CSM water and PLSS water, so that's added on. Okay. Next. LiOH. Using the CSM cans you will have 16 cans at 12 hours per can to give you 192 or 192 hours of LiOH. And in the LM using it's cans you have 44 hours remaining.

GET

81:48 SC: Vance, is that with the PLSS secondaries?

CAPCOM: That's affirm. That's affirm. That includes PLSS secondaries. Okay. Oxygen. You have remaining 44 pounds in the LM. At a usage rate of .36 pounds per hour that leaves you 120 or one two zero hours of oxygen. Okay. Next. RCS. RCS A stands at 62 percent and B at 62 percent. We only expect 2 percent to be used for the PTC so you're in good shape for RCS. Next DPS DELTA V. You have 1190 feet per second remaining. And finally, CSM EPS. We estimate that you have 99 amp-hours. That's an estimate. And that's it. Over.

82:29 SC: Okay Jack, my only other concern now is the CO_2 lines in the spacecraft. I guess you're keeping a handle on that?

CAPCOM: That's affirm Jim. We have you up to 10.6 now and we're willing to go a little higher on that. We have another cartridge and we have a procedure for making the command module cartridges up. We'll pass that on later.

SC: I'm not worried about that. I just wanted to make sure that you, that - we just don't want to go to sleep here and forget about the lines to O_2.

CAPCOM: Roger. We're watching it for you. We have it here. It's now 10.7 and we have a medical go to 15 millimeters.

SC: That's a new one.

SC: There's a new bird for you.

CAPCOM: Okay Jim, we've estimated, we've got 1 more hour on the primary cartridge and 6 or 7 hours on the secondary.

SC: Okay. Fine.

SC: Say, this is still primary practice back here too isn't it? So this gives us another, how long?

SC: (Garbled)

SC: Yes. Yes. That's yours though, isn't it?

CAPCOM: And you're right, Jim. We've got another primary cartridge back there behind the ascent engine covers.

GET

82:00 CAPCOM: All of our analysis is based on power down to 14 amps, but we're reading on you right now, 12.3 and so we're better off than we were in our analysis.

83:04 CAPCOM: And, Fred, your CO_2 is building up. It's at 11.3 on our gage, and we've got a medical buildup at 15 millimeters at which time we'll switch over to secondary. Looks like we've got plenty of lithium hydroxide. About 192 hours including the CSM cartridges. And as you know, we've got a way to use those. As soon as we get them written in some good words, we'll pass that along. You might be able to make one.

83:08 CAPCOM: Okay. Fred, for your information, your CO_2 reading onboard is a little higher than what we're reading here on the ground, and so when it gets to 15 on your meter, switch to secondary. And we'd like to get a status about every thirty minutes - we'll give you a call on that. But just to let you know we're still thinking about you, we'd like you to go biomed right, please.

SC: Okay. Going biomed right.

83:34 SC: Okay. That sounds good.

CAPCOM: And we don't - we think there might have been a misunderstanding earlier on the potable water. Don't worry about drinking water. You can drink all you want. There's plenty of it. There's 38 pounds, and the surgeon recommends that you use some of the fruit juices as well. Over.

SC: Okay. Yes. We went up and used the procedure pressurize first tank, and Jack and I made up a total of 22 drinking (garbled) of water.

84:15 SC: That's affirm.

CAPCOM: And Fred, you're doing a little better on water than we had anticipated. Our numbers were designed for 3.5 pounds per hour, we're using about 3.0 and expecting to go a little bit less.

SC: Beautiful. When this flight's all over we'll really be able to figure out what a LM can do.

SC: Okay. Jack, the Earth LPD angle is 24 degrees.

CAPCOM: Roger. I heard that 24. And it looks like you're getting up to about 15 on the CO_2 so we want you to select secondary and swap out the primary cartridge. Over.

SC: Okay. I'll select secondary and swap out the primary cartridge.

GET

84:15 CAPCOM: Okay, Fred. And when you select - you swap out the primary cartridge don't reselect primary. Stay on secondary until we use the secondary up. Over.

85:54 CAPCOM: Aquarius, in comparing initial estimates of water usage and electrical power usage, it appears that we're right on the money. Water usage, we're using a little less amperes than we had originally expected in the first analysis, so we're either right on the money or just a little bit ahead of the game, in that regard.

