NASA0003

TINDALIGRAMS 1969

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: June 13, 1969

69-PA-T-93A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some significant LUMINARY program changes you should know about

I really blew it at the June 5 Apollo Spacecraft Software Configuration Control Board meeting. Although dozens of rather minor changes were approved, the one I was most concerned about wasn't even discussed and I completely forgot it. This memo is to inform you that we are now desperately trying to include a capability in the LM computer program for a lunar landing flight in November which substantially improves descent abort targeting and procedures. Currently the LM descent abort programs target the spacecraft to insertion conditions which is not entirely accurate. This is because the more sophisticated equations required to do the job right were too complicated to get in the program for the G mission and we settled for some approximations that only do a pretty good job. Unfortunately, if we have a descent abort this makes it necessary to trim the insertion conditions based on ground targeting. This is the so-called "tweak" maneuver you've heard so much about which either the LM or command module must execute shortly after LM insertion into orbit. It is a messy procedure and the program change proposed will eliminate its need. Furthermore, for aborts late in powered descent (that is, after PDI + 10 minutes) it is necessary for the LM to execute a phasing maneuver approximately one-half rev after insertion to set up the proper rendezvous conditions. This, too, is a messy ground targeted procedure which will be eliminated if this program change is implemented.

Although I wanted to tell you about that, my main purpose in writing this memo was to inform you that in order to get this program change in we have to sacrifice some other things and I thought you should have an opportunity to complain if you wanted to. First of all, storage has again become a problem and so we propose that, if necessary, MIT should delete the two Stable Orbit Rendezvous targeting program (P38 and P39) from the LM program. We have never discovered an operational use for these programs but maybe this deletion may bug somebody. (Incidentally, in order to provide more room for the dozen or so other changes already approved, the externally targeted Lambert pre-thrust program (P31) has already been deleted.) The other capability which may have to be dropped is the rendezvous radar automatic acquisition provided by the PGNCS during the Descent Abort programs (P70 and P71). Disabling this capability (R29), may be required to avoid a computer cycle problem. That is, obviously the computer can only do so much in a given period of time and it is MIT's option that adding the proposed sophistication in the guidance may cause us to exceed that limitation. This in turn forces us to give up another task and we have chosen the so-called Rendezvous Radar Designate Routine.

This final paragraph is on another subject, but I thought I would point out that one of the more significant capabilities added last Thursday was the capability for the crew to readout raw rendezvous radar range and range rate data on the DSKY during the operation of the Rendezvous Navigation program (P20). This capability had been requested several times previously but never made it in to the program due to scheduling problems. It is a real nice thing to have.

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: June 11, 1969

69-PA-T-92A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: CSM Rescue Mission Techniques are complete and clean

On June 9 we had our final Mission Techniques meeting on CSM Rescue. I am pleased to report that this stuff appears to be in very good shape. After much hard work by many people, the CSM rescue rendezvous plans shake down to only two basic profiles. Each of these has minor modifications to account for the number of revs required for [illegible] and [illegible] effect of various separation ranges on the rendezvous time [illegible]. The point to be made is that even though it is possible [illegible] great variety of versions for CSM rescue depending on the initial conditions and status of the LM, the fact that the differences between them are so minor gives us assurance that the limited training and simulations we are able to afford should serve to check them out adequately and to provide adequate assurance that they will work if we need them. The G and H CMP's chose to deal with them somewhat differently, but I think their differences are clearly within the realm of crew preference. Specifically, Mike Collins (G) has requested and being provided with what he calls a "Cookbook" of procedures. It consists of about 18 different two-page checklists, each designed for a specific abort situation. In the event of one of these aborts, it will only be necessary for him to select and use the appropriate pages defining the operation of the guidance and propulsion system in the usual checklist detail and giving specific input targeting parameters and tracking schedules. They also contain typical relative motion plots and maneuver magnitude all referenced to GET. These two-page contingency checklists will each be thoroughly reviewed by FCD, FCSD, and MPAD people this week to make sure they are accurate. Dick Gordon (H) apparently prefers now to rely somewhat more on his memory and knowledge of how the programs work and so forth and does not intend to carry these contingency procedures with him. It is his feeling that the differences are really minor enough that he should have no trouble in carrying out the appropriate procedures.

My personal opinion is that either of these approaches are perfectly acceptable and should work just fine.

There was very little new to discuss at this meeting. Probably the most significant result was our detailed specification of control center to CSM targeting assistance required for the abort situations. Specifically:

a. If the CSM must make the "tweak" maneuver (that is, if the LM inserts into orbit unstaged), the ground will supply the GET of the burn

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Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: June 5, 1969

69-PA-T-87A

FROM : PA/Chief, Apollo Data [illegible] Coordination

SUBJECT: PRN ranging [illegible] lunar or[illegible] unnecessary

This memo is to restate our requirements for PRN ranging while in lunar orbit. I am writing it since there is evidently some confusion about it.

At no time in lunar orbit can PRN be classified as more than "desirable" - never "mandatory," or even "highly desirable" as long as things are going reasonably well. [illegible] only time ranging could become a requirement is if the entire tra[illegible] determination system blows up and it is necessary to reinitialize [illegible] scratch when knowledge of the current state vector is essentially [illegible]

Since the specia[illegible] [illegible]ions arising recently deal with PRN requirements during powered flight - that is, ascent and descent, I would like to further state that during these periods PRN ranging is virtually of no use whatsoever. In fact, the powered flight processor in the RTCC will not even accept that type of data. Accordingly, if there is any advantage to be gained in configuring the spacecraft to exclude PRN during those periods in order to enhance the quality of other communication requirements, I recommend that this be done.

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: June 4, 1969
69-PA-T-84A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: G Rendezvous Navigation OJT is proposed

CMP Mike Collins called the other day to ask if there is any reason why he should not do active rendezvous navigation between DOI and PDI on the G mission. That is, he would like to run P20 incorporating sextant and VHF ranging data to update the LM state vector in the CMC. His primary purpose is to get some on-the-job training (OJT) before he has to do it for real during the upcoming rendezvous. You recall, this was in the F Flight Plan and I assume John Young did it, although I'm not sure. I told him that I knew of no reason why he shouldn't and I have asked several other experts who agree. I also suggested to Mike that he contact John personally to get any pertinent F mission feedback.

This memo is to inform you that this activity will be included in the G mission timeline unless somebody comes up with a valid objection. Do you have one?

BT

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 29, 1969

69-PA-T-83A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: DPS low level propellant light

During our final review of the Descent Mission Techniques on May 28, GAEC presented a comprehensive review of the low level DPS propellant light - its operation and accuracy. The most significant piece of information coming from this was that we are assured of about 98 seconds more DPS operation at the hover thrust level after the light comes on. An uncertainty of about four seconds is included in that number thereby making it the "worst" case. Note that this is quite a bit smaller than numbers quoted in the past.

We are proposing the following technique. The crew should commit to landing or else they should abort one minute after the low level light comes on. That is, the descent is continued in a normal manner for one minute after the light, at which time the crew must decide that they can assuredly land or they should abort right then. By aborting right then they have approximately eight to ten seconds of DPS capability remaining at full thrust prior to propellant depletion. Selection of one minute as the go/no go point came about based on an intuitive feeling that approximately eight to ten seconds of DPS thrusting is a reasonable minimum to get the LM the hell out of there coupled with the operational simplicity of keeping track of a integer minute during this busy and exciting time. It should be emphasized that time since the low level light should be the primary cue and would require no secondary cue provided the light is not malfunctioning and the crew noted the time it came on. In that event, of course, they must use the backup system - namely the more critical propellant tank gauge indication of three percent remaining as their cut-off time for making the go/no go decision.

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 28, 1969

69-PA-T-82A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Descent, Lunar Surface, and Ascent Mission Techniques with the H crew

On May 20 and 21 we reviewed Descent, Lunar Surface, and Ascent Mission Techniques with the H crew (Pete Conrad and co.). This get together had two major objectives - to tell the H crew how we think these things should be done and conversely, for the first time to get a flight crew reaction to the techniques since in the main, they have been firmed up too late to review thoroughly with the G crew. In general, I think we are in pretty good shape on this stuff although there are, of course, the inevitable open items and questions we never seem able to rid ourselves of completely.

It was interesting to note that the H crew seems desirous of cutting back some of the activities the G crew considered worthwhile. There are also obvious philosophical differences in their attitude regarding the use of the automatic systems vs. a more manual mode. Conrad seems much more inclined to stay with the automatic system longer than Armstrong as well as insisting that they work. For example, he does not propose to continue in the face of no landing radar data, whereas Neil apparently feels he can substitute visual data for it. Some other interesting examples are:

a. Pete would like to drop out all the visual observations of the lunar surface, both before and after PDI including the LPD altitude checks.

b. Pete would like to substitute a landing radar altitude check prior to PDI.

c. Pete wants to do PDI face up. (Hallelujah baby!)

d. Pete also wants to drop the crew voice report of their estimate of where they actually landed.

It might be worth reporting some other interesting things resulting from our discussion:

a. We probably ought to add in some sort of AGS drift check pre-PDI after the PGNCS alignment check using the sun.

b. There is still a controversy over when we should switch to the AGS. Some feel it should be done only if the PGNCS is degraded to a point where it can't make a safe orbit; others feel we should switchover as soon as it is certain the AGS will do a significantly better job than the PGNCS.

c. The decision has been firmly made that the crew will not manually backup the automatic landing radar antenna position switch.

d. There is still some work to be done in establishing procedures in the event the GDA failure light comes on late in descent. Early in descent, I think everyone agrees the crew must await secondary cues before deactivating the GDA. There may be some advantage to immediately turning it off if the light comes on late in descent in that it may be possible to complete the landing using RCS attitude control only.

e. It was suggested that some sort of VHF ranging check could be done while the LM is on the lunar surface, perhaps during the last overpass prior to LM ascent or even during the ascent itself. We will have to look into this to see if it is practical and useful.

Given the longer lunar stay of the H mission, it is clear the guidance system must be turned off to conserve electrical power. This has obvious implications on how the system should be used just after landing and just before lift-off. We have also decided to throw out the simulated countdown for lift-off at the end of the first CSM rev. As a result of these and other things, I have asked TRW to revise the Lunar Surface Mission Techniques and we will review them with everyone when they get done.

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 26, 1969
69-PA-T-81A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Attention worthy Descent Program Anomaly

Gene Kranz brought the attached G mission LUMINARY Anomaly Report to my attention. I have no idea how he happened to find it amongst all the more insignificant ones. No one else seemed particularly aware or concerned about it, but I wanted to bring it to your attention.

I have asked MIT to define the workaround procedures definitively and to find out how tolerant the system will be for delay in the crew's response.

Howard W. Tindall, Jr.

Enclosure

PA:HWT:js

MIT/IL SOFTWARE ANOMALY REPORT

1.1 ORIGINATOR	1.2 ORGANIZATION	1.3 DATE	1.4 ORIGINATOR CONTROL NO.	PROGRAM	PROGRAM REVISION
C. SCHULENBERG	MIT/IL	4/28/69		LUMINARY	97

LNY 64

1.5 DESCRIPTION OF ANOMALY

hardware or software (either type!)

If a restart occurs in P63 between the nominal ignition time and the time of FTP, the LGC will fail to throttle the DPS to maximum thrust and the landing guidance equations will not be put into operation.

CONTINUED ON PAGE

1.6 DESCRIPTION OF ...

Anomaly pointed out in TRW memo, entitled, Questional Items in LUMINARY 97 Listing (A-201, 4/23/69).

CONTINUED ON PAGE

- MIT ANALYSIS -

2.1 CAUSE

Programmer Error.

CONTINUED ON PAGE

2.2 ... CONDITION

See Section 1.5.

CONTINUED ON PAGE

2.3 MISSION EFFECT

If the recovery procedure is not taken in a timely manner, the landing would have to be aborted via selection of P70 or P71.

CONTINUED ON PAGE

2.4 AVOIDANCE PROCEDURE

None

CONTINUED ON PAGE

2.5 RECOVERY PROCEDURE

Force DPS to maximum thrust via manual throttle at FTP time. Then key in V24N01E01252E02462E[redacted]. Then wait a few seconds and reduce manual throttle to 10 percent.

CONTINUED ON PAGE

2.6 PROGRAM CORRECTION

Correct restart protection for P63 throttle-up task.

CONTINUED ON PAGE

2.7 RECOMMENDED DISPOSITION (Fix, Work-around, etc.)

Fix program or be prepared to use recovery procedure depending on the likelihood of a restart in this time interval.

CONTINUED ON PAGE

2.8 RECOMMENDED RE-TESTING

Restart test of P63.

CONTINUED ON PAGE

2.9 MIT SIGNATURE [signature] DATE 5/1/69

3.1 NASA DIRECTION

CONTINUED ON PAGE

4.1 CLOSING ACTION TAKEN

CONTINUED ON PAGE

3.2 NASA/MSC SIGNATURE	3.3 ORGANIZATION	3.4 DATE	4.2 SIGNATURE	4.3 ORGANIZATION	4.4 DATE

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Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 15, 1969

69-PA-T-78A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some "improvements" in the Descent preparation procedures

As we wade deeper and deeper into Descent Mission Techniques, one thing coming into focus is that, of all IMU error sources, the two that hurt the most are accelerometer bias and y-axis (pitch) misalignment at PDI. Having recognized this, we are now proposing some specific procedures to minimize them. This memo is to tell you all about it in some length, I'm afraid.

There is no better test bed for determining accelerometer bias than a spacecraft in orbit. Any output from an accelerometer is bias and procedures have been well established for monitoring, selecting, and updating the accelerometer bias compensation terms in the LGC. On flights prior to G, the practice has been to establish a threshold below which the compensation would be left alone and above which it would be updated from the MCC. Many of us now feel, and I am proposing that on the G mission, it should be standard procedure prior to DOI for the MCC to update accelerometer bias compensation terms in the LGC routinely, regardless of how good or bad the currently stored values are. The threshold is zero.

Pitch misalignment is a little bit tougher. May I first just state some facts to build on?

a. The current Mission Techniques provide only a coarse IMU drift check by comparison of the docked IMU alignment at DOI - $2\frac{1}{2}$ hours to the undocked AOT alignment performed at DOI - $\frac{1}{2}$ hour. The docked alignment uses the CSM IMU as its reference and has an estimated accuracy of 0.5° in all axes, so drift rates as large as 0.5°/hr could go undetected. (Specifically, the accuracy of this drift estimate is ± .25°/hr.) PDI occurs about $1\frac{1}{2}$ hours after the AOT alignment, which means it is possible for pitch misalignments like 3/4° to build up. That's sort of a worst case kind of number, and to quote such a value will drive statistically-minded people out of their gourds, but it helps me make a point.

b. Tolerable pitch misalignment at PDI to support a successful landing is in the order of 1° assuming the landing radar comes in early enough to compensate for the dispersions that have built up.

c. Descent aborts become hazardous if the pitch misalignment at PDI exceeds about 0.35°. (This number is being more accurately determined, but I'll bet it comes out within 0.05° of that guess.) This is assuming the worst abort situation, namely aborting at an altitude of about 13,000 feet because no landing radar data has been accepted. If we are willing to go beyond that point with no landing radar, the tolerable misalignment is smaller than that. The point is that the IMU performance requirement to support descent aborts appears to be the more constraining than to support descent itself and I think we all feel that it is intolerable to continue descent beyond the point a safe abort could be executed with the degraded PGNCS.

d. Since the AGS has to be aligned to the PGNCS prior to PDI, and pitch misalignment in the PGNCS has an equal effect on the AGS. They are not independent in this respect.

e. Given high bit rate telemetry, ground monitoring techniques are adequate to detect an unacceptable IMU misalignment within the first two minutes of powered descent. Thus, the crew could be informed and instructed to abort safely.

f. To abort a lunar landing mission, if it could have been saved by improving procedures, is rather unacceptable.

Based on all that, we have two recommendations, either or both of which should help the situation considerably.

The first is a proposal for a better docked PGNCS alignment suggested by Bob White of MIT, which should allow us not only to detect a drifting IMU, but to update its compensation such that we may proceed with a nominal mission. Detailed procedures development and performance analysis is under way at this time. It will demand some modification in the crew timeline during the LM activation and checkout period as well as the implementation of a new RTCC and/or ACR computer program and MCC procedures. The technique requires two spacecraft attitude maneuvers while in the docked configuration with the LM and CSM crew simultaneously keying out CDU angles before and after each of these attitude changes. All of this must be done after the LM IMU has been coarsely aligned as in the current flight plan. With this data, the flight controllers can compute the LM IMU orientation and torquing angles required. This technique is expected to be as good as an AOT alignment. It does not require knowing the relative orientation of the two navigation bases nor reading the docking ring index!

The other proposal involves making a drift check prior to PDI; it requires no MCC participation. Considerable effort was given to including an IMU alignment in the timeline but many of us have concluded the lighting conditions make it chancey at best. The only place it fits in the timeline is from PDI - 30 to PDI - 15. This period is almost perfectly centered around local high noon. Either the sun or the moon is in the AOT field of view for almost this entire time, making use of stars almost impossible. Except the sun! The nice thing about the sun is that it is certainly visible. Also since the whole mission profile is keyed to lighting regardless to landing site and month of the year, the sun will always be located in the same place with respect to the LM. MIT has been asked to write up a precise step by step procedure for doing this. Essentially it consists of the following:

After entering the descent program (P63), the crew would accept the option offered them to go into the alignment program (P52). They would specify the sun as their first "star". The LGC has the solar ephemeris and will control the spacecraft attitude to place the sun in the center of the AOT. (The rear detent position should probably be used to minimize attitude change unless we do PDI with windows up.) The crew would readout the CDU gimbal angles to which the LGC is positioning the spacecraft; of particular interest is DSKY register No. 2 - the y-axis. The crew would then take over attitude control and cause the sun to cross the AOT retical line in the pitch direction at which time the actual spacecraft CDU angles would be keyed out on the DSKY. The difference between this actual pitch CDU angle and the previously noted predicted value is a direct indication of drift since the AOT alignment one hour earlier. The mission rule would be: if indicated misalignment is less than 0.25°, the nominal mission should be continued: if the indicated misalignment exceeds that value, PDI must be delayed one rev, an AOT alignment would be performed two hours after the previous one and the MCC would determine and update the PGNCS drift compensation prior to LOI.

The value of the first recommendation is that it provides a chance to detect and fix a problem without perturbing the nominal mission. The value of the second is that it allows detecting and fixing a problem before PDI is attempted, although in the worse case it forces delay of PDI one rev, which I am sure we are going to find is a highly undesirable thing to do.

That in a million words-or-less is where we stand on this matter today. We will continue our analysis and procedures development based on this. One unfortunate fact is that if we adopt these proposals, they will not have been tested on the F mission, but I think we would all be naive if we thought we are not going to learn things on F that force us to change the procedures anyway.

Howard W. Tindall, Jr.

PA:HWT:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 12, 1969
69-PA-T-77A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Manual Steering for LM Ascent

Over the years various groups have attacked the problem of if and how the crew can manually steer the LM back into orbit from the lunar surface. These studies were started before GAEC was even selected to build the LM and some analysis is still going on to define the optimum pitch attitude profile, which should be used in this mode. On May 8, I invited representatives of the MSC groups I knew had been involved in this business to a discussion - the purpose of which was to pin down just what the state is today. We were also interested in determining if something useful could be done between now and the G mission. In summary, I think we all agreed that:

a. We should certainly not count on a manual operational backup mode for lunar ascent in the same sense that manual modes backup some other critical mission phases such as rendezvous targeting, burn control, etc. However, it's better than nothing and we ought to be prepared to do something.

b. Without a rate command attitude control system, it is extremely doubtful they could achieve orbit even if they had trained thoroughly in the technique. (Currently there is no training planned for the G crew.)

c. There are some things we should and will do before the G mission to prepare for this contingency, since it is an unfortunate fact that there are apparently quite a variety of two-failure combinations that can put us into this serious situation.

One of the first impressions you get when you start looking into manual ascent is that the procedures which should be used are strongly dependent upon the character of the system failures. That is, there are many different combinations of failures, each of which should be handled in a different way. As a matter of fact, the multiple-procedure-sets idea, combined with the low-probability-of-occurring idea has probably been the major reason we haven't got this whole thing all worked out in detail now. However, Jack Craven has finally convinced me the situation is not that remote and a worse situation can hardly be imagined. Furthermore, our discussion leads me to believe that these multitude of procedures don't really present an insurmountable problem that can only be resolved in real time. I get the feeling that the "variation in procedures" which came about from many of the component failures is primarily a reconfiguration of spacecraft switch settings and the crew procedures probably aren't too different than for the nominal ascent itself. Of course, in that case the MCC must be prepared to advise the crew exactly how the spacecraft should be configured to best support ascent in one of these degraded modes. It was interesting to find that the method which must be used for the next level or class of failures essentially boils down to the following few options:

a. Prior to lift-off, some sort of initial azimuth reference must be chosen such as a prominent landmark or probably the LM's shadow on the lunar surface. Immediately after lift-off, the crew would yaw the spacecraft to place the LPD line on the shadow prior to initiating pitchover, after which a landmark to aim for could be selected by the crew in real time.

b. After manual "Engine Start", the crew would hold the vertical rise pitch/roll attitude for 15 seconds. They would then pitch the spacecraft in accordance with pre-selected four step pitch profile. These angles are essentially known today both:

(1) In inertial coordinates for use if a spacecraft inertial reference system is available and

(2) In a relative coordinate system - that is, the overhead window marks which should be held on the lunar horizon.

c. Propellant depletion should probably be used as the "Engine Off" technique and it is recommended that the interconnect not be used for attitude control since APS propellant is marginal to start with and should be utilized exclusively for getting into orbit. The "Engine Off" command could possibly be issued manually using the DEDA output of ΔVX provided the AEA and x-axis accelerometer are functional but probably shouldn't be.

This procedure, which essentially targets the spacecraft to the nominal insertion altitude and flight path angle most likely will result in a large dispersion in velocity, which of course would foul up the subsequent rendezvous. At least it provides the greatest chance of achieving orbit at all and probably minimizes the dispersions to give us a reasonable whack at rendezvous.

It is evident the two things that the crew needs to do on this job are an attitude reference and an attitude control mode. I was very interested to find that if we constrain ourselves to talking about pure manual as opposed to the various levels of degraded automatic ascent modes, we really came out with a very short list of candidates for these two things. Specifically for attitude reference, we have the following:

a. If the CES is broken, but the AEA, ASA, FDAI, and needles are available, they provide an excellent attitude reference. In fact, in this case, the crew should fly the needles as opposed to the four step pitch profile noted previously since they are driven by the actual ascent guidance error signal. (Unfortunately, it probably means having to fly in Direct Attitude Control - heaven forbid!)

b. If only the LGC is broken, we can use the IMU and GASTA driving the FDAI to provide a good inertial attitude reference if we can align it somehow (caging, probably) and can figure out how it is aligned.

c. The overhead window has been especially configured for use with the horizon during ascent, which fortunately is sunlit throughout the nominal ascent. (A sunlit horizon is not always available for descent aborts or lift-off immediately after touchdown.) Spacecraft pitch is controlled using the horizon and window marks; spacecraft yaw utilizes the horizon tilt and roll (that is, azimuth) must use some landmark as noted previously.

Those are all the choices we could think of for an attitude reference if automatic control has been lost. Furthermore, we found there are only three manual attitude control modes, which I will list in order of preference:

a. If a PGNCS accelerometer is broken, it is possible to use the LGC, IMU gyros, and hand controller to obtain a DAP rate command mode.

b. If the ASA and/or AEA is broken, it is possible to use the ATCA, rate gyros, and hand controller to obtain a rate command mode.

c. The rotational hand controller (ACA) can be used in either of two Direct Attitude Control modes, both of which are probably unacceptable. They are four jet - 12° (hardover) and two jets - 2½°.

Following is a list of things we are going to do:

a. MPAD/TRW will recommend the final angles - inertial and horizon - to be used for carrying out the four step pitch profile.

b. FCSD will check with the crew to determine if they want to add these numbers into their checklist along with the nominal attitude profile check points they have already, or if they want to leave this for a real time voice relay from the MCC.

c. Clark Hackler and Jack Craven are going to develop a complete matrix defining the preferred spacecraft configuration and capability remaining for degradation or failure of each component. This should be done by the first week in June. Incidentally, something along this line has apparently been worked out by GAEC already.

d. I am going to see if it possible for some experienced pilot, preferably Pete Conrad, to run a few simulations of some of these manual abort modes, particularly to evaluate using the overhead window attitude reference with the three rate command and direct attitude control modes noted above.

In mid June, we will set up a Mission Techniques meeting on this subject with world-wide participation - particularly MIT, TRW, and GAEC - to see where we stand at that time. Considering the catastrophic nature of the situation under discussion here, it seems some effort is certainly justifiable to get prepared. I would recommend that it be an effort equivalent to manual TLI steering. In other words, a blank check. Everyone at MSC and particularly the prime crew can spend full time on it, if they want to. And, I currently plan to have a Mission Techniques document prepared specifically for it, too - prior to G.

Howard W. Tindall, Jr.

PA:HWT:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 12, 1969

69-PA-T-75A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Cis-lunar state vector updating procedure change

A lot of you won't care - but I want to make sure that those that need to know, do. It deals with state vector updates from the MCC to the CSM during cis-lunar flight on the G mission.

On the G' mission, state vector updates were always transmitted to the LM slots in computer memory in order to avoid messing up the infamous W-matrix. Since essentially no onboard cis-lunar navigation will be carried out on G, there is no need to protect the W-matrix and the crew has expressed a strong preference for preserving their sacred state vectors onboard the spacecraft. With some justification, they want the ground to update only into the CSM state vector slots, after which they will make some checks to determine if they have been received and stored properly and are reasonable. They will then transfer them to the LM slots for safekeeping. In other words, the LM slots are for the crew to use as they wish. The flight controllers have agreed to do it this way.

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 8, 1969

69-PA-T-74A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: The LM4 RR/LGC interface may be broken, but that's okay - sorta

This memo is to document the Data Priority position regarding a recent LM4 systems problem. To wit, it is considered acceptable to proceed with the nominal F mission with a questionable or known interface failure between the rendezvous radar (RR) and the LM spacecraft computer (LGC). It should be emphasized that a properly operating rendezvous radar with crew readout is still considered mandatory for DOI. Also, this recommendation does not necessarily apply to the G mission.

Justification for this position is based on the unique character of the F mission and on the availability of three adequate alternate data sources. The F mission rendezvous starts with precisely controlled, known initial conditions since one spacecraft separates from the other in orbit; furthermore, consumables - particularly, propellant - are abundant. The alternate data sources which can be used for rendezvous navigation and maneuver targeting in the event of an RR/LGC interface failure are:

a. The crew backup charts using raw RR data as displayed on the tape meter and/or DSKY

Error analysis by FCSD has proven the crew backup chart solution to the rendezvous problem is competitive with the PGNCS. These charts are utilized in the nominal crew procedures. The tape meter is the primary source of input data, however, it is also possible to obtain raw RR data by use of the RR Self Test routine (RO4) with the RR test switch set to the "Off" position. Incidentally, the crew already uses this routine periodically to check and calibrate the tape meter. It should be noted, however, that RO4 cannot be used simultaneously with the rendezvous navigation program (P20) nor if the RR/LGC interface is totally broken rather than intermittently malfunctioning.

b. The CSM using sextant and/or VHF ranging data

This solution is also routinely available and competitive with the PGNCS. It should be noted, however, that the VHF ranging system has never been flight tested and there is certainly no great confidence in the high intensity tracking light on the LM. It failed on D! However, either of these data sources is adequate for successful operation of the system.

c. The MSFN solution based on pre-separation tracking and PGNCS navigation through LM maneuvers

This solution is also comparable in accuracy to the PGNCS and, in fact, is the real foundation upon which we are able to base our case for this recommendation. It assumes, of course, that the PGNCS is operating nominally - controlling and navigating through the maneuvers. It should be noted that if it is known the interface has failed and PGNCS rendezvous radar navigation cannot be carried out, it is possible for the MCC to update state vectors to the LGC enabling it to obtain its own targeting more-or-less equivalent to the MCC. Procedures for doing this are well known to the flight controllers.

d. It is important to emphasize that AGS rendezvous navigation and maneuver targeting should not be utilized on the F mission due to computer program limitations which result in unacceptable errors. The AGS can be used for maneuver execution, of course.

If an RR/LGC interface failure occurs but is not detected by some other means, it is quite possible that the LGC LM state vectors could be damaged by acceptance of bum RR data - that is, crew editing is not infallible by a long shot. However, special rendezvous solution comparison and AGS state vector update procedures are not required since current mission techniques were developed especially to prevent execution of wrong maneuvers. Failures of this type are the reason for the very existence of Mission Techniques!! The specific situation under discussion here is not unique except that preflight concern makes everyone alert for this specific problem. (I am assuming that the crew will be adequately briefed, although, I am not sure when and by whom at this time.)

This paragraph is to present the other side of the coin. Our only real concern is the added vulnerability to failures of other systems which can force switching the mission to a rendezvous abort sequence (such as an APS failure at the insertion maneuver). Crew backup charts are not available for these high ellipse cases (except for a CDH chart for the PDI abort situation). Multiple failure cases leave us dependent upon the CSM solution, item "b" above, plus the PGNCS solution noted in item "c" above, which should be adequate for a safe return without RR data, although probably dispersed and perhaps costly.

This recommendation has been coordinated with authoritative representatives of FCD, FCSD, and MPAD, who all agree with it. No crew input has been obtained, however, I would be amazed if they do not also agree. Assuming Stafford's vote, I assume this matter is settled. The mission rules do not specifically address this interface problem and require no change unless it is desirable to add this.

Howard W. Tindall, Jr.

PA:HWT:js

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 7, 1969
69-PA-T-73A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Apollo Mission Techniques Documentation Schedule

Here is another Mission Techniques Documentation Schedule, since the last one is three months old and barely reflects real life any more. The Lunar Orbit Activities Document will almost certainly have to be updated to reflect whatever we learn on the F mission. A June 30 release date for that update will be kinda late, of course, but that is a problem everyone has when the launch occurs seven weeks after the last splashdown.

Howard W. Tindall, Jr.

Enclosure

PA:HWT:js

MISSION TECHNIQUES DOCUMENTATION SCHEDULE

as of May 7, 1969

SUBJECT		FEB 5 EST	CURRENT EST	ACTUAL
Saturn V/Apollo Launch Phase Aborts		-	-	Oct 22, 1968
	Update	Mar 15	-	Mar 31, 1969
F/G Earth Parking Orbit & TLI		Feb 17	-	Feb 10, 1969
F/G Translunar Midcourse & LOI*		Feb 17	-	Feb 17, 1969
F/G TEI MCC & Entry*		Feb 24	-	Feb 28, 1969
F/G Contingency Procedures*		Mar 3	-	Mar 24, 1969
F/G MCC-H/RTCC Data Selection		Mar 17	-	Apr 9, 1969
F/G Lunar Orbit Activities	Draft	-	-	Jan 27, 1969
	Final	Feb 14	-	Feb 28, 1969
	F Update	Mar 31	May 12	-
	G Update	-	June 30	-
G Descent	Final	-	-	Aug 22, 1968
	Update	Mar 31	May 26	-
G Lunar Surface	Final	-	-	Oct 6, 1968
	Update	Feb 24	May 12	-
G Ascent	Final	Mar 24	May 26	-
G Descent Aborts and Subsequent Rendezvous	Draft	-	-	Feb 3, 1969
	Final	Mar 24	-	Mar 27, 1969
	Update	-	June 9	-

* Change pages will soon be distributed

Enclosure

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list below

DATE: May 6, 1969
69-PA-T-77A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Comments on IMU compensation procedures

Attached is an MIT memo I thought you should see. It proposes that the MCC update the IMU compensation terms in the spacecraft computers whenever they are detectably wrong. One benefit, of course, is the possibility of eliminating a bunch of IMU alignments. But more important, it keeps the system right.

Incidentally, the threshold listed in the F and G Mission Rules beyond which the PIPA bias will be updated is twice too big. The Data Priority recommended value is .[illegible]3 ft/sec². (See F Rules 15-11 and 20-10, G Rules 11-11 and 24-3.) I'm sure you appreciate my calling your attention to this important matter! Seriously, I'd like to emphasize the significance of this on the LM during descent. Accelerometer bias is one of the two most undesirable LM IMU errors and should be minimized as much as possible. (The other, of course, is y-axis misalignment at PDI and that's a tough one.)

Howard W. Tindall, Jr.

Enclosure

Addressees:
FA/C. C. Kraft, Jr.
FC/E. F. Kranz
G. S. Lunney
C. E. Charlesworth
FC3/A. D. Aldrich
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PA:HWTindall, Jr.:js

Instrumentation Laboratory
Massachusetts Institute of Technology
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APOLLO PROJECT MEMORANDUM #38-69

To: Distribution

From: A. Laats and G. Edmonds

Date: 17 April 1969

Subject: Reduction in Number of P52 Alignments During Apollo Missions

References: 1. RAPSIC Memo No. [illegible]
2. Apollo 10 Flight Plan, March 12, 1969

Experience in Apollo 8* has established that if the G&N system is left in operate continuously during a mission accurate gyro drift measurements can be obtained from realignments and the gyro bias drift terms are stable. (Ref. 1). As a result, the number of P52 realignments can be reduced if the gyro drift compensation is updated during the mission.