86:08 CAPCOM: Earlier in the evening we though there was a misunderstanding about the amount of potable water you can drink. But I want to advise you that you can drink as much water as you want to. There's 38 pounds in the potable tank, and that's about all you need. The doctors say, yes, you drink as much fruit juices as you want, too.

90:01 SC: Okay, Jack's up with me now. (Garble) general procedure for making these lithium hydroxide measures and soon as he gets done helping he'll be ready to copy, and then he'll (garble).

CAPCOM: Roger, that Jim. Are you going (garble). Go ahead.

PROCEDURE FOLLOWED

94:32 SC: Okay, I'd just like to know how our little (garbled) set up (garbled) appears to be working down there.

CAPCOM: We are reading 0.2 on our CO_2 sets here and we're all delighted, it seems to be working fine.

95:25 SC: Brings up another possibly, now we've got all that stowed and the bags and the condensate can and it's probably blow through the (garble) sublimator and work on waste water.

CAPCOM: It might work if we had to do it, Fred. Right now we're looking at a comfortable excess of water through the sublimator. We were talking among ourselves this morning about having you try out the PLSS to ascent tank water transfer situation and we decided not to do it, not to recommend it because we figure it'd take us 30 hours to empty one of the ascent tanks, which you have to do in order to get PLSS water to it and we'd rather use the descent water and we don't think we've gotten any sweat.

GET

95:48 CAPCOM: The docking window, Rodger that -

CAPCOM: Somebody just handed me your latest consumables status report and you're using 11 or 12 amps per hour real steady and it looks real good.

97:15 CAPCOM: Okay, Fred. We understand that and one more item for clarification on the water. We don't really know what your usage of potable is. That was purely an estimate assuming a fairly healthy usage.

SC: Okay.

100:59 CAPCOM: Jim, it looks to us like your battery is good, that this is in fact a sensor problem, therefore, I request you close the cross tie bal LOAD on circuit breaker on panel 16 advise.

106:20 CAPCOM: Okay. And if the SCH tank does burst during this time frame before we get trajectory info why that will delay our trajectory info somewhat. Your consumables, your water is now good through 150 hours.

106:23 CAPCOM: Okay, Jack. I will do. Jim and I were able to spot constellations from the windows of the LM when there's no venting taking place. Could you give me some time on these consumables that you predicted once more? I think you started to give times. I didn't hear or was I just hearing things?

CAPCOM: We started to give you some times. We think we might be able to give you some better ones pretty soon. But it looks like your water is good through 154 hours, and you've got O_2 through 272 hours, plenty of lithium hydroxide -

106:38 CAPCOM: You got toxon O_2 through 272 hours, plenty of lithium hydroxide, and your amp powers ought to be good through 199 or 200 hours. Over.

SC: Okay. Good. Copy that.

CAPCOM: We expect that your water rate is going to drop off and at the time DELTA will go up to 160 - 165 hours quite shortly. Another thing we're interested in is what your status on rest and medication.

GET

106:44 SC: Yes, Jack. I just got a question - how long are you predicting the Command Module LiOH canisters to last in here?

CAPCOM: Okay, Jack. We've got 14 cartridges that'll last 157 hours, plus we've got the LM primary cartridge with 23 hours, and we've got two PLSS cartridges with 7 hours apiece.

SC: Okay. I was just curious as to how much time we've got out of these two cartridges.

CAPCOM: Standby one. I've got a prediction on that. By the way, I hope you're keeping track of the ones you've used and the ones you've not.

SC: Yeah. Right now, we have numbers 7 and 8 in the LM here.

CAPCOM: Roger.

SC: They were two brand new fresh ones.

106:50 CAPCOM: Aquarius, Houston. In regards to the CO_2 canisters, by the way the PCO_2 is reading 1.6 down here now. We expect that we can get six more hours out of the two canisters that we have there. Six hours at least. However, at 112 hours, when we've got several people up, we're going to rig up two more and we have the new simplified procedure for doing this. However, in the meantime, should we need to have a canister change, we plan to switch to the LM primary canister. Over.

SC: Okay. Copy that, Jack.

110:06 CAPCOM: -- Hanging in there. Your water's good up to 161 hours now.

110:16 CAPCOM: Okay. One of the first things we want to do is charge the battery in the CSM so we can get some LM power over there to do that, and we have procedures lined up to do it.