The following criterion are recommended. All realignments used for drift measurement must use the REFSMMAT option.

1. Two realignments to REFSMMAT after TLI. The second realignment to be at least six hours after TLI. If the average of these two measurements is more than 0.36 meru different from the prelaunch load for any gyro, that NBD compensation is updated to the measured value. The 0.36 meru is the largest standard deviation of the measurements for Apollo 8 (Ref. 1). (Two measurements are suggested to reduce the chances of gross errors.

2. At least 1 alignment to REFSMMAT per day. If more than 6 hours have elapsed since the last alignment, the results should not differ by more than 0.72 meru from the value obtained in 1 above. If the change is greater than 0.72 meru consideration will be given to updating the compensation or performing additional drift measurements such as described in 5 below. (This criterion would not have been exceeded on Apollo 8 if a good value had been loaded as in 1 above).

*Apollo 9 data is not considered [illegible]

Realignments before every major burn (i.e., before all burns including entry but not before MCC burns). Generally these alignments will be to a new preferred orientation, and so gyro drift measurements will not be possible. (If the gyro torquing option is used approximate gyro drift measurements can be obtained.)

4. Special alignment requirements may be required:(a) the use with P22 around the moon in Apollo 10; (b) before LM docked alignment; (c) accurate alignment for rendezvous back up. Update drift compensation on the same basis as in 2 above. The [illegible] do not know how the requirements for these alignments were obtained. Perhaps they should be reviewed also.

5. Additional measurements will be required if the above measurements indicate unusual gyro performance. This would include a bias change of more than 5 meru between periods and that obtained in 1 above and drift measurement standard deviation significantly larger than the 0.36 meru experienced in Apollo 8.

The application of these rules to Apollo 10 would eliminate about 10 P52 alignments from the time line of Reference 2.

Error Analysis

Using Reference 1, it can be seen that the [illegible] under 1 above will give the gyro drift to about 0.36 meru 1σ. If this error exists for 24 hours, the platform misalignment on a 3σ basis will be

$$3 \times 0.36 \times 10^{-3} \times 15 \times 24 = 0.390^{\circ}$$

This will be accurate enough so that auto optics can place a star within the SXT field-of-view. This is also an acceptable error for nominal MCC burns.

Aln Laats
Technical Director
Apollo Guidance and Navigation

Attach
Distribution:
Page 3.

OPTIONAL FORM NO. 10
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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 6, 1969

69-PA-T-71A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Ascent newsletter

This memo is to report several interesting things regarding lunar ascent, both nominal and after a descent abort.

1. It turns out we demand better performance of the PGNCS to support ascent to orbit than we do descent. Accordingly, if it is necessary to abort during descent due to degradation of the PGNCS, it is automatically necessary to switchover from the PGNCS to the AGS. Of course, this assumes that the AGS is performing better than the PGNCS.

2. We have recently had a running philosophical argument regarding ascent switchover. Of course, switchover in itself is not catastrophic as is an abort; if the system you switch to is working okay, the mission continues just as planned. This led me to push for establishing fairly tight switchover limits since I felt that it was highly desirable to assure as near nominal rendezvous characteristics as possible. That is, why stick with a degraded PGNCS if the AGS is working <u>better</u>? The only disadvantage seems to be the hazard involved in the <u>act of</u> switchover itself; all the switches, relays, and so forth have <u>to</u> work. In other words, it comes down to a tradeoff between the hazards involved in switching over versus the dispersions in the rendezvous situation which could be avoided by switching over.

More recently we have adopted a procedure for eliminating dispersions at insertion following descent aborts by making an adjustment maneuver immediately after insertion. This so-called tweak burn is used specifically to assure satisfactory rendezvous conditions. This procedure may also be used to compensate for degradation of the PGNCS during ascent and makes it possible to leave the PGNCS in control as long as it is still capable of providing a safe orbit. However, if the PGNCS degradation is sufficient to justify it (say, worse than 3 sigma) the crew should be advised of the situation during powered flight such that they will stand by for a tweak burn to be executed immediately after insertion using the same procedures as for the descent abort.

Having adopted this technique, it seemed reasonable to set the PGNCS switchover limits fairly wide. The value chosen was 6 sigma. The compromise here, of course, is the operational messiness of a tweak burn traded off against the switchover to AGS "hazard."

3. One thing which could give us bad trouble is a misaligned PGNCS prior to ascent, particularly if we align the AGS to it as was planned. The problem, of course, is that small misalignments can result in unacceptable insertion conditions and, even though ground monitoring would probably detect the situation during ascent, switchover would do no good since the AGS would be equally misaligned. To avoid this situation entirely, we have concluded that the best course of action is to independently align the AGS while on the lunar surface rather than to align it to the PGNCS. This makes the two systems truly independent, which not only gives us a cross-check on the accuracy of the alignment of each but also permits a useful switchover if somehow a PGNCS misalign escapes our detection techniques. Incidentally, this also eliminates the problem of CDU transients in the AGS lunar surface alignments. Accordingly, we are proposing that the procedures be changed to always utilize the AGS gravity lunar surface alignment technique rather than alignments to the PGNCS. I expect this will be done once some details have been worked out.

4. It is interesting to note that the problem just discussed is not quite as severe in the event of a descent abort. In that case, of course, the AGS must have been aligned to the PGNCS and so they both will suffer the same misalignment at PDI. What happens then if we have a descent abort and try to achieve orbit with both systems misaligned? It turns out that this particular error is partially compensating - that is, the trajectory dispersion during descent is partially eliminated by the trajectory dispersion during ascent back into orbit. In addition, the descent abort limits will be tight enough that unacceptable dispersions should not occur prior to descent. In other words, we feel we have a safe situation here.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

OPTIONAL FORM NO. 10
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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 5, 1969

69-PA-T-70A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Descent Monitoring Mission Techniques - a status report

I think we are beginning to see the light at the end of the Descent Monitoring Mission Techniques tunnel. At the April 24 meeting on that subject we thoroughly discussed the integration of the onboard techniques with the activity at the MCC during powered descent and I feel the resultant is as reasonable and complete as possible, consistent with practical operational constraints.

One thing we have finally been able to get under control was this squirmy idea that there is some way for the crew to compare the output of the AGS and PGNCS onboard the spacecraft with the objective of making abort and/or switchover decisions. Obviously there is no question that a massive system failure will be obvious to them and their course of action will be clear. Obvious too, is the fact that the crew will be monitoring both of these systems as well as many other data sources throughout powered descent. But, now known to everyone, is the fact that there is no way for the crew to compare AGS and PGNCS such that they are able to detect which system is malfunctioning, if that malfunction is of a slow drift degradation type, at least not with the assurance necessary to take any action. Therefore, just as in the case of ascent, not only is the MCC prime for carrying out the task of slow drift malfunction monitoring, but we now recognize that MCC is the <u>only</u> place this can be done. That, my friends, is a fantastic event - the death of a myth we have been haunted by for two years. Don't get the idea I'm happy with the situation. What I am pleased about is that everyone now agrees it <u>is</u> the situation.

There is another thing about powered descent crew procedures that has really bugged me. Maybe I'm an "Aunt Emma" - certainly some smart people laugh at this concern, but I just feel that the crew should not be diddling with the DSKY during powered descent unless it is absolutely essential. They'll never hit the wrong button, of course, but if they do, the results can be rather lousy. Therefore, I have been carrying on a campaign aimed at finding some way to avoid the necessity of the crew keying up the on-call displays. This campaign has not been altogether successful. I guess partly because not everyone shares my concern.

Although, I started out by saying the end is in sight, we still have quite a batch of unresolved issues which I would like to list here so that everyone can continue to think about them.

a. There is still a wide open question concerning what is considered our real time minimum landing radar data requirement in order that descent can be continued. There are many of us who feel that failure to obtain a certain amount of good landing radar data by some point in the powered descent is sufficient justification to abort - for example, landing radar altitude updating by 13,000 feet has been suggested as a requirement. The crew apparently feels that this constraint is not real and that their observations - visual, I suppose - are an adequate substitute. Just how we are able to integrate in these real time crew observations to overcome the landing radar deficiency has not been established yet and I am not sure who, if anyone, is working on it.

b. Although, a month or so ago, the decision was made that the crew is to manually backup the automatic switching of the landing radar antenna position during a nominal descent, there is still substantial concern that this is not the right thing to do. For example, the LM systems people point out that the switch the crew uses to do this must be cycled from "auto" through the old landing radar position to get to the new landing radar position and a switch failure could override a perfectly operating automatic signal and send the antenna scurrying back to the position it just came from.

c. I am still not content with the AGS altitude update techniques. That is, how many times and when during powered descent should this be done?

d. There is some point in powered descent after which it should be possible to continue the landing with an inoperative gimbal drive actuator. Procedures for handling this situation in real time remain to be established.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 2, 1969

69-PA-T-69A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: CSM rendezvous navigation works fine using just VHF ranging

I made an announcement during the F Operations Review which was absolutely flat-out wrong. This memo is to correct that statement and/or just to make sure you know what capability really exists in the CSM for rendezvous navigation.

Sometime long ago, I got the impression that acceptable rendezvous navigation could not be done in the CSM using VHF ranging data alone. That is, I thought that if sextant tracking were not also available due to failure of the optics or the LM tracking light, there was no point in processing the VHF data. It turns out that this is not true. In fact, under certain circumstances, such as before CSI on the F and G missions, use of VHF ranging data alone is said to be better than using the combined data sources. In fact, the only place there is some question about using VHF ranging alone is after TPI where some analyses show it breaks down.

My apologies to you, Mr. Charlesworth.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: May 1, 1969

69-PA-T-67A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Descent Aborts and subsequent Rendezvous Mission Techniques

On April 28, 1969 we reviewed the Descent Aborts and subsequent Rendezvous Mission Techniques with the crew and the rest of the world. I think most of this is quite complete and agreeable to everyone concerned, with one major exception. I was shocked and ashamed to find that I had badly misunderstood the situation regarding the CSM rescue techniques and, although there were plenty of ideas, the detailed techniques were not at all firm at that time. Subsequently, (April 30) a much smaller group of us beat that into the ground too. Therefore, this memo is to document my understanding of the agreements we reached at both of these sessions. I'm sorry it's so long - just a big subject, I guess.

1. Abort after separation if there is to be no DOI

During our meeting we inadvertently got into a lengthy discussion on conditions governing whether or not DOI should be attempted on the first or second opportunity. That, of course, is important but was not our real purpose of this meeting. We did finally conclude that in the event no attempt is made at DOI, the LM should use the brute force, immediate return technique for getting back to the CSM. The point is the separation velocity setting up the equal period mini-ball orbit is so small that automatic closure is by no means certain. Accordingly, when it is decided to abort, the crew should take positive action to establish a fairly substantial closing rate. The present recommendation is that they should set up a closing rate which in feet per second is equal to eight times the current range expressed in nautical miles. This is the same procedure that should be used for fouled up DOI maneuvers. It is useable until about ten minutes after DOI.

Some of the crew present expressed a concern that the factor "eight" seems excessive under certain circumstances and requested that somebody make sure it is really the best value. I guess this is your job, Mr. Mineberry, if you can find time between now and July to handle it. I think we should all realize, however, that simplicity in procedures may prohibit using the value that is optimum under all circumstances.

2. **Abort if no attempt is to be made to initiate powered descent**

At one time it was considered impractical to go an extra rev and attempt PDI two hours late, primarily due to fear of an unacceptable rendezvous/abort situation. This has proven to be unfounded. The same rendezvous abort procedures work after an extra rev, although there is an extra cost of about 70 fps for insertion from descent aborts. The extra insertion velocity does make APS propellant depletion more likely for late aborts, but the RCS can be used to make up the difference. Time required to complete a CSM rescue can be increased up to 12 hours and at a cost of 800 fps. This is used to put the CSM in a dwell orbit. But, this is only necessary if the LM experiences many failures and does not seem sufficient justification to scrub the landing attempt. Eight LGC descent abort coefficients for P70/P71 and one for the AGS must be updated in real time. (Incidentally, the current plan is to update these in real time on the nominal mission to account for dispersions in the CSM orbit.) A platform alignment should be performed by the LM prior to the second PDI attempt. The major open item is for the Flight Dynamics people to establish what Pad and command messages must be sent to the spacecraft and when. (There is also some question of accuracy of the revised descent targeting.) The primary concern deals with time available to do this. Incidentally, these same techniques may also be useable for a DOI maneuver delayed one rev.

3. PDI Abort

A PDI abort is only used if it is known that PDI will not be attempted or possibly, if the DPS engine does not ignite. Considerable thought was given to using an onboard capability for targeting this maneuver. Specifically, the technique was for the crew to initiate the powered descent programs following the nominal timeline through engine ignition and then hitting either the Abort or Abort Stage button to utilize the DPS or APS Descent Abort programs which automatically target the abort maneuver. It was finally concluded, however, that this technique by itself was not really adequate because spacecraft systems problems could occur at PDI time which would make it highly desirable not to have to commit instantaneously either to aborting, nor to going around another rev. That is, it seemed almost mandatory to provide an abort opportunity a short time after PDI to provide a little time to think over the situation and decide what to do - go around and try PDI again, or to abort now. Since the delayed abort opportunity was considered a requirement for this purpose, the question boiled down to whether the crew and everyone else should learn and be prepared to use the instantaneous PDI abort technique as well. Since there are some problems not yet worked out with it and special procedures are required, we concluded that it was best to drop use of the onboard technique and to provide a ground targeted abort opportunity at PDI plus 10 minutes. This abort would utilize the standard pre-thrust and thrust programs (that is, P30 and P40 or P42) and PDI Abort Pad message voiced to the crew before DOI. Since this maneuver assumes nominal conditions coming into PDI, the targeting for this burn is essentially known today. Accordingly, Ed Lineberry is to supply the ΔV_g values to FCSD to be included in the crew's checklist. Simulations and experience may eventually prove that the pad message need not be sent.

Incidentally, if DPS ignition does not occur at PDI there is no need for the crew to remove ullage since it is so small.

4. Aborts from Powered Descent

It has been established that a trim maneuver (we've been calling it the "tweak") is necessary after LM insertion into orbit in order to compensate for known errors in the LGC abort target coefficients and measured dispersions in the insertion conditions. Tweak targeting will be carried out by the MCC (not onboard) based on the best available data source for cutoff state vector - ordinarily the LM PGNCS - and will be relayed to the crew within 1[illegible] minutes after main engine cutoff. The tweak burn is nominally horizontal but spacecraft attitude can be substantially in error with negligible results.

I think everyone agreed to the necessity of the tweak burn but there was considerable discussion on how the post-insertion situation should be handled. We finally recognized that the thing that most confused the issue was the DPS. For example, plume impingement precludes making large burns while docked, making jettison procedures necessary under certain ΔV circumstances. Systems problems might make it mandatory that the DPS not be jettisoned, meaning that procedures were needed for both cases - staged and unstaged and so forth. There appeared to be minimal problems associated with the situation if the LM had to stage the DPS in order to achieve orbit. This led us to the final resolution, namely:

a. If the LM achieves orbit using the DPS and the V_{go} is less than [illegible] fps, the CSM will make the tweak maneuver at DPS cutoff plus 12 minutes. This maneuver will be under UNCO control using the SPS or RCS, whichever is called for. In this case, the LM can carry the DPS as far as docking with the CSM if that is considered desirable or it may be jettisoned at any convenient time, provided the act of jettison is carried out without any perturbation to the trajectory. If the DPS is carried along, it may be used for some of the rendezvous maneuvers.

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b. If the LM insertion into orbit is on the APS, the LM makes the tweak burn as soon as possible, probably within two minutes after engine cutoff using the RCS and the "average G" program (P47).

c. The significance of "V_{go} less than 30 fps" mentioned above is that if the DPS cutoff occurs with more than 30 fps left to be gained, the crew is supposed to Abort Stage and finish the maneuver on the APS. This is a rule we have agreed to for a long time.

d. The LM does not trim any ΔV residuals after main engine cutoff for any descent abort unless the MCC fails to advise the crew within 30 seconds after cutoff that the MCC targeting will be available. The point here is that if the MCC has lost communication, which includes even the high-bit rate telemetry needed for targeting, the course of action is for the crew to trim the residuals as soon as possible. On the other hand, it is advantageous to wait if they are going to make the MCC targeted tweak burn. They should know within 30 seconds after cutoff which of these situations exist.

e. The voice message from MCC consists of only two parameters - TIG and ΔV_x.

f. Just as in a nominal mission, the MCC will always update the LM state vector in the CMC based on LM telemetry data regardless of which vehicle makes the tweak burn. However, if the CSM is the active vehicle, the LM crew must update the CSM state vector in the LGC using the target ΔV program, P76.

5. Late Aborts from Powered Descent

Aborts during the first 10 minutes of powered descent utilize variable insertion velocity targeting in the LM guidance computers - both PGNCS and AGS. The subsequent rendezvous sequence is essentially the same as a nominal rendezvous. As a result, standard CSM mirror image targeting can be used to backup the LM and no special procedures are required aside from the tweak burn noted above. However, after approximately ten minutes into powered descent the variable insertion targeting would result in an apogee less than 30 n.mi., which we consider too low. Therefore, aborts after that time are targeted for a standard low orbit - 9 by 30 n.mi. and the rendezvous situation begins to degrade. That is either the terminal phase lighting conditions or the coelliptic differential altitude becomes undesirable. It is recognized that for aborts occurring during an additional 40 seconds into descent the standard rendezvous sequence can be continued since we consider the resultant increase in differential altitude up to 20 n.mi. acceptable. After that point, something else must be done. The something else is as follows - in order to maintain nominal lighting and ΔH, an extra rev is required. Two extra maneuvers are required in the subsequent rendezvous sequence costing a total extra ΔV of as much as 80 fps. (This extra ΔV cost diminishes to zero as the abort is delayed.) The first extra maneuver, called "Phasing," occurs about 50 minutes* after insertion and is targeted by MCC to establish the nominal ΔH and TPI time. The Phasing maneuver is horizontal: its ΔV is a function of abort time. It will be transmitted by voice using the standard External ΔV Pad format. CSI_1 is the other extra maneuver and occurs [illegible]° after Phasing. It is targeted onboard using an MCC supplied TIG. Following these two extra maneuvers, the spacecraft go through the standard CSI/CDH/TPI sequence. All of these maneuvers are, of course, computed onboard.

The CSM performs standard mirror image targeting as usual with one exception. Since the Phasing burn could be excessively retrograde, the CSM backup of Phasing must be limited to about [illegible] fps. If this occurs and the CSM must execute it, the crew [illegible] some special P32 procedures for CSI_1 to compensate for the limited Phasing adjustments. (The complete procedures are being [illegible] thoroughly by MPAD and FCSD.

That's long and [illegible]. In summary, let me point out the key things. Our problem - the one that took a day to resolve - was to figure out some way to work with both spacecraft so that:

a. The rendezvous situation would be completely acceptable - particularly the lighting and elapsed tracking time and

b. That at any point, either spacecraft could take over the active role as the situation dictates and

c. That the technique be relatively simple - especially not loaded with special procedures that differ from nominal.

The solution satisfies these things very well much to the credit of Jerry Bell, Ed Lineberry, H. David Reed, Milt Contella, and probably some others.

The tasks to clean this up are:

a. OMAB - Pin down the precise timeline, ΔV's and TIGs, lighting, ranges, rates and angles - that is the reference trajectory for a few key descent aborts.

b. MPT - Establish the rendezvous navigation tracking schedule and all that goes with it.

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* Phasing shall actually occur at a fixed GET corresponding to the CSI time for an abort occurring at 10 minutes into powered descent. This GET time will be on a pre-DOI Pad.

c. FCSD - Prepare the detailed crew procedures - particularly CSM - and identify which specific parts should be given highest simulation priority if the crew can give <u>any</u> attention to them preflight.

d. OMAB - Compute the rendezvous maneuver biases which must be applied to one spacecraft solution for use by the other for the various abort modes.

6. Aborts After Touchdown

Current planning includes two "preferred" times for aborts after touchdown. "Preferred" is misleading in that for the first stay/no-stay period, it is preferable to Abort Stage as soon as its need is recognized and then to carry out the rendezvous sequence precisely as described above in Section 5.

Since it is considered undesirable to remain in the insertion orbit through perigee, it was decided to establish a minimum Phasing burn of 10 fps which will always be executed by the LM to raise perigee. This, of course, changes the stay/no-stay decision time about 30 seconds earlier and the second preferred abort time one minute earlier since it reduces the catch-up rate in the parking orbit.

7. Here are some odds and ends of interest to me:

a. All rendezvous navigation, both nominal and following aborts in both spacecraft, will be operated to update the LM state vector regardless of which vehicle is active. This is done because the CSM state vector is known better inertially than the LM.

b. It is important to recognize that after a descent abort there is a very good chance the LM will have a substantial DPS and/or APS capability remaining - particularly the latter. Some of these rendezvous maneuvers can be very large - up to 120 fps. The MCC must be prepared to assess and assist the crew in choosing which engine should be used to avoid all the many constraints the LM has regarding plume impingement and APS restarts. Also, regarding PGNCS minimum burn accuracy and how to use the interconnect, etc.

8. That's it!

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: April 30, 1969
69-PA-T-66A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: What's descent all about?

As a result of some stirring around within NASA on how the various guidance and control systems are used during descent, George Cherry of MIT took it upon himself to write a complete description of the capabilities that exist and how they may be used. Without doubt, this is the finest, briefest, most readable description I have ever seen on this subject and for that reason I am forwarding a copy to you under this shining white piece of paper.

Howard W. Tindall, Jr.

Enclosure

PA:HWTindall, Jr.:js

[illegible]

Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge, Massachusetts

AG# 154-69

March 21, 1969

National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas 77058

Attention: Mr. W. R. Kelly
Project Officer (PP7)
Guidance and Navigation
Apollo Spacecraft Program Office

Mr. H. W. Tindall (F..)
Bldg. 30, Room 3068

Through: NASA/RASPO at MIT/IL

Subject: Lunar Landing Guidance and Control Modes

Gentlemen:

Malcolm Johnston has passed on to me the letters from Maj. General John D. Stevenson to Mr. Donald K. Slayton and Mr. George M. Low, the letter from George Low to General Stevenson, and your inquiry concerning a description of lunar landing guidance and control modes, their testing at MIT, and our version of their mission usefulness.

The letter from George Low to General Stevenson is quite a good description of the guidance and control modes available for lunar landing. I believe I can add a little detail concerning mode descriptions and their usefulness, however. I have talked to some of the folks here and at MSC (principally Neil Armstrong, Buzz Adrin, Donald Cheetham, Warren North, etc.) about the mission usefulness of the various guidance and control modes and, of course, I am familiar with the testing we will perform on these modes. So here goes our answer to your questions.

P63 Program 63, the Braking Phase Program Mode, slows down the LM and guides it to hi-gate. The hi-gate target is arranged relative to the initial landing site so that the guidance program's solution to the two-point boundary valued problem between hi-gate and lo-gate tips the LM up and allows the astronaut to view the site.

Enclosure

The astronaut can display the PGNCS total guidance error on the FDAI error needles (ATTITUDE MON switch in PGNCS) by having keyed in V62 through the DSKY. He can then steer out the PGNCS P63 attitude errors with the AGS (GUID CONT in AGS and AGS MODE CONTROL in ATT HOLD) manually (ACA) or with the PGNCS manually (GUID CONT in PGNCS and PGNCS MODE CONTROL in ATT HOLD) or automatically (PGNCS MODE CONTROL in AUTO).

Note, then, that there are three attitude control submodes in P63: AGS manual or PGNCS manual or PGNCS auto. This is true for P63, P64, and P65. So I will not repeat this for P64 and P65. One word of caution, however, if the astronaut hits the ROD (rate-of-descent) switch while he is in PGNCS ATT HOLD, the LGC will irrevocably transfer him out of the auto guidance program modes into the ROD program mode, P66.

Major program mode P63 is not just useful; it is essential. It is useful, of course, to be able to steer out the PGNCS guidance errors with the AGS ATT HOLD mode or the PGNCS ATT HOLD mode in order to assess the handling qualities of the AGS analog autopilot. We cannot test at MIT, the AGS steering because we do not simulate the AGS on our hybrid simulator.

In major mode P63, P64, P65, or P66 the control of the throttle should be automatic. Thus, the astronaut can assume the attitude control function with the AGS or PGNCS ATT HOLD modes in these major modes but he should let the LGC control the throttle. Indeed, Neil Armstrong has told me that this help from the LGC is very much appreciated and that simultaneous control of attitude (and horizontal velocity) and throttle (descent rate) is a formidably difficult crew task.

• P64 Program 64, the Approach or Visibility Phase major mode should result in a LM thrusting attitude which permits astronaut line-of-sight out the LM window through the LPD to the landing site. During most of this phase (after the astronaut has responded to the flashing DSKY request to arm the SITE REDESIGNATION routine until about 20 seconds before the end of the phase) the astronaut can use the ACA to redesignate the landing site. It is worth noting that that the PGNCS MODE CONTROL switch must be in AUTO for the ACA to function as a landing site re-designator. If this switch is in ATT HOLD the ACA functions as a rate command/attitude hold stick.

I think that the ATT HOLD sub-mode in P64 is very useful for it permits the astronaut to assess the handling qualities of the LM with the current status of the RCS jets (failed or unfailed) and the lower inertias encountered after the braking phase. In fact, after his final use of the ACA in conjunction with the LPD as a site re-designation device I would anticipate that he would switch from AUTO to ATT HOLD for good and control the attitude of the spacecraft manually while the LGC controls the throttle automatically with P64 and P65, until he wants a different descent rate from the automatic one and operates the ROD switch to select P66.

Incidentally, a good chance for the crew to assess the handling qualities of the LM is at the junction between P63 and P64 when the automatic guidance system commands about a (nominally) ten degree thrust attitude change (V62 must have been entered to see the total change at once). This maneuver, if done manually, gives the LM commander a chance to maneuver the spacecraft according to the FDAI error needles through a fairly large change and feel the response.

• P65 Program 65, the Automatic Terminal Landing Phase major mode, has the guidance and control objectives of nulling the horizontal components of velocity, establishing a descent rate of about 3 ft/sec, and achieving an erect orientation of the LM. To use this mode completely automatically the astronaut must leave both the MODE CONTROL switch and the throttle control (THR CONT switch) in AUTO. But, of course, he can fly the PGNCS FDAI error needles manually while P65 handles the throttle. This mode seems very useful if the astronaut does not have good visibility out the window but can believe the landing radar and trust the PGNCS. Notice that there is no positional control in P65. The spacecraft simply settles down from about 150 feet LGC altitude at about 3 ft/sec while nulling the horizontal velocity until lunar contact is made. The automatic throttle to control descent rate to 3 ft/sec may be particulary useful here if the LGC estimate of descent rate is reasonably accurate. The attitude control by the astronaut could be based on the PGNCS guidance errors on the FDAI error needles or by a combination of eight ball and out the window cues. Thus, P65 can be looked at as a P66 (with only one descent rate, 3 ft/sec) and FDAI error needle cues as to how to null the horizontal velocity components and get the spacecraft erect. This represents somewhat of an over-simplification of the dynamical differences between P65 and P66 because P66 has one-half the guidance sample and DSKY display period (once per second) that P65 has (once per two seconds). Futhermore, the control law time constants for nulling the descent velocity error are quite different in the two programs. The vertical thrust acceleration commanded every two seconds in P65 is $A_{vert} = (\dot{h}_d - \dot{h})/10 + g$ (P65) and the vertical acceleration commanded every one second in P66 is $A_{vert} = (\dot{h}_d - \dot{h})/1.5 + g$, (P66). It can be seen that P66 will eliminate the descent error faster than P65. The reason for the longer time constant in P65 is that both the throttle command and the attitude commands are generated from the same equation in P65, to wit $\underline{a}_{tc} = (\underline{V}_d - \underline{V}_{meas})/10 - \underline{g}$, (P65).

The thrust vector is commanded along $\underline{a}_{tc}$ and the throttle is set to make the thrust acceleration equal to the magnitude of $\underline{a}_{tc}$. A longer time constant is needed to stabilize the attitude commands which are generated from $\underline{a}_{tc}$. (Incidentally, both the number 10 in P65 and the number 1.5 in P66 are erasable quantities. These values are our best present estimates of what these quantities should be). The longer time constant in P65 should be acceptable since the descent rate at the beginning of P65 is nominally 3 ft/sec (lo-gate) and there is very little descent rate error to null. Notice that there will be a difference in reaction of the two control laws to landing radar noise. P66 will be more reactive.

While mentioning radar noise, I ought to remind you that P65, P66, and P67 all have the capability of estabishing new landing radar velocity weighting factors. We are presently using 0.1. We are doing fairly extensive testing of P65 in the completely automatic mode on our all-digital simulator. We will do some testing in the ATT HOLD mode on our hybrid. I hope that the crew will evaluate the usefulness and handling qualities of this mode. I do believe that they ought to give it strong consideration because it only has one strong competitor, P66.

P66 Program 66, the rate-of-descent terminal phase major mode, requires manual attitude control but provides automatic control of descent rate by LGC control of the throttle. The astronaut can command changes in the descent rate by 1 ft/sec incrementing or decrementing inputs from the rate-of-descent switch. (The 1 ft/sec is actually a quantity in erasable storage.) This mode can be entered from P63, P64, or P65 by putting the MODE CONTROL switch in ATT HOLD and operating the ROD switch in one direction at least once. This mode is not designed for large velocities, however, or long ranges from the landing site and it is expected that it will be entered from P64 at about five-hundred feet altitude or later.

This appears to be the leading contender for the touch-down program and we have put a great deal of engineering and testing into this program. For example in regard to engineering improvements, Craig Schulenberg has increased the frequency of the control loop to once per second, reduced the computation log, improved the throttle compensation, and speeded up the DSKY displays. I believe that the LM pilot calls out the descent rate he reads on the DSKY to the LM commander. This display will now have a higher frequency and greater freshness. P66 receives a great deal of testing emphasis at MIT.

P67 Program 67, the completely automatic landing mode does not appear to be very useful as a lunar landing touch-down mode but it may have other uses. Crew members have told me that it is really a formidable task to land with manual throttle and manual attitude control. The throttle in particular appears to be hard to handle manually. We do not give this landing mode much emphasis at MIT except to show that it works. We do not do man-in-the-loop type landings to any extent with P67. I would not anticipate that the crew would train on landing with P67.

I do see one possible use of P67 during landing, however. If the crew wants to abort, they might want to switch to P67 first in order to erect the vehicle's attitude and throttle up the DPS. He must throw the THR CONT switch to MAN in order to obtain P67, however, and then throw the MODE CONTROL switch to ATT HOLD in order to obtain manual control of the DAP. This seems to gain little over just throttling up (the manual throttle overrides the auto throttle when it is at a higher value no matter where THR CONT is) in P63, P64, and P65 with the MODE CONTROL switch in ATT HOLD.

Incidentally, the only thing I might think of taking exception to in the enclosure to George Low's letter is the statement that the "AGS provides a rate command attitude hold mode.... that will provide essentially equal handling qualities to that of the equivalent PGNCS mode." I would like to point out that on the basis of LMS and MIT/IL tests we have engineered with the Flight Crew Support Division an ACA quadratic stick that pleases the crew with its handling qualities and reduces the RCS jet activity and DPS plume impingement during hover. I do not believe the AGS autopilot has this kind of rate command system. There may be other dynamical and handling qualities differences between the two systems.

Extensive testing will be made on the DAP manual modes at the hover inertia configuration of the DPS.

Yours very truly,

George W. Cherry
LUMINARY Project Director

GWC/kp

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: April 16, 1969
69-PA-T-6AA

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: How the MSFN and sextant data are used to target DOI and Descent

We had a meeting on April 9 which was extremely interesting to me. We discussed and settled on how the MSFN tracking and sextant landmark observations would be used in the MCC/RTCC to produce optimum DOI and Descent targeting for the LM. The big new factor that had to be taken into account somehow was the propagated state vector errors resulting from our inaccurate modeling of the lunar potential. This has forced us to change our planned techniques somewhat from those proposed before the C' mission. Most of what we now plan to do is just as the Math Physics Branch (MPB) of MPAD proposed to us at this meeting. I feel they should be commended for a pretty fair piece of work.

I would first like to describe the manner in which MPB proposed that the RTCC orbit determination consistency checks be made during the flight. As you recall, in a previous memo I noted that they feel it is best to use the orientation of the orbital plane determined pre-LOI to which they add the in-plane orbital elements based on new MSFN tracking. Of course, it is necessary to continuously monitor and confirm that the plane established in this way is right. They intend to do this by performing single-pass MSFN solutions after each lunar orbit and comparing the resulting inclination with that established pre-LOI. It is expected that the single-pass solutions will show a random variation about the pre-LOI value indicating it is safe to continue using it. If they detect a bias or trend in these single-pass inclinations away from the pre-LOI value, they will have to update it.