110:56 CAPCOM: That's a negative, Jim. According to the latest update, we've got ampere hours out to 203 hours.

111:16 CAPCOM: Okay, Jack. That's going to take 120 amp hours out of the LM which is equivalent to 10 hours, which will put us back to 193 hours and that's plenty.

SC: Okay. Let me relay that to Jim here.

GET

113:06 CAPCOM: Okay, this is your friendly do-it-yourself kit along with a suggested procedure in the lithium hydroxide situation. You're looking good. We read 1.8 millimeters, and you do have sufficient LM food to last you the rest of the flight. However, being on the conservative side, we would like to use one more set of Command Module canisters to guard against some possible problems (garbled). I have a central flight procedure to do (garbled).

115:41 CAPCOM: Okay, Jim. It's about time, at your convenience, for another volts and AMPS reading on the command module. For your information, we put 6 amp hours back in the battery already and we've got about 14 to go. It's looking real good, and I also just got the word that the reentry weather tomorrow is looking better all the time. Really looks great.

115:50 CAPCOM: Okay, we are looking at a vacuum perigee right now of 23.6; flight pad manual minus 6.25, and if we decide we want to trim that up, we're looking at a midcourse at about 2 feet per second; your consumables of course are getting better all the time; we've got 163 hours of water, 230 hours of oxygen and 172 hours worth of electrical power; over.

AQUARIUS: That sounds good.

117:06 CAPCOM: Okay, we copy 39.3 and 1.20, and Jim, I've got one more item for information for you. That, in about 45 minutes or so, you will get an H_2O quantity caution light on the descent tank. We expect this. It occurs at 16 percent. It's no problem, because we intend to run the tank dry just for drill. To reset the light on Panel 2 just set the O_2 H_2O quantity monitor to the caution point and reset position and the light will go away. Over.

122:19 SC: You say you figure you are going to be charging bat A until about 126?

CAPCOM: Roger. About 1 26 30 is the estimate, Jack.

SC: Okay. You figure it will be fully charged then, huh?

CAPCOM: Yes. That's right. We'll have all the batteries up to about 116 amps hours.

SC: That's good news.

GET

122:58 SC: Okay. But I guess what I was really asking is if you'd have any violent objections if we filled two drinks bags from LM water rather than repressurizing the thirst tank.

CAPCOM: Okay. Stand by.

SC: Also, Jim is asleep up there and we didn't want to bother him either.

CAPCOM: Okay. We understand. And, Jack, we'll be changing stations in one minute so we may have a temporary dropout in COMM.

CAPCOM: Aquarius, Houston.

SC: Okay, Vance, go ahead. Loud and clear.

CAPCOM: Okay, Jack, we're going to bargain with you on this one. Instead of two, we wish that you would get just one bag full. That shouldn't do any harm; however, we are not all that fat on water that we want to do any drinking out of the LM as a regular thing after this one bag. So would you let us know when you get the water out and give us a mark on it so we can watch the TM. Over.

132:49 SC Okay. Delete the third step.

CAPCOM: And Aquarius, for your information, as far as our water supply is concerned including our plans for power up, we have an additional 18 hours of water remaining from this point.

SC: Okay. 18 hours of water remaining from this point, Jack.

133:17 SC: Sounds good and you're sure we have plenty of electrical power to do this.

CAPCOM: That's affirmative. We've got plenty of power to do it. I can get you a number though.

CAPCOM: Jim, you've got about 100 percent margins on everything from here on in.