In addition to the inclination check performed continuously, they also plan some discrete consistency checks made in revs 6, 7, and 8. These checks will be made by processing MSFN tracking just as will be done later for the DOI and Descent targeting. That is, they will determine the orbit based on rev 3 and 4 data and propagate it to rev 6. They will make a "plane-free" single-pass solution in rev 6 based on rev 6 tracking. They will compare the three position components in local vertical coordinates (that is, downtrack, altitude, and crosstrack) at 20 minute intervals throughout rev 6 and will plot the differences vs. time. These plots should show the propagated error from the older solution as a function of time throughout rev 6. They will do the same thing using revs 4 and 5 data propagated to rev 7 and compared with a single-pass rev 7 solution. They will do the same thing with revs 5 and 6 propagated to rev 8. These position difference plots determined for revs 6, 7, and 8 will be superimposed upon each other to make sure there is consistency on determination of propagated state vector errors. This consistency, incidentally, has been demonstrated on C' and we expect to reconfirm it on the F mission prior to G. If it works as expected, it should be possible to determine the propagated error in all three components as a function of time on a state vector propagated ahead two revs. The significance of this, of course, is that the DOI and descent targeting is performed with a state vector which is two revs old and if we are able to determine the propagation error, bias may be applied to compensate for them. That is a description of a rather complicated process. The important thing for you to understand is that a technique appears to be available for determining and compensating for propagation error in real time.

The manner in which we intend to use sextant tracking of the landing site has not changed since before C'. That is, we intend to determine the landing site position by applying the measured relative displacement in all three components - latitude, longitude, and radius - to the current MSFN solution at the time of the sextant observations. Thus, the targeting solves the relative problem compensating for errors in both MSFN state vectors and the preflight estimate of the landing site location. We have established that the change from the preflight value in each of these components based on the real time data must not exceed the following values:

a. Latitude must not be changed more than 12,000 feet.

b. Longitude must not change more than 6,000 feet.

c. Radius must not change more than 6,000 feet.

These values are based on our current 3 sigma estimates of preflight map accuracy RSSed with the MSFN orbit determination accuracy. It is felt that corrections larger than these must indicate some sort of gross failure demanding either that the sextant tracking be redone by delaying DOI one rev or that the sextant tracking be ignored and the Descent targeting be based on the preflight values. Incidentally, the mission rule defining which of these choices to pursue is a significant open item which must be resolved.

Now I would like to describe how the propagated errors are compensated for.

a. Crossrange, which is essentially latitude, will not be compensated for propagation errors at all. Since we are using the frozen plane technique, by definition, no propagated error can occur.

b. Error in spacecraft altitude is compensated for by changing the radius of the landing site by an amount equivalent to the propagated state vector error in the altitude direction. The empirical correction is determined from the propagation state vector plots described above by reading out the error in altitude associated with a time in orbit equivalent to touchdown time. The point is that the state vector is not corrected, but rather compensation is applied to the landing site radius since this is a much cleaner procedure.

c. Downrange error is more-or-less equivalent to landing site longitude and presents special problems. Consideration was given to compensating downrange propagation errors by changing landing site location in a manner similar to the radius bit just discussed. That would work fine for Descent, but can result in a serious problem in Descent aborts. Specifically, downrange error in the state vectors during powered flight act in a way equivalent to a platform alignment error in inertial space. Specifically, 10,000 feet downrange error is equivalent to 0.1° IMU misalignment. Therefore, if we were to leave the propagated downrange error in the state vector, all powered flight by the inertial guidance system would be carried out with 0.1° error and, in the event of a Descent abort, would cause the system to aim for the wrong insertion conditions by that amount. Of course, the AGS, which is initialized from the PGNCS would also have this error. Although we don't expect the downrange error to exceed about 5,000 feet, we have no assurance of this and conservatively feel that an alternate approach for compensating downrange error is preferable. The alternate approach we adopted is to change the time tag on the state vectors such that the downrange error at touchdown time is zero. Changing a state vector time tag is not a simple thing to do in the RTCC. It has not yet been "automated." As a result, it is necessary for the Data Select Officer to manually enter the entire state vector into the RTCC using his typewriter like input device. This is a time consuming process because it must be very carefully checked. (It is recognized that the RTCC program for the lunar landing mission has been frozen, but it was suggested to the Data Select people that they consider automating this input since it is becoming part of the nominal operation.) It is to be emphasized that this time tag compensation is applied to both the LM and CSM state vectors in all three computers - RTCC, LGC, and CMC. We may eventually establish a lower bound in this downrange compensation below which it is considered acceptable to live with the error. For example, if the downrange error is less than 5,000 feet, we may choose to apply that small correction to the landing site longitude and leave the state vectors time tag alone since that is a much simpler thing to do. But that's not the current technique.

One significant open item I failed to mention in passing is that there is still a controversy raging on whether a single-pass or two-pass MSFN orbit determination should be used for Descent targeting. That is, the sextant tracking is done on rev 11 and the MSFN tracking on that rev is certainly used. The question is, should rev 10 MSFN tracking be incorporated in as well? The solution to this depends on ironing out inconsistencies between two computer programs which are given conflicting results. The answer could come at any time. Once the one-rev vs. the two-rev decision is reached, of course, it will not only apply to orbit determination techniques for Descent targeting but will also be incorporated in the MSFN propagation error determination technique described above.

It is currently planned that these G mission operations will be carried out on the F mission exactly as if that flight were a lunar landing. This obviously means that to the maximum extent possible these techniques will also be used in the F mission simulations. There is some question, however, if changing the state vector time tag to compensate for propagated downrange error is a reasonable thing to do on the F mission. Accordingly, this must be discussed with the F mission operations people before we naively assume they will do it.

Much of the preceding discussion deals with the landing site location to be used in the LGC during Descent. The landing site position (RLS) to be loaded in the command module computer should be the preflight map values of the prime landing site landmark and there is no reason to go through this "mickey mouse" of updating the CMC values from the MCC before the LM lands.

The time tags on the state vectors transmitted to the spacecraft computers on G are essentially the same as on the F mission. The LM state vector sent to both the LGC and CMC will be time tagged at DOI -10 minutes. The CSM state vector sent to both spacecraft will be time tagged at PDI + 25 minutes, which should be close to the initiation of rendezvous navigation in the case of a late Descent abort.

Except for the open items noted above, I think this pretty well establishes how we plan to do the targeting for DOI and Descent on the lunar landing mission, at least until F mission results come in.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: April 15, 1969
69-PA-T-63A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some things about Descent

This memo is to list a few odds and ends dribbling out of our latest Descent Monitoring clambake.

1. We have identified a new entry for the PDI pad message voiced to the crew before DOI. Just prior to PDI the crew makes a crude estimate of their altitude above the lunar surface by measuring the time it takes for a lunar landmark to move from one end to the other of their LPD line on the LM window. (I believe it normally takes about 20 seconds and therefore two seconds is equivalent to about a mile accuracy in altitude.) The new pad entry is the time at which the altitude check landmark should appear at the lower end of the LPD line. It is currently proposed that the landmark to be used will be the same one the crew performs their on-the-job training sextant tracking on LOI day. This has the additional benefit of providing the MCC with data for determining its location with some precision before the altitude check.

2. During powered descent the crew monitors their various data sources to ascertain whether or not the DPS is producing an acceptable thrust. If there is thrust degradation of a fairly small amount, they are supposed to exercise established malfunction procedures in an attempt to improve DPS performance. If the degradation is more severe, malfunction procedures will not help and the crew should abort. LM systems flight controllers were requested to establish the amount of thrust degradation which the crew should tolerate before beginning the malfunction procedures and what amount they should use to decide on an immediate abort.

3. There has been a great deal of discussion over the merit of the crew observing the lunar landscape during the early part of powered descent. There are some benefits the crew is supposed to obtain from this but it is important that it not be carried on so long that landing radar data is lost as a result. Since it is possible to start getting landing radar data as early as two minutes after PDI, if altitude is dispersed low by one mile, it is proposed that the crew yaw the spacecraft from its face down attitude no later than PDI + 2 minutes. Yawing sooner would be fine.

4. The attitude the crew should hold after yawing to acquire landing radar is 6° off the principle axis in order to give symmetrical landing radar antenna coverage. This, of course, provides greater probability of acquisition and "data good." (Incidentally, a possible candidate for future spacecraft computer program change is to have the automatic system also control to this attitude, compensating for the 6° landing radar antenna offset.)

5. It has been said that the hi-gain S-band pointing angles during the braking phase of powered descent are more or less constant once the spacecraft has been yawed for landing radar acquisition. It would be very useful for the crew to have these pointing angles in their onboard data for use in manual acquisition during this period if the S-band were to lose lock. Who figures out what these angles are - Rocky Duncan is that you?

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : PA/Manager, Apollo Spacecraft Program

DATE: April 23, 1969

69-PA-T-62A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: F mission rule regarding DPS gimbal drive failure indication

This memo is to report how it is currently planned to handle an indicated failure of the DPS gimbal drive actuator (GDA) on the F mission.

On the F mission there are two DPS maneuvers - DOI and Phasing. The DOI burn is about 71 fps achieved by [illegible] seconds duration at 10 percent thrust and about [illegible] seconds at [illegible] percent. The Phasing burn is about 195 fps achieved by [illegible] seconds at 10 percent and about 19 seconds at full thrust. The question to be answered was what should the mission rule be covering a GDA fail light occurring on either of these burns?

From the offset it should be made clear that advice from the MCC during the maneuvers is out of the question due to the communication delay when the spacecraft is operating at the moon. And of course, the DOI burn is performed in back of the moon.

The fail light coming on can mean any one of three things - the gimbal is moving when it is not supposed to be, the gimbal is not moving when it is supposed to be, or the indication itself is at fault. Apparently by far the greatest probability is that the failure indication itself is in error. As you know, there is no direct cockpit readout of DPS gimbal angles. Accordingly, the only way the crew has of determining that the light is in error is by waiting for some other cue such as excessive attitude error on the FDAI and hearing or seeing the RCS jets firing to maintain attitude, as they will when the LM attitude error as controlled by the DPS gimbal positioning exceeds 1°.

If the light comes on during the G mission, the mission rule will almost certainly be to await the second cue before taking any action because even a runaway gimbal cannot create a problem and you unnecessarily have blown the mission by turning off the GDA if the light is wrong. It is currently intended to use this same rule on F, although it is not so clearly proper for F as G. Specifically, in the event we really do have a runaway gimbal, it is almost certainly possible to continue on with the nominal mission provided the crew deactivates the GDA immediately in all cases. That is, by freezing the DPS gimbal position, it is possible to complete not only the DOI burn, but also the entire Phasing burn using RCS for attitude control. Analysis has shown the RCS propellant required is not excessive and the plume impingement constraints are not exceeded. For example, if the GDA misalignment were 1½° throughout the entire Phasing burn, only 15 seconds of RCS would be required of the worst jet. This gives the crew more than 5 or 6 seconds to deactivate the GDA in the worst situation - namely a runaway gimbal moving at 0.2° sec. If the crew does not deactivate the GDA as soon as they get the light, but rather awaits the second cue, mistrim may be too great to permit use of the DPS for the Phasing burn. This would force us either to use the APS for Phasing or to perform a PDI abort, which essentially eliminates the long range rendezvous navigation exercise and results in a non-nominal rendezvous sequence. We don't think this is the case and are getting some computer simulations run to prove it. That is, we expect that even by awaiting the second cue, the resultant misalignment will be within RCS control capability.

In the event of a real GDA failure during the DOI there are some things the MCC can do once the LM appears from behind the moon. Care must be taken, however, to make sure that these tests do not result in further misalignments of the DPS gimbal during the Phasing burn. Certainly the MCC can make an estimate of which direction the mistrim appears to be the largest prior to the maneuver and could recommend that the opposite RCS jets be used for ullage in order to reduce the probability of reaching the plume impingement constraint during the Phasing burn.

The mission rule is currently written this way, with the approval of everyone I know who is interested. The only perturbation I can foresee would result from the analysis noted above showing we might lose the DPS for Phasing if the crew awaits the second cue. In that case, a review might be worthwhile.

Howard W. Tindall, Jr.

cc:
(See list attached)

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: April 15, 1969

69-PA-T-61A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Let's drop one of the lunar surface RR tests

During our review of the G Mission Lunar Surface Mission Techniques Document on April 1[illegible], we came to a conclusion which may interest you. It deals with the need, or really lack of need, for the crew to do some things that are in the current flight plan. Specifically, in the crew LM timeline, we have included two periods of LM rendezvous radar tracking of the command module - the first is two hours after landing and the second is two hours before lift-off. Neither of these periods are really needed although it may be interesting to try it once. On the other hand, it does require crew activity, uses electrical power, wears out the radar, and so forth and may even place a constraint on command module attitude during his sextant tracking of the LM. It was our conclusion that at least one of these periods of tracking should be eliminated and we are recommending that it be the first. The reason for deleting the first is that it interferes with the crew countdown demonstration (CDDT) for ascent, which is synchronized with the first CSM passage over the LM. If the crew were to perform rendezvous radar tracking, the CDDT would have to be terminated about 1[illegible] minutes before "lift-off." By eliminating the rendezvous radar test, the CDDT can and should be run until about TIG minus one minute.

Although we are not proposing to delete it yet, it should be noted that the CDDT itself is of marginal importance and if it interferes with other more important activity, it could also be eliminated. It is not a precise countdown, anyway, since obviously the crew must not fire pyros, bring the APS batteries on line, pressurize tanks, and so forth, unless they really intend to lift-off. This CDDT should certainly be eliminated from lunar landing missions after the first.

As noted in a previous memo, the command module sextant tracking of the LM is not mandatory either, although the flight controllers will use the data if they get it to reinforce confidence in their other data sources. And, of course, the post-flight people will undoubtedly find it interesting. Here again, though, it may be worthwhile to consider omitting one of the two sextant tracking periods. We are not proposing this yet either.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

APOLLO DATA PRIORITY COORDINATION
MEETING SCHEDULE

AS OF April 14, 1969

69-PA-T-60A

	April													May						
SUBJECT OF MEETING	14	15	16	17	18	21	22	23	24	25	28	29	30	1	2	5	6	7	8	9
G Descent Monitoring*					■					■										
G Abort and Rescue**						■														
G Odds and Ends***											■									
SPECIAL MEETINGS																				

■ (filled top) Meeting begins at 9:00 a.m.

■ (filled bottom) Meeting begins at 1:00 p.m.

* Meetings in Room 378, Building 4

** Meeting in Room 3087, Building 30

*** Meeting in Room 378, Building 4

Howard W. Tindall, Jr.

MSC Form 1283 (Rev Sep 68)

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: April 11, 1969
69-PA-T-59A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: F Rendezvous Mission Techniques Clean-up

On April 5 we had what I expect is the last of the F Mission Rendezvous Techniques meetings. We resolved a number of open items which had not been covered before, or which popped up during simulations. This memo is to list them for the record. Some are trivial, some are really quite significant.

1. Since the first planned DPS maneuver is DOI, it was agreed that the gimbal angles included in the LGC erasable memory load should be right for that maneuver. These values should also be included in the crew check list (Stan Mann please respond).

2. The LM attitude and attitude rate limits for the DPS burns are 5° and 5°/sec unstaged and for the APS are 10° and 10°/sec.

3. We agreed upon the following course of action regarding imperfect DOI maneuvers.

a. First of all, only the x-axis residual shall be trimmed. The y and z-axes residuals shall be left untrimmed since they do not bother anything and trimming wastes RCS propellant and can result in excessive plume impingement.

b. Underburns - Underburns less than 5 fps will be trimmed up to 7 seconds plus x RCS burn duration, which is a plume impingement constraint. (Note: that's only 3 fps of trimming and thus can leave a small residual which will force retargeting the later burns) Underburns in excess of 5 fps will not be trimmed and will result in a "PDI abort." (A PDI abort, you recall, involves making a maneuver at about PDI time yielding CSI one-half rev later. In other words, it eliminates the rev in the nominal mission between phasing and insertion. The PDI abort will be made with DPS if it is considered an operating system, otherwise with the APS.)

c. Overburns - Overburns less than 12 fps will be trimmed with minus x RCS. Again, this limit is based on a RCS plume impingement constraint. It should never occur since this is about a 4 second overburn which could have been manually stopped before reaching this value.

Overburns greater than 12 fps result in lunar impact and therefore call for a direct return of the LM to the command module by the immediate, brute force technique discussed in previous memos.

d. I guess it goes without saying that any PGNCS failure during DOI also dictates a direct return start.

4. The following agreements were reached regarding the phasing maneuver:

a. It was emphasized that at least 40 fps should be achieved by the LM somehow if at all possible.

b. Underburns - Trim under[illegible] less th[illegible] fps with plus x RCS up until the 7 second plume im[illegible]ent limit. [illegible] the underburn is greater than 5 fps, but less than 25 fps, a[illegible] complete the maneuver with RCS. If the underburn is in exces[illegible] fps, stage and complete the burn with APS using the AGS.

c. Overburns - Trim overburns less than 12 fps with minus x RCS. For overburns in excess of that, trim out 12 fps and standby for an update of the Insertion targeting.

5. Insertion

a. Underburns - If the total velocity gained is less than 45 fps, take it out using minus x RCS. This limit is based on the 30 second minus x RCS plume impingement constraint. In this event, the CSM does the insertion burn three minutes later. If the underburn is less than 80 fps, use the plus x RCS to complete the maneuver. (This limit is based on the 55 second RCS plume impingement constraint.) For the approximate 100 fps band of cutoff velocities in between these two limits, the LM should do nothing immediately and the command module will have to rescue.

b. Overburns must be removed somehow to avoid lunar impact.

6 [illegible]t has been said repeatedly before, and I say again here today, that [illegible]re is no such thing as a 200 n.mi. range limit on the VHF ranging by the CSM. That is merely a fictitious design value which has no bearing on how the operation should be conducted. VHF ranging should be used to its full 327 n.mi. recycle limit provided the data is good. The ΔR ΔV limits, which the CMP should use to decide if it's good or not are currently set at 0.5 n.mi. and 3 fps. (These values may be changed this week following a rendezvous navigation meeting of the experts.)

It was agreed that the CMP could do P20 rendezvous navigation, updating the LM state vector in the CMC, between DOI and phasing, if this does not conflict with other more urgent activity.

7. The TPI window has been established as being from minus 8 minutes to plus infinity. The nominal TPI location is at the time the target vehicle is 23 minutes before sunrise. The significance of the window is that if after CSI it is discovered that the TPI associated with the elevation angle option has slipped earlier than 8 minutes, the crew will recycle the TPI program (P34) using the time option with nominal TPI minus 8 minutes on the input time.

8. The CSM always uses the LM computed CDH time for input to P33 as long as the LM PGNCS is assumed to be working okay.

9. It was agreed that all CSM mirror image targeting (that is, for CSI, CDH, and TPI) shall use the same TIG as the LM. That is, mirror image targeting will not be delayed one minute or three minutes as had previously been considered. This technique considerably simplifies procedures and results in (minor) difficulty only if the LM failure, which forces the CSM to become active, becomes apparent when the LM attempts to make the maneuver. Such a last instant failure on an RCS burn is considered very unlikely and does not result in too bad a situation if the command module then executes the maneuver late.

One of the simplifications obtained by eliminating TIG delays is the elimination of all biases that need to be applied to the CSM solutions for use in the LM with one exception. It is necessary to subtract 1 fps from the CSM CSI (P32) solution when the LM uses it for comparison with their own solutions or for execution.

10. Comparison limits were established for evaluating the acceptability of the various rendezvous maneuver solutions. In each case, it is most desirable to use the LGC if possible. Accordingly, it will be used if it compares favorably with either the CSM or the LM chart solution. If it fails, the LM chart is compared with the CSM solution and is used if acceptable. If both the LGC and chart solutions fail their test, it is recommended that the LM execute the maneuver computed by the CSM since a rendezvous radar failure is the most likely cause of trouble. The comparison limits are 2 fps, 5 fps, and 6 fps for x, y, and z-axes, respectively, in both local vertical and in line-of-sight coordinates.

This comparison technique shall be used for the CDH and TPI burns for sure. It may also be possible to use it for CSI, provided analyses between now and the flight show that the CSM will have an acceptable performance. Since it is not certain that the CSM will shape up, we have adopted the following weird technique which should be used for CSI unless the CSM is eventually certified to be okay. It is based on use of three possible solutions - the PGNCS, the LM chart, and the pre-separation canned burns. It is also based on a desire to insure too large a CSI burn, if anything, in order to avoid having TPI slip early, which is considered a serious dispersion, as noted in paragraph 7 above. The rule is that the LM crew should execute the latest of these solutions, provided it is no more than 2 fps bigger than the next-to-largest solution! If the rendezvous radar has failed, it wipes out both the PGNCS and chart solution, the LM crew uses the same comparison scheme, only in this event it is a comparison of only two sources - the pre-separation canned burn against the CSM CSI solution after it has been biased 1 fps as noted in paragraph 9.

11. There were at least two situations in which it seems desirable for the CSM and LM to share the braking task and it was agreed that they would do so if either occurs. If the LM fails to stage the DPS or if the LM is not able to visually acquire the CSM during braking, lateral line-of-sight control by the LM is not practical and the CSM shall do it. The LM will continue to be responsible for performing the actual braking maneuver provided the rendezvous radar is working.

And that's how we spent Saturday.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: April 10, 1969

69-PA-T-58A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Descent monitoring at MCC

We have reached a plateau in our work on Descent Monitoring, perhaps making it worthwhile to send out this memo. First of all, I don't think there is any question that Descent is the thing that requires most of our attention between now and the G mission, at least in the empire of Mission Techniques. There are still a lot of things to do and so starting about a month ago we have been having one full day meeting per week, which will probably continue for another month. I think we have pretty well established what the MCC has to do and how they do it during Descent. That's really the subject of this memo. Our job is to work over the onboard techniques and integrate them with the ground monitoring to make sure everything is complete and consistent.

After considerable discussion, we have established that the ground's job during Descent is to attempt to do the following things (not necessarily in order of importance!):

a. Detect DPS malfunctions and excessive RCS plume impingement.

b. Predict that adequate propellent margins are available to permit landing.

c. Detect impending PGNCS failures.

d. Make sure PGNCS guidance is not diverging.

e. Make sure trajectory constraints of some sort or other are not being violated.

As far as we can tell, all of the necessary telemetry and tracking data programs have been identified and are being implemented in the RTCC; all necessary display formats have also been provided in the MCC. There are a couple of items associated with this which I would like to mention:

a. We are on the verge of assuming that RCS plume impingement is a honest-to-God constraint which must not be violated. Choke! The LM systems guys have a display which processes telemetry data yielding the

cumulative plume impingement from each of the downward firing jets. They subtract this from the value GAEC has established as the total allowed duration and display the results. That is, it is a display of permissible time remaining. It is proposed that when this parameter reaches zero, indicating we have violated the plume impingement constraint, they will recommend that the crew "Abort Stage" out of there!!!

b. Another interesting computation and display that the CSM people have provided themselves is a prediction of DPS propellent margin at touchdown. This is an especially sophisticated processor which utilizes a number of PGNCS guidance parameters obtained by telemetry to predict the amount of DPS propellant required to fly the remainder of the descent trajectory. They subtract this propellent requirement from the measured propellant still remaining obtained from telemetry data, to obtain the predicted margin at touchdown. This parameter is plotted vs. horizontal velocity on an analog display. It is proposed that if the prediction of propellant crosses "zero," the crew should be advised to "Abort." It has been stated there is no question, when this prediction reaches zero, that propellent depletion will occur before landing and so aborting is the thing to do. It is not safe to assume the converse - that is, it does not always accurately predict that sufficient propellant is available to complete the Descent. We're going to check this program thoroughly to see if it really does that.

c. Impending PGNCS failure will be detected from strip charts displaying guidance system differences, very much the same as during the launch phase. That is, differences between the AGS and PGNCS and differences between MSFN and PGNCS will be displayed on the strip charts. Abort limit lines will be provided upon which that action will be recommended. Other displays are used in conjunction with these strip charts to positively ascertain that the PGNCS is the errant system.

d. There was a somewhat surprising outcome from our discussion of trajectory constraints. Unlike launch, we were basically unable to find any "hard" descent trajectory constraints with a possible exception of the APS abort line (previously callously referenced as the "Dead Man" curve). That is, there appears to be no reason we could identify which would prevent the LM from flying all over the sky, if that is what you call it at the moon. As a result, it seems as though we have two options - either provide no trajectory abort limits or alternatively select dispersion limits (for example, 3 sigma, 6 sigma, or 9 sigma) beyond which we will arbitrarily not allow the trajectory to diverge from nominal. This currently is my personal preference, mostly based on intuition and no data. There is by no means a general agreement on that yet.

And that's our plateau.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: April 8, 1969

69-PA-T-56A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some things about Ascent from the moon

On April 3 we had an Ascent Mission Techniques meeting - the first in a long time. This memo is mostly to express some rather general observations.

I guess we all recognize that Ascent is really different from most other maneuvers in an Apollo lunar landing mission. It is one in which fairly small dispersions in the guidance can create an unsafe situation either by setting up an imminent lunar impact or poor conditions for carrying out the subsequent rendezvous, or by running the APS out of propellent. Accordingly, special efforts have been spent in trying to set up techniques for monitoring and detecting dispersions of this type onboard the spacecraft so that the crew can switch over from the PGNCS to the AGS in hopes of correcting the degrading situation. Of course, in a case of an obvious failure like the platform turned upside down, or something, the crew should have no problem in knowing they should switchover. However, I am confident that they will not be able to detect insidious, slow drift malfunctions of a magnitude, which could be catastrophic, in time to save the mission. The techniques which have been proposed for this are not sure-fire, even if executed to perfection. And, they are so complex that I seriously doubt the crew, with their limited training, would ever learn to use them with enough confidence that they would switchover from the PGNCS to the AGS even when it was necessary. If my assumptions are correct, then it seems we must recognize that the ground is not only prime for detecting and advising the crew of slow drift malfunctions but, in fact, MCC is virtually the only source for this. This in turns means that if the MCC loses hi-gain S-band telemetry there will be no drift malfunction monitoring carried out and we will simply have to trust that the PGNCS is working. Off-hand, that does not strike me as an unacceptable situation since we only get in trouble if communications are lost AND the PGNCS fails insidiously.

Another thing we must face up to is that we do not have a manual backup for Ascent Guidance and Control. Unlike the rendezvous, where crew charts provide an excellent capability to press on in spite of guidance system failures, no such capability exists for backing up Ascent. It is true that techniques have been studied and proposed, some of which might possibly work. However, the fact is that we do not have a workable technique in hand today, and even if we did, it certainly could not be considered operational unless the crew were thoroughly trained in its use. And, that they certainly will not be. Here again, this situation strikes me as no worse than "unfortunate."

So much for general observations. Following are a few specific items coming from our discussion:

a. I would like to re-emphasize that like most other maneuvers in the Apollo mission, lift-off must occur on time. We are not planning for some sort of launch window. Accordingly, if in counting down to Ascent TIG the crew falls behind for some reason, the lift-off should be delayed one CSM rev and the trouble that caused the tardiness should be cleaned up. For example - one test for determining whether it is possible to lift-off or not is the PGNCS alarm coming on at about TIG -40 seconds, indicating average g will not be turned on at the right time and the PGNCS will not be ready for lift-off.

b. In the event the PGNCS displays a ΔV Thrust Monitor Alarm after the APS engine actually comes on, the crew should stick with the PGNCS which should be holding attitude until they have determined that the PGNCS is not going to control the spacecraft properly such as yawing it to the proper launch azimuth and pitching over as programmed. When these various cues have all confirmed lack of PGNCS guidance, the crew should switchover to the AGS without attempting to recycle the PGNCS first. Of course, before switching over to the AGS they should ascertain that it is working better than the PGNCS. To do this we recommend that the nominal display for initial ascent on the AGS DEDA should be altitude rate ($\dot{H}$). Following switchover, recycle attempts should be made to clear up the ΔV monitor alarm in an attempt to get the PGNCS back on the air.

c. In order to provide redundancy for the "Engine On" signal, procedures call for manually pushing the "Engine Start" switch. It is to be emphasized, however, that this should be done only after the crew determines that the LGC "Engine On" command has caused the engine to start. We do not want to lift-off if the PGNCS is not issuing commands. Of course, in order to get an automatic guidance engine cutoff at insertion, this manual Engine Start signal must be removed. The procedure calls for doing this when the velocity remaining to be gained is about 200 fps (i.e., about 10 seconds to go). Immediately preceding setting the "Engine Arm" to "off" the interconnect should be closed. If removing the "Engine Arm" does turn off the engine, the crew should use the same switch to turn it back on. Of course, they will then have to stop the engine again when the velocity displayed by the PGNCS reaches nominal.

d. We have no procedure for monitoring and backing up the PGNCS "Engine Off" command like those used for TLI, LOI, DOI, and TEI. Due to RCS attitude control activity during Ascent, the burn time can vary as much as 20 seconds from nominal, which makes that a useless parameter for this purpose. The AGS and the rendezvous radar range rate are potential candidates, but it was finally decided that rather than adopt some complex voting logic involving those systems, the best technique was to simply utilize the ground monitoring to determine which system should be used to control the Ascent Guidance and to use whichever system is guiding as the sole cue for APS cutoff. That is, as long as we are riding the PGNCS, let it do the job and back it up manually only if <u>it</u> indicates the spacecraft has exceeded the desired velocity. If a switchover to AGS has occurred, then use the AGS as the sole source. It seems to us that, since this maneuver is always in sight of the ground, a procedure like this is acceptable. Of course, it depends on not losing telemetry.

Howard W. Tindall, Jr.

FA:HWTindall, Jr.:js

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: April 4, 1969
69-PA-T-55A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: AGS alignments in lunar orbit and operations on the lunar surface

On April 2 we finally got around to establishing how to operate the AGS on the lunar landing mission. The two basic subjects for discussion were how to handle CDU transient problems when aligning the AGS to the PGNCS in lunar orbit and how to operate the AGS in total while on the lunar surface.

I am certainly no authority on CDU transients and only attempt the following brief description so that the rest of the memo will make some sense to you. If you are interested in what CDU transients really are, I recommend that you find an authority on them. There are lots of 'em - and as many versions. As you know, the AGS uses the PGNCS as the primary reference in its alignments. As I understand it, CDU transients have something bad to do with the electronics in the PGNCS which are used to generate the data transmitted to the AGS which the AGS uses in its alignments. Unless certain precautions are taken, CDU transients can occur and are not ordinarily obvious to the crew. I gather that they can result in errors in the AGS alignments of up to 1½ degrees or so. During much of the operation even the largest misalignment errors would not particularly concern us. On other occasions, such as during descent, they would essentially disable the AGS as a useful guidance and control system.

I will go through each of the AGS alignments:

a. LM Activation before Undocking

The command module should be used to orient the spacecraft to a so-called AGS calibration attitude which is essentially just displacing all three spacecraft axes at least 11½ degrees away from zero or multiples of 45 degrees from the IMU principle axes. This action, it is said, will permit the AGS alignment and calibration to be carried out free of CDU transients.

b. Pre-DOI after Undocking

The AGS is aligned to the PGNCS after its AOT alignment in preparation of DOI. Since AGS alignment errors do not create a problem but are more of an annoyance in the AGS monitoring of the DOI burn, no precautions will be taken to avoid CDU transients.

c. Pre-PDI

This alignment in preparation for descent is most critical. The AGS must be aligned accurately and, in order to minimize drift, it must be aligned to the PGNCS very late before PDI. The choices here were to add special crew procedures into an already crowded timeline to avoid CDU transients vs. taking no precautions against their occurring, but being prepared to redo the alignment if the MCC detects a CDU transient alignment error has occurred. Either of these two approaches were considered acceptable and are almost a toss-up. It was finally decided to avoid the special procedures and to take a chance on the transient. If the MCC determines that a CDU transient has occurred, the crew will be informed within 30 seconds and they must then rezero the CDU's and repeat the alignment. This procedure is felt to be simpler for the crew and, in particular, it avoids attitude maneuvers which are part of the CDU transient avoidance procedure.

d. Post-Insertion Alignments

After insertion into orbit the AGS should then be aligned to the PGNCS. Again in this non-critical period it was decided to take a chance on a CDU transient occurring, particularly since this alignment is carried out within sight of the earth and the MCC is in a position to advise the crew if a realignment is necessary.

Attached to this memo is a detailed sequential list of AGS options on the lunar surface at each step of which it is assumed the PGNCS is still operational. In other words, it is the nominal sequence. If the PGNCS becomes broken on the lunar surface, different and more extensive operations will be required, which we have yet to define. In the development of the attached sequences, some items of interest and action items popped out which I would like to add here.

a. Whenever RLS is updated in the PGNCS, it should be standard procedure to update the AGS lunar launch site radius (Address 231). This update will be based on a voice relay from the MCC of the value to be input via the AGS DEDA by the crew.

b. With regard to CDU transients during AGS alignments on the lunar surface, it was decided that we would rely on the MCC to monitor and advise the crew if a CDU transient has occurred. That is, the crew would follow no special procedure to determine if one had occurred except in the case of no communication.

c. Guidance and Control Division and TRW were requested to advise what timetag should be associated with the CSM state vector voiced to the crew for input into the AGS in the event the PGNCS has failed.

d. MPAD was asked to determine if it is acceptable to input state vectors into the AGS 15 minutes or more prior to PDI. The question here really is whether or not the AGS numerical integration causes unacceptable state vector errors for descent aborts if the state vectors are loaded too early. Early loading, of course, is desirable to reduce crew activity just before PDI.