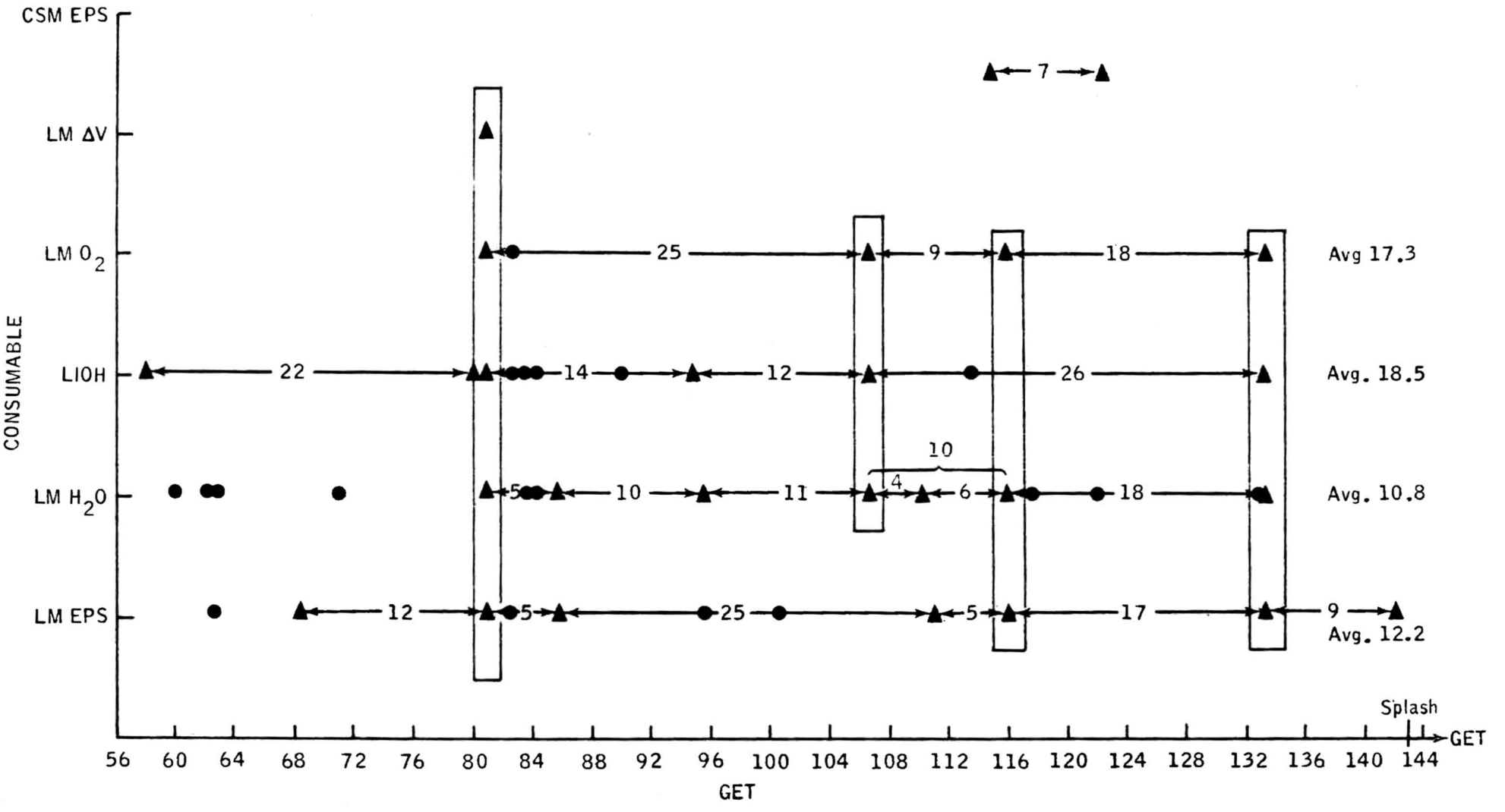
SC: That sounds encouraging.

CAPCOM: Rog. That's in the LM. We're not talking about the CSM right now.

SC: I understand.

GET

142:10 CAPCOM: Okay, you're still looking real fat on power - we show you having over 30 amps on the water. If you do get into a bind and don't come up - that's amp hours - don't come up with recovery you can always power down and you can always put the PYRO batteries on. If you need them (Garble).



Code:

- ● General status, such as: "looks good" or "nominal usage".
- ▲ Specific status, such as: "pounds remaining", systems lifetime, or usage rate.

RF

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

MAY 22 10 36 AM '70

REPLY TO ATTN OF: MAP

MAY 21 1970

ACTION LA
INFO AA, AB, AC

Col. James A. McDivitt, Manager
Apollo Spacecraft Program Office
Manned Spacecraft Center
Houston, Texas 77058

Dear Jim:

Attached are copies of correspondence between Dr. DuBridge, Mr. J. A. Pierce of Bell Telephone Laboratories and Dr. Paine on the subject of early planning for the use of the LM as a backup system. George Low's comments are indicated on the DuBridge letter.