All of this AGS jazz will be added to the Lunar Surface Mission Techniques Document. I think it's the last chunk. We will review the whole subject of lunar surface activity next week and then can forget it - I hope.

Howard W. Tindall, Jr.

Enclosure

PA:HWTindall, Jr.:js

April 2, 1969

First Two Hours on the Lunar Surface
After Touchdown and First Stay Decision

1. PGNCS goes to P68
2. 413 + 10,000 Lunar Surface flag to store azimuth and terminate average g
3. 414 + 10,000 State vector update (V47) after verification of PGNCS
4. 400 + 20,000 AGS align to PGNCS
5. 400 + 10,000 Initialize for Ascent
6. 413 + 10,000 Store better azimuth
7. Stay for two hours decision
8. Crew readout to MCC addresses 047 and 053
9. 400 + 60,000 AGS gyro calibration [5 minutes required]
10. Load $J_3 = J_2$ = "45 n.mi. apogee"
11. Verify Inc $\dot{H}$ = 30 fps and H = 60,000 ft.
12. PGNCS Option 1 alignment
13. 4[illegible] + 4[illegible],000 Lunar Surface align [3 minute system test]
14. PGNCS Option [illegible] alignment
15. 4[illegible] + [illegible],000 AGS to PGNCS align
16. 413 + 10,000 Store best azimuth
17. Crew readout addresses 047 and 053 to MCC
18. Pause
19. Receive Ascent [illegible]
20. Load AGS azimuth [Address 047 and 053] with values for MCC
21. Pause
22. PGNCS Option [illegible] alignment
23. 414 + 10,000 State vector update

24. Pause

25. 400 + 30,000 Align to PGNCS

26. 400 + 10,000 Initialize for Ascent

27. Verify 410 is "+000000" [Ascent Program]

28. Exit lunar CDDT and switch AGS to "off" [warm-up mode]

April 2, 1969

Normal Ascent

1. Power up AGS [[illegible] minutes required]
2. AGS System Test (?)
3. Initialize AGS time [K + [illegible] hours]
4. [illegible] + [illegible] gyro [[illegible] state vector update] (V-7)
5. PGNCS Option [illegible] to [illegible]
6. [illegible] AGS to PGNCS [illegible]
7. [illegible] gyro calibration [[illegible] minutes]
8. [illegible] AGS to PGNCS align
9. [illegible] Track [illegible] CSM
10. [illegible] Ascent [illegible]
11. [illegible] with value from MCC-H
12. [illegible]
13. [illegible]
14. [illegible] state vector update
15. [illegible]
16. [illegible] + [illegible],000 align to PGNCS
17. [illegible] + 1[illegible],000 Initialize for Ascent
18. Verify 410 is "400000" [Ascent Program]

OPTIONAL FORM NO. 10
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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: April 4, 1969
69-PA-T-54A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: RLS Determination

On April 2 we had a Mission Techniques meeting to discuss how we should handle the determination of the LM's position on the lunar surface (RLS). Specifically, we were concerned with how to determine its values and, after improved values are determined, when they should be loaded into the spacecraft computer. One obvious conclusion, if anything can be called obvious coming from this discussion, is that we have many excellent data sources for determining RLS, each of which is estimated to be of a quality much better than we need to support the operation.

"RLS" is actually the LM position vector on the lunar surface consisting of three components. It is moon fixed - that is, rotates with the moon - and is simply the latitude, longitude, and radial distance of the LM from the moon's center.

Prior to landing it is necessary to establish the values of RLS to be used in Descent targeting. For the first lunar landing, where the F mission will have thoroughly surveyed the landing site, the consensus is that we should use the RLS determined on the F mission and only use in-flight mission G measurements as a system check similar to the horizon check made before retrofire. For landings at sites which have not been surveyed previously, the RLS must be determined in real time based on the MSFN/sextant tracking done pre-DOI. The Math Physics Branch (MPB) of MPAD proposes that this be handled in the following way and I think everyone finally agreed it was logical, at least pending results of the F mission:

a. The CSM/LM state vectors will be a so-called single pass MSFN solution based solely on data obtained during the sextant tracking pass. Orientation of the orbital plane of this solution will be constrained by the pre-LOI plane plus confirmed maneuvers. (In fact, MPB proposed that we use this technique throughout lunar orbit from LOI through TEI. Data Select and MPB people have the task of establishing the technique for monitoring rev by rev single pass solutions with the orbital plane unconstrained to confirm that the pre-LOI value falls within the scatter of these determinations and of establishing the limits beyond which they would abandon the pre-LOI plane orientation.)

b. Having established the CSM state vector as described in "a," the sextant tracking data is given full weight in the determination of RLS. That is, the landing site location will be based entirely on the sextant data determination of its position relative to the CSM state vector. But I would like to iterate that this RLS determination is only used as a system check for a surveyed site such as planned on the nominal mission.

After landing we have five good data sources for determining various components of RLS. (MPB has the task of establishing their relative accuracy.) We have decided to put off figuring out how we will actually use them in real time until after the F mission since it is anticipated that it will impact our choice tremendously. The various data sources are as follows:

a. The crew observations made during descent and after landing referenced to onboard maps - This is simply a matter of the crew informing the ground of where they think they landed in terms of longitude and latitude based on their visual observations. In addition to relaying latitude and longitude, they should also express an opinion of how certain they are about where they are.

b. The position is determined by use of star observations and the gravity vector data obtained during the first IMU alignments on the lunar surface. This data will be processed both onboard the spacecraft and at Mission Control Center. It is also only capable of determining latitude and longitude - not radius.

c. The Lear powered flight processor which uses MSFN doppler data during descent is expected to have outstanding accuracy in determing the change in LM position from PDI to touchdown, provided we do not encounter sustained periods of data dropout. The problem in determining LM position on the lunar surface with this data, of course, depends on the accuracy of our knowledge of the LM position at PDI to which we will add the position change measured by Lear. According to MPB it is possible to obtain a very accurate estimate of LM position at PDI using a MSFN short arc solution with the orbital plane constrained as discussed previously. (They emphasized, however, that the short arc solution is only accurate in the determination of position - not velocity - and would only be obtained during post-landing processing of tracking data obtained on the LM between AOS and PDI.) RLS then is found by determining the LM position at PDI using the short arc solution and manually adding to it the change in latitude, longitude, and altitude as measured by the Lear Processor during powered descent. Note that this yields all three components of RLS.

d. PGNCS telemetry data may be used in a similar manner to the Lear Processor. That is, by taking the PGNCS estimate of position at PDI and at landing we are able to determine its measurement of change in latitude and longitude during descent. They may also be added to the short arc solution described above to get RLS. It is to be emphasized, however, that PGNCS acceptance of landing radar destroys the capability of determining the change in altitude as measured by the PGNCS.

e. We can do the same thing with the AGS state vectors as described for the PGNCS. Again, since altitude updates are currently planned during descent, only latitude and longitude can be obtained.

The question now is which of these sources do we use?

a. For RLS radius our preferred source is the pre-flight determined value if we land at a surveyed site. If not a surveyed site, we would either use the radius determined by the MSFN/sextant observation obtained pre-DOI or from the Lear Processor plus short arc solutions. These two sources are currently estimated to be roughly equivalent.

b. For latitude and longitude all of the sources noted above (i.e., crew/map, AOT/g, Lear, PGNCS, and AGS) are all considered competitive and their priority must await F experience. It should be noted that Lear, PGNCS, and AGS are not completely independent in that they are all initialized from the same source.

Flight Dynamics, Data Select, and MPB people were given the task of establishing the precise technique for obtaining the Lear, PGNCS, and AGS solutions for RLS latitude and longitude. This is not something that falls automatically out of the RTCC but will require a considerable amount of manipulation of many different state vectors stored in it and a bunch of manual (simple) computations.

You will note that all of the above data sources are available within an hour after landing and, as far as we are concerned, should provide all of the data ever needed to carry out the operation. However, we have currently planned to obtain rendezvous radar and sextant tracking of each spacecraft by the other, both two hours after touchdown and two hours before lift-off. Based on our discussions at this time, the consensus is that this tracking is by no means mandatory. In particular, if rendezvous radar tracking by the LM becomes even slightly problematic, it can easily be dropped. For example, if it conflicts with other crew activity, uses too much LM power, presents thermal problems, or wears out the rendezvous radar we can eliminate it from the timeline. Of course, if in real time our other data sources get moddled up in some way, it would have to be added back in at that time. In fact, I should emphasize that we are not proposing that it be dropped from the timeline, but rather that it could be dropped if necessary - so can the sextant tracking for that matter, although no reason for dropping it occurred to us.

In summary, we have many excellent data sources for RLS determination. How we will use them will be established after the F mission. Rendezvous radar tracking by the LM on the lunar surface is no longer a requirement. And, a couple of new MSFN facts are that a short arc solution yields a good position vector and it is proposed that the pre-LOI determined orbital plane plus confirmed maneuvers be used throughout the lunar orbit activity.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list below

DATE: April 3, 1969

69-PA-T-53A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some G Mission Techniques action items

This memo is just a list of action items assigned to MPAD and/or MIT which I remember coming from our recent G descent/ascent abort meetings. In addition to reminding those responsible for them, they serve as some sort of indication of what's going on in this business which you might find interesting.

1. <u>Orbital Mission Analysis Branch</u>

a. Establish a preferred rendezvous maneuver sequence to guard against lunar impact in the event of late descent aborts on the AGS. This includes a recommendation [illegible] ΔV trimming at insertion, too.

b. Determine if an unacceptable abort situation would exist if PDI were delayed one rev in real time.

2. <u>Math Physics Branch</u>

a. Determine how the flight controllers should decide when to apply the altitude bias update to the Lear Processor Display of H vs. $\dot{H}$. Is there some way to take into account the known lunar surface slope? Specifically, find out from the mapping people what the exact slope is for the landing sites.

b. Determine the effect of non-synchronization of the data sources when updating the Lear altitude from PGNS.

3. <u>Landing Analysis Branch</u>

a. Establish a technique for testing and determining acceptability of the LGC LM state vector pre-PDI. Also, recommend the action - that is, under what conditions they should abort, update the state vector, advise crew of large ΔH, or what?

b. There is a PDI attitude turn check made at TIG - 2 minutes, referenced to the horizon. Determine how accurately a preflight value may be established and thus if it is necessary to update this value in real time. Also, ascertain if the sun will interfere with this test.

c. Is there some way to monitor the PGNCS to determine failure [illegible] the P63/P64 program change to occur when it should have by using the V, H, H DSKY display? I would like to avoid having to call up T_{GO}. Also, establish what course of action the crew should take if they fail to get the program change.

4. <u>Guidance and Performance Branch</u>

Establish strip chart limit lines defining [illegible] performance in terms of acceptable, marginal, and failed. [illegible] limits are also required for the telemetry comparison at [illegible].

5. <u>[illegible] Analysis Branch [illegible]</u>

Determine if and how the [illegible] must be updated in the event PDI is delayed one rev in real time after DOI.

6. <u>Guidance and Performance [illegible]</u>

Establish abort limits for [illegible] impending failure of the PGNS [illegible] imminent.

7. <u>Landing Analysis Branch, [illegible]</u>

a. Establish attitude error and attitude rate limits to be used by the crew during descent and recommended action if violated.

b. Establish what constitutes [illegible] landing radar data. Specifically, what should be used as [illegible]:

(1) The amount of [illegible] and when it was obtained.

(2) Δh from the [illegible] at the time of landing radar loss.

(3) Others?

Howard W. Tindall, Jr.

Addressees:

FA/G. M. Low
FA/C. C. Kraft, Jr.
FC/C. E. Charlesworth
FC44/R. L. Carlton
FC44/J. B. Craven
~~FC55/J. H. Greene~~
FC56/S. G. Bales
FM/J. P. Mayer
FM/[illegible]
FM/D. H. Owen
FM/[illegible]
FM13/J. R. Gurley
FM/C. [illegible]
FM4/P. T. Pixley
FM7/[illegible]
FM/Branch Chiefs

PA:HWTindall, Jr:js

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: April 1, 1969
69-PA-T-52A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: PGNCS operations while on the lunar surface

During our March 27 Lunar Surface Mission Techniques meeting I think we finally settled how we think the PGNCS should be operated. How many times have I said that before? This memo is to broadcast a few new items that might be of general interest.

MIT has recently made a significant change in the PGNCS lunar surface alignment program (P57). They have added a new alternative governing the orientation to which the IMU can be aligned. Specifically, before this change there were only two alternatives - a "preferred" alignment associated with lift-off time computed by the LGC and an alignment to a REFSMMAT uplinked from the Mission Control Center. The new alternative provides the capability of an alignment to the stored REFSMMAT - that is, the same REFSMMAT to which the IMU was aligned the last time. This program change significantly simplifies crew procedures and since it will be used several times during the lunar stay you should be aware of it.

We have finally converged on the sequence of P57 options to be used on the lunar surface. They are described in considerable detail in the attachment. Briefly the sequence is:

a. A gravity alignment (Option 1) to determine the direction of the gravity vector.

b. An AOT star alignment (Option 2) to establish an inertial reference which can be used with the gravity vector to determine the LM's position on the lunar surface. This alignment will also provide a drift check on the IMU since the pre-DOI AOT star alignment.

c. A gravity and star alignment (Option 3) in preparation for lift-off at the end of two hours stay, if that is necessary, and to initialize the system for a sustained IMU drift check.

d. Two Option 3's in the nominal ascent countdown. The first, which completes the drift check, also sets up the system for the rendezvous radar tracking of the command module two hours before the lift-off. The second supports the Ascent itself.

This sequence not only provides all of the data needed to support the actual operation but also exercises all of the options which makes the engineers happy. The consensus was that we have trimmed this activity just about to a minimum and it should be fairly easy to include in the crew timeline.

Flight Dynamics' flight controllers were requested to select the stars to be used for the lunar surface alignment on the nominal G mission as soon as possible.

It is our understanding and recommendation that the IMU will remain powered up throughout the lunar stay. We should emphasize that it is also necessary that the LGC remain powered up as in order to maintain gyro compensation in the IMU as well as to provide the downlink data continuously to the Mission Control Center. Apparently there was some uncertainty about this.

After considerable discussion it was decided that our best course of action is to update both the LM position on the lunar surface (RLS) and command module state vector in the LGC during the first two hours on the lunar surface to support an ascent at that time, if it is necessary. The RLS will be based on the AOT alignment and gravity vector data as well as crew observations during the landing and perhaps on data gathered prior to DOI. (The exact manner in which the Mission Control Center will do this job is the subject of a meeting next week.) The CSM state vector will be the best MSFN estimate at the time of the update. This is such an obvious choice you must wonder how we wasted our time. The only point we were concerned with was making sure that the RLS and CSM vectors were compatible enough to support ascent guidance at the end of a two hour stay. We feel that this technique will probably provide that, but we may want to reconsider after obtaining F mission experience.

In addition to the Data Select business noted above about how to establish RLS, we are also scheduling a meeting specifically to discuss the AGS operation on the lunar surface next week. After incorporating the results of these meetings into the Mission Techniques Document for Lunar Surface Operation, we will review and finally publish that document a couple of weeks later. Hopefully, at that time this mission phase should be fairly well closed out.

Howard W. Tindall, Jr.

Enclosure

PA:HWTindall, Jr.:js

3. Post Touchdown

a. Option 1 to REFSMMAT to obtain the g vector

Do not torque the IMU - specifically, the crew should recycle (V32E) out of the program at the V06N93 torquing angle display

b. Option 2* to REFSMMAT - to obtain IMU drift since pre-LOI alignment. Given the g vector of Option 1 this supplies all data required for LM position determination on the lunar surface both onboard and at the Mission Control Center.

c. Update RLS and CSM state vector in the LGC based on best sources of data available - no attempt is made to make these "consistent."

4. Touchdown plus 1¼ hr to prepare for RR track or lift-off after first CSM rev.

Option 3* to landing site - using updated lift-off time from the Mission Control Center.

5. During lunar stay (about 19 hours duration) monitor CDU angles continuously at the Mission Control Center.

6. Lift-off - 2¼ hours

Option 3* to REFSMMAT to obtain drift and to align for RR tracking.

7. Update CSM state vector in LGC. Optional update of RLS.

8. Lift-off - 45 minutes

Option 3* to landing site for Ascent.

*(a) Is attempt at Option 2 fails because stars are not visible, replace with Option 3 using sun or earth if possible.

(b) If attempts at Option 3 fail (even with sun or earth) replace with Option 1's.

Note: Unset REFSMMAT flag before #6 above if using Option 1 to eliminate drift effect over long lunar stay.