We are evaluating this matter to determine the actual history of the "life boat" mode and whether or not any individual actions are worthy of recognition. Would you send me any relevant information on this subject available either from the contractor or the files at MSC? I am also asking Bob Wagner of Bellcomm if he has any further information in his files.

Sincerely,

Rocco A. Petrone

Rocco A. Petrone
Apollo Program Director

6

✓ HL

DALE MEYERS — Dale — this is interesting, and I for one was previously not aware of it. Are you conducting a detailed search as to how the "life boat" mode came into being. It would be useful to have this in planning records, and for the sake of history.

April 28, 1970

Dear John:

I am impressed that as early as 1962 someone in Bellcom had the foresight to examine possible emergency situations during the Apollo mission and recommend that design of the LEM propulsion system should be adequate for unforeseen contingencies such as the precise emergency situation encountered in Apollo XIII. This far-sighted effort may deserve special recognition from the National Aeronautics and Space Administration, and I am forwarding your correspondence to Dr. Paine, together with a copy of my reply, for his information and consideration in this regard.

Pls let me know the result.

Thank you for sending me this rather intriguing bit of background information from the early days of Apollo.

Sincerely,

Leo

Leo A. DuBridge
Science Adviser

Mr. J. R. Pierce
Executive Director
Research-Communications Sciences Division
Bell Telephone Laboratories
Mountain Avenue
Murray Hill, New Jersey 07974

cc: Dr. Thomas O. Paine

Action Copy to B
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Rec'd in NASA 4/30/70
Suspense Date Indefinite
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Special recognation to Bellcom to be considered with other Apollo 13 awards, if any. See Dr. Paine's acknowledgment to Dr. DuBridge, dtd May 1.
Rec'd in Exec. 5/12/70
Suspense Date 5/25/70
Prepare Reply for Signature of

Bell Telephone Laboratories
Mountain Avenue, Murray Hill, N. J. 07974
Telephone 201-582-2626

J. R. Pierce
Executive Director Research-
Communications Science Divsion

April 21, 1970

DR. L. A. DuBRIDGE
Special Assistant to the President
for Science and Technology
The White House
Washington, D. C. 20501

Dear Lee:

In the aftermath of Apollo 13, I just thought that someone would like to know that back in 1962 one T. M. Burford was worrying about astronauts in trouble and how the LEM propulsion might help them (the memo was fed into Bellcom.)

Yours,

John

Att.
"A Novel Use for the LEM
Propulsion System" by T. M. Burford,
October 31, 1962.
Memo T. M. Burford to J. A. Hornbeck,
September 28, 1962.
"The Utility of Using LEM Propulsion
with CM or CM/SM Attached Draft"
by T. M. Burford, December 14, 1962.

September 28, 1962

This mib comment!

MR. J. A. HORNBECK:

This concerns the SSG document titled "List of System Studies for Apollo" by G. Robillard. As you suggested, I have compiled another list making an attempt to set priorities.

These things seem important in determining priority of system studies:

a) Timeliness is of course first, i.e. studies that relate to those parts of longest lead times have a natural precedence. Therefore, studies that may have a pronounced effect on propulsion are certainly among the first to consider. Also timely are studies of relatively mature programs such as Ranger.

b) Difficulty. Some parts of the Apollo project seem innerently most difficult and technical solutions are not obvious. It is sensible then to make early studies of these parts, irrespective of lead times, both to bring more minds in on the problems and also to produce a climate that may inspire suggestions for simpler alternatives.

c) Novelty. A redefinition of system operation or a suggestion of a significant change in the system may require early study because worthwhile novelties need time to percolate through the organization. (LOR is an extreme example.) Studies of novel ideas should be begun only after very careful selection since there is always a danger of diluting the major effort.

Within the above categories a specific listing follows. (Studies that roughly correspond to items in the SSG list are marked by the SSG numbers in parentheses.)

a) Timeliness

1. Performance Study (I3A)

2. Trajectory Study (I2A)

3. Project Schedule (IIC2)

4. Relation of Gemini and the unmanned program to the Apollo project.

5. Distribution of margins between the S/C and the launch vehicle bearing in mind the desirability of eliminating the SIVB restart.

6. Study the possibilities of a cryogenic SM. (III 14) Note that this work may be a part of an LLS study.

b) Difficulty

1. Check-out on the lunar surface.

2. Lunar orbit rendezvous operations.

3. The abort problem including functional back-ups, abort trajectories and guidance (IID1,D5,D6,D7,D8; III 4,5,9).

4. Study of lunar environment hazards (IIB6).

c) Novelty. The only novelty I can suggest that I believe has a sufficiently good chance of being worthwhile concerns the use of the LEM propulsion for abort. A near free return trajectory is usually assumed for Apollo because, in the event of SM engine failure, small mid-course corrections can accomplish the return to earth. The disadvantage of the free return is the severe limiting of the trajectory choice which leads to relatively small and infrequent launch windows together with a nearly fixed time of flight. A much wider choice of trajectory is possible if the near free return is given up and the LEM engines can be used, after an SM failure, to place the CM on return trajectory. My very rough calculations show that the LEM engine can deliver 9,000 ft/sec to a payload of the LEM and CM. There may be structural or operational difficulties in this mode but a study may be needed to point them out and to show quantitatively the increase in trajectory flexibility.

The list above is no doubt incomplete and for example does not include the bread and butter interface studies that would normally flow from the specification writing such as the ramifications of changing the lunar orbit altitude or determining whether alternative guidance schemes such as using DSIF data have been properly evaluated. Also a priority listing is a matter of opinion and it would be presumptious to claim particular validity for this one. If a priority list is worth having it should be a joint effort of several people of different backgrounds.

T. M. BURFORD

Copy to
Mr. W. D. Lewis

A Novel Use for the LEM Propulsion System

October 31, 1962
T. M. Burford
Case No. 110

MEMORANDUM FOR FILE

ABSTRACT

It is proposed that early design choices should be such as to allow the use of the LEM propulsion when the CM and a full or empty SM are still attached to the LEM. the advantages are additional abort modes and, most importantly, the opportunity to remove the free return constraint on the trajectory.

A Novel Use for the LEM Propulsion System

October 31, 1962

MEMORANDUM FOR FILE

I. Introduction

If it is possible, without undue complications, to use the LEM propulsion in a way not previously intended, a variety of system advantages may be had. The proposal made here is to make effective use of the LEM propulsion possible when the CM and a full or empty SM are still attached to the LEM and are therefore carried as payload by the LEM. The advantages are useful additional abort modes and an increase in trajectory flexibility in the nominal, non-abort, case.

II. Velocity Increments Available from the LEM with Various Payloads

The following velocities, calculated by R. S. Farbanish, assume the weight distribution and specific impulse of the Chance-Vought LOR study.

A. If the LEM carries the complete CM, fueled SM, and LEM landing gear, the LEM engines can deliver 3,200 ft/sec.

B. If the SM fuel and LEM landing gear are jettisoned, the LEM engines deliver 5,930 ft/sec.

C. If the complete SM and LEM landing gear are jettisoned, the LEM engines deliver 7,970 ft/sec.

III. Utility of the Velocity Increments Available

A. Abort Capability

At various points in the mission profile, the velocity available from the LEM can be used to either add to or replace the SM capability. For example:

1. During the earth-moon portion of the trajectory, a return to earth (perhaps because of a solar flare) could be speeded by adding the LEM increment to that of the SM. In the same trajectory phase, an SM failure might be detected and therefore the LEM propulsion would be useful.

2. While in lunar orbit but before LEM descent, an incipient SM failure might be detected. The 5,930 ft/sec. in IIB above from the LEM propulsion is more than sufficient to return the CM and empty SM in this case.

3. If through error or design the spacecraft is not on a free return trajectory and a failure in the SM happens or is feared then the LEM can often accomplish the return. This point has many ramifications and is discussed further below.

B. Trajectory Flexibility

A near free return trajectory is usually assumed for Apollo. That is, an earth to moon trajectory is selected which has the property of returning the spacecraft to earth with no more propulsion than mid-course corrections in the event of SM failure. A disadvantage of free return is the severe limiting of the trajectory choice. However, if one is willing to assume that the LEM propulsion will be used, as suggested here, to return the spacecraft after an SM failure, then the requirement for free return disappears and the trajectory choice becomes quite wide. Among the new possibilities would be: substantial changes in time of flight, greater departures from the moon's orbital plane, and the establishment of lunar orbits that are significantly inclined to the lunar equatorial plane.

A quantitative example of the capability of the LEM propulsion for a non free return abort is the following rather extreme case. Suppose that instead of the usual, approximately three day free return trajectory, it is desirable to use a parabolic two day trajectory. (No reasons are given here for desiring a two day time of flight, the point is only to show the capacity of the LEM propulsion in an extreme case). As can be shown by a simplified analysis, a return to earth after an SM failure in the neighborhood of perilune can be accomplished with a velocity increment of 5,300 ft/sec. This increment is within the capability of the LEM if the SM fuel and LEM landing gear are jettisoned as in IIB above. Furthermore the return to earth with this velocity change has a two day flight time.

It is obvious that some departures from free return are good, others poor and that much thought is required to identify the desirable ones. There would seem little doubt however that with a wider class of trajectories available to choose from, the system could be better balanced, with wider launch windows, greater choice of landing site, perhaps preferable flight times, etc. than is possible when only free return trajectories can be considered.

IV Problems

1. The overall trajectory problem without the free return constraint but within the LEM capability for abort. What are the effects in launch window, landing sites, earth visibility, etc?

2. A problem of abort philosophy; Is it reasonable to assume an abort mode that requires the LEM engines?

3. A structural problem in using engines in a way not usually intended; i.e., can the SM/CM be accelerated in a direction opposite to the usual, can the LEM guidance and control system be arranged to tolerate a drastic change in the payload being accelerated, etc?

4. Is it fair to assume that the fuel of a malfunctioning SM can be safely jettisoned or can the entire SM be sometimes jettisoned? This question is also pertinent in the free return case.

T. M. Burford

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Statement of Work

The Utility of Using LEM Propulsion

with CM or CM/SM Attached Draft,

December 14, 1962.

I. Introduction

The LEM is attached to the CM from the redocking after injection to the separation after establishment of the lunar parking orbit. If the LEM propulsion system can be used during this period, a velocity increment of several thousands of feet per second could be imparted to the combination. A companion study of feasibility will furnish the amount of velocity increments available which will depend on what parts of the CM-SM-LEM combination can be safely jettisoned before the use of the LEM propulsion.

II. Objective

The objective of this study is to determine the utility of using the LEM propulsion under the circumstance given above. The possible utility is of two kinds: improvement of, and additional means of, abort; and the extension of mission capability.

III. Scope

A. General

1. Use the velocity increments as determined by the companion study of feasibility.

2. Use the constraints on available, not jettisoned, equipment as determined by the feasibility study.

3. Consider various SM fuel loadings, including full.

B. Aborts

1. Study safe return to reentry by means of LEM propulsion after SM propulsion failure under the following conditions:

   a. The SM propulsion fails at the time of transfer from the earth-moon trajectory to the lunar parking orbit. Estimate the latitude in choice of non-free-return nominal trajectories made possible by the availability of the LEM propulsion.

   b. The SM propulsion fails anywhere on the earth-moon trajectory.

   c. The SM propulsion fails after transfer into the lunar parking orbit but before LEM descent.

2. Study the return to reentry in minimum time from anywhere on the earth-moon trajectory using both LEM and SM propulsion systems in a manner determined by the feasibility study.

C. Mission Capability

Evaluate the utility of the non-free-return nominal trajectories permitted by Bla with regard to:

1. Flight times on the earth-moon trajectory.

2. Earth launch windows including the possibility of a flight time unfixed until time of launch.

3. Inclination of the lunar parking orbit to the moon's orbital plane within the constraint of SM propulsion as mentioned in A2.

4 Other significant system parameters that may become evident during the study.

T. M. Burford

MAY 1 1970

Honorable Lee A. DuBridge
Science Adviser to the President
Executive Office Building
Washington, D. C. 20500

Dear Dr. DuBridge:

Thank you for forwarding the account of Bellcom's efforts in contingency planning for Apollo lunar missions as supplied to you by Mr. J. R. Pierce of Bell Telephone Laboratories. I feel sure that as we recognize significant contributions to the Apollo 13 mission, other similar accounts of concentrated forethought will emerge. We will certainly retain this specific reference for consideration as appropriate recognitions or awards are being developed.

Sincerely yours,

Original signed by
T.O. Paine

T. O. Paine
Administrator

cc: A/Covert

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