Enclosure

APOLLO DATA PRIORITY COORDINATION
MEETING SCHEDULE

AS OF March 27, 1969

69-PA-T-50A

SUBJECT OF MEETING	APRIL 31	1	2	3	4	7	8	9	10	11	14	15	16	17	18	21	22	23	24	25
G Ascent Monitoring *				■																
G Descent Monitoring *					■			■					■							
G Lunar Surface-RLS Determination			▀																	
G Lunar Surface-AGS Operations			▄																	
G Lunar Surface Review									■											
SPECIAL MEETINGS																				

▀ Meeting begins at 9:00 a.m.

▄ Meeting begins at 1:00 p.m.

* G Ascent in Room 378, Building 4
G Descent in Room 378, Building 4 on 3/4/69
G Descent in Room 261, Building 4 on 3/9/69

Howard W. Tindall, Jr.

MSC Form 1285 (Rev Sep 68)

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: March [illegible], 1969

69-PA-T-4[illegible]

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: [illegible]

[illegible]

I realize [illegible] there were [illegible] [illegible] inconsistent, [illegible] [illegible] [illegible] In [illegible] [illegible] mismatch [illegible] were able to resolve.

[illegible] material [illegible] [illegible] LM [illegible] [illegible] opportunity [illegible] [illegible] moon [illegible] [illegible] not only [illegible] view of the lunar [illegible] [illegible] launch [illegible] (lunar cis-lunar coast) if the launch date slips.

[illegible] attached [illegible] [illegible] [illegible]

[illegible] vertical pitch [illegible] rate [illegible] degrees; the roll and yaw angles are 0. [illegible] will supply the following data in real time:

a. Time at which the Initial Point (I.P.) [illegible] at elevation angle of [illegible] degrees.

b. [illegible] to [illegible].

c. [illegible] rate in [illegible].

d. [illegible] as an indication [illegible] to [illegible] landmark [illegible] ground track.

[illegible] if the landmark [illegible] to [illegible] avoid excessively [illegible] rate [illegible] crew take care of [illegible]. [illegible] constraint is that the [illegible] trunnion [illegible] than [illegible] degrees.

Landmark tracking [illegible] the LM [illegible] on the F and G [illegible]. The first time [illegible], it occurs on the [illegible] primarily for on the job training [illegible]. The second [illegible] just before DOI for [illegible] a second OJT [illegible] to [illegible] problems encountered on the first. [illegible], this would be [illegible] in real time, perhaps at the [illegible] sleep if the situation warrants it.

[illegible] have been [illegible] inertial attitude for [illegible] during sleep in lunar orbit. [illegible] alignment with the [illegible] engine [illegible] in the direction [illegible] orbital motion and a pitch angle [illegible] in the zenith [illegible] degrees or perpendicular to the [illegible]-axis. The spacecraft should be [illegible] degrees deadband. The inertial angles will be computed [illegible] will provide continuous [illegible] S-band coverage but not a continuous view of the lunar surface. Duncan was requested to determine the LM [illegible] attitude for the APS burn to depletion which provides best S-band coverage.

The attitude/attitude rate sequence for the undocked landmark tracking exercise prior to [illegible] is different from the docked one. It was decided that the spacecraft will maintain orbit rate torquing continuously with a pitch angle of about [illegible] degrees. This will give an optics tracking period of about [illegible] seconds. [illegible] asked to tune-up the pitch angle a little to give about the same period of coverage before zenith as after. In this exercise, of course, it will only be necessary for the [illegible] to supply the crew with the [illegible] acquisition time ([illegible] noted above).

Howard W. Tindall, Jr.

[illegible]

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: March 12, 1969

69-PA-T-45A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Simplification to the pre-PDI abort procedure

As a result of a [illegible] comment in one of my previous notes, Tommy Gibson and George Cherry looked into what it would take to provide automatic PGNCS targeting for LM aborts at initiation of powered descent (PDI). They found the capability already exists in the LUMINARY program. How's that for great!

The situation I am discussing is when the need for abort is recognized after DOI and before PDI on a lunar landing mission. The ideal procedure, of course, is for the LM to make a maneuver at about PDI time which will set up a nominal rendezvous sequence with CSI ½ rev later. This is exactly what the DPS and APS abort programs (P70 and P71) do automatically, but it was thought these programs could only be used if powered descent was actually started and we certainly didn't want to start powered descent - a retrograde maneuver when the abort maneuver must be posigrade. That would make it necessary to execute a large attitude change while thrusting. It turns out that the crew may obtain automatic targeting for an abort maneuver by proceeding into the descent program (P63) just as if intending to land, except that he must maneuver the spacecraft manually into the posigrade abort direction prior to PDI time. He actually starts the DPS burn in P63 but since P63 does not start descent guidance until the engine is throttled up, it will automatically maintain the abort attitude the crew has established. After achieving engine stability at about TIG plus five seconds, the crew can press the Abort button which will automatically call up the DPS Abort program (P70) to compute the abort maneuver targets, immediately throttle up to full thrust, and control the burn.

This certainly seems like a straightforward procedure, completely consistent with standard descent procedures, and aborts immediately after PDI. I think we should establish this as our primary abort technique for this mission period.

Great work, Tom and George. Keep that up and I predict you'll go places.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: March 14, 1969

69-PA-T-44A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Happiness is having plenty of hydrogen

As I understand it, there has been a desire or requirement to have the capability of surviving a cryo-tank failure at any time in the lunar mission. After C', it was decided to keep the IMU powered up throughout all lunar missions even though it might be at the cost of having the backup cryos. However, according to a recent analysis by MPAD's Guidance and Performance Branch (R. C. Wadle, W. Scott, and D. A. Nelson), these two characteristics are not incompatible. Since this is quite different from what I have heard in the past, I thought you might find it interesting, too.

According to Wadle, Scott, and Nelson, it is possible to operate with the platform powered up and even if one tank fails as late as TEI, there is still enough hydrogen left in the other tank to provide a four day return-to-earth in a powered-down state. (Hydrogen is the most critical consumable.) The powered-down state still provides for communications; essentially it consists of just taking the guidance system and one fuel cell off the line and turning off non-essential equipment.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

APOLLO DATA PRIORITY COORDINATION

MEETING SCHEDULE

AS OF March 11, 1969

69-PA-T-43A

SUBJECT OF MEETING	March 17	18	19	20	21	24	25	26	27	28	31	April 1	2	3	4	7	8	9	10	11
*F Lunar Orbit, Abort & Rescue																				
G Descent Monitoring																				
G Ascent Monitoring																				
G Lunar Surface																				
SPECIAL MEETINGS																				

* Note date changed from March 17.

Meeting begins at 9:00 a.m.

Meeting begins at 1:00 p.m.

Howard W. Tindall, Jr.

MSC Form 1223 (Rev Sep 68)

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: March 7, 1969
69-PA-T-42A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: G Lunar Surface stuff is still incomplete

On February 27 we held a Mission Techniques meeting which I thought was going to simply edit the "final" version of the Lunar Surface Document prior to its release. To my chagrin we discovered that there are at least two areas requiring much more thought and analysis. We will probably meet again to resolve these during the last week of March. The release of the Mission Techniques Document will have to be delayed accordingly.

Before delving into these major items, there are a couple of other things I would like to mention. The first may seem trivial. It deals with terminology - specifically, use of the expression "go/no go" regarding the decision whether to stay or abort immediately after landing on the lunar surface. Every time we talk about this acitivity we have to redefine which we mean by "go" and "no go." That is - confusion inevitably arises since "go" means to "stay" and "no go" means to "abort" or "go." Accordingly, we are suggesting that the terminology for this particular decision be changed from "go/no go" to "stay/no stay" or something like that. Just call me "Aunt Emma."

Last summer GAEC honored us with their presence at one of our meetings and to celebrate the occasion we give them an action item. We asked them how to make the tilt-over decision and to establish the attitude and rate limits for aborting. We haven't heard from them since, on that or anything else except RCS plume impingement. Don't worry, we still have four months to figure out how to do it.

I would like to emphasize that we do not want to trim residuals following the CSM plane change maneuver. It is recognized that they may be rather large since it is the first SPS undocked burn, but we would rather take them into account by adjusting the ascent targeting than by spending CSM RCS propellant.

Another thing we realized about the CSM was that we had not definitively established the attitude the CSM should maintain during LM ascent nor whether it was necessary for the MCC-H to compute the associated IMU gimbal angles.

Our biggest problem in this mission phase deals with platform alignments. Specifically, we are still not sure what sequence of alignment options should be used, although, I think everyone agrees we should use a gravity alignment for the actual ascent. The basic problem seems to stem from a lack of understanding or just how the LM Lunar Surface Program (P57) actually works and, in each case, what the torquing angles really indicate. Of course, the thing we are primarily interested in accomplishing is to evaluate the performance - that is, the drift of the IMU - in order to decide if it is working, if we should align the AGS to the PGNCS, if we should update the IMU compensation parameters, if we should lift-off on the PGNCS or the AGS, etc. Prior to our meeting at the end of March, TRW will write out in detail how they think the system actually works along with a description of how we should use it. Guidance and Control Division may do the same. Then, we will all get together with MIT to see if we can get this thing straighten out and cleared up.

Finally, our other big problem has to do with how we should handle the LM location on the moon (RLS) and the CSM state vector, particularly during the first two hours on the lunar surface in preparation for the countdown demonstration and, if necessary, ascent at the end of the first CSM revolution. The point is we will have all the data needed to determine the LM's location but we do not want to change it in the various computers (LGC, CMC, RTCC) unless we can maintain a consistant CSM state vector, too. And, it is not at all clear how we can do all that. This subject becomes another major item on the agenda of the "ides of March" meeting.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

LGC = LM Guidance Computer
CMC - Command Computer
RTCC - real time Computer Complex

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 28, 1969
69-PA-T-40A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: There will be no VHF ranging data collected while tracking the LM on the lunar surface

It has been suggested that, in addition to optics and rendezvous radar tracking one spacecraft of the other while the LM is on the lunar surface, we should also utilize VHF ranging. This data would certainly be useful for post-flight analysis if not in real time. I have attempted to resolve the situation with regard to obtaining this data and have come to the conclusion that it is too late to get it, as unfortunate as that may be. The basic problem is in the formulation of the RTCC program. And, the program changes required appear to be too large for obtaining data which at best must be labeled "desirable."

Through the years our plans for CSM tracking of the LM while on the lunar surface have all been based on just using the sextant. Obviously, we intended to use the Lunar Orbital Navigation program (P22), which not only provides automatic optics tracking but also complies the desired optical data, time tags, spacecraft attitude and landmark I.D. in a special downlist package for transmission to the MCC-H. The RTCC programs have been formulated to accept this data in that format and process it in real time.

First indications are that the spacecraft Rendezvous Navigation program (P20) would serve the crew as well as P22 for tracking the LM on the lunar surface with regard to automatic optics, and would have the additional advantage of including VHF ranging data on the downlist. Unfortunately, though, the P20 downlist format is substantially different than the P22 downlist and would require rather extensive changes in the RTCC program. For example, the sextant data is not stored in a batch of five observations as in P22 but would have to be stripped out one at a time as the observations are obtained.. This could easily cause us to miss some points. But more important, the RTCC would have to be coded to store them for processing. Finally, it is to be noted that P20 only collects a VHF data point once per minute - almost not worth the effort! Implicit in the above is that VHF telemetry via the CMC is the only source; raw VHF does not come down directly.

In summary, we are abandoning efforts to get VHF for the G flight. It may be worthwhile to put in a PCR to add VHF sampling to the P22 program and its downlist at a reasonable data rate. Jim McPherson - would you take the action on this, if it seems reasonable to you?

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : FM/Technical Assistant, Mission Planning and Analysis Division

DATE: February 28, 1969
69-PA-T-39A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some MPAD work needed for the G mission

During the February 26th Data Select Mission Techniques meeting, Math Physics Branch (MPB) picked up three action items for the G mission, of which you should be aware.

1. Prior to DOI sextant data is used to determine the relative location of the landing site with respect to the CSM orbital elements. Based on this data the landing site coordinates will be changed to facilitate descent targeting. However, it is clear that there is a limit beyond which we will be unwilling to change the landing site coordinates from those established pre-mission because such a big change would appear to indicate something is fouled up. Accordingly, we have requested the MPB to determine the magnitude of the various error sources which would contribute to this real time change in order that the flight controllers can intelligently assess the situation in real time. In addition to this they are also to recommend a lower bound - that is, a "who cares" limit wherein the change is so trivial it should be ignored.

2. On the first pass after touchdown and on the last pass prior to LM lift-off, the two spacecraft observe each other with optics and rendezvous radar. As presently configured, the RTCC processes the LM and CSM data independently. However, there are apparently techniques for combining the solutions to get the best total solution. The MPB was requested to analyse and document the techniques which should be used in the processing of this data in real time. Incidentally, it is to be noted that on both of these occasions this process should be aimed at changing the orientation of the CSM orbital plane as opposed to moving the LM position. That is, we will use our best estimate of the landing site (RLS) as the fixed reference in establishing this relative situation in preparation for ascent targeting and the CSM plane change.

3. MPB was also requested to re-examine the quality of the various state vectors which could be used for targeting LOI_2 - especially in the out-of-plane direction. As I recall, when we were figuring the battle of the two-stage LOI, the consensus was that our knowledge of the lunar orbital plane based on the approach trajectory plus GNCS navigation through LOI_1 was superior to the single pass MSFN solution after LOI_1. As a result we were recommending as a standard procedure that LOI_2 should always be targeted as a completely in-plane maneuver basically because no new out-of-plane

information was available prior to LOI_2 based on which we could do this targeting. Obviously this must assume small G&N dispersions in the execution of LOI_1. The question is - is that still the right way to go? I accidentally discovered that the flight controllers were figuring on using the post LOI_1 data to do out-of-plane targeting on LOI_2.

Dave, if task assignments are needed, will you make sure they are prepared? I suspect this work is already covered.

Howard W. Tindall, Jr.

cc:
FM/J. P. Mayer
FM2/F. V. Bennett
FM4/J. C. McPherson
E. R. Schiesser
FM6/E. C. Lineberry
FM13/R. P. Parten
J. R. Gurley
FC/C. E. Charlesworth
FC5/P. C. Shaffer
TRW/P. J. Boudreau
MIT/M. W. Johnston, IL 7-279

PA:HWTindall, Jr.:js

APOLLO DATA PRIORITY COORDINATION

MEETING SCHEDULE

AS OF February 27, 1969

69-PA-T-38A

	MARCH																			
SUBJECT OF MEETING	3	4	5	6	7	10	11	12	13	14	17	18	19	20	21	24	25	26	27	28
F Lunar Orbit Attitude * Time History						▀														
F Lunar Orbit Abort and ** Rescue											■									
F Earth Orbit Rendezvous																■				
F/G Launch Aborts			+							■										
F/G Contingency						▄														
G Descent Monitoring				+				■					+					■		
SPECIAL MEETINGS																				

▀ Meeting begins at 9:00 a.m.

▄ Meeting begins at 1:00 p.m.

+ Note Meeting Changes from last meeting schedule

* Meeting in Room 378; Building 4
Starts at 9:30 a.m.

** Meeting in Room 378; Building 4
Starts at 10:00 a.m.

Joanne Sanchez
for Howard W. Tindall, Jr.

MSC Form 1283 (Rev Sep 68)

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 27, 1969
69-PA-T-37A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some more trivia for the F mission

This memo is to point out a couple of oversights in our F Mission Techniques.

1. With regard to docked DPS burns we should remember that the LUMINARY program used on F is the same as the SUNDANCE program to be used on D, which due to scaling problems or something barely recognizes that the DPS is running when it is at only 10 percent thrust in the docked configuration. Accordingly, it is necessary for the crew to manually advance the throttle to 40 percent thrust for awhile prior to going to full thrust in order for the PGNCS to trim the DPS thrust vector through the CG. (Note: LUMINARY 1A for G has been fixed so that gimbal trimming will be done at 10 percent and the stopover at 40 percent is not required.)

2. During the planning of the special F mission landmark tracking exercise just prior to TEI we forgot to include the CMC state vector updating from the MCC-H once per rev. This is so obviously necessary that it would certainly have been caught during the earliest simulations. However, we might as well start including it in F mission documentation now to be done at about the same time as the periodic P52 platform realignments.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 26, 1969

69-PA-T-36A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Review of the Launch Phase Abort Mission Techniques Document for Missions F and G

1. References:

MSC Internal Note No. S-PA-8T-026, "Apollo Mission Techniques Saturn V/Apollo Launch Phase Aborts, Techniques Descriptions," dated October 22, 1968.

2. A review of the subject document is scheduled for March 6, 1969, at 9 a.m. in Building 4, Room 378. The purpose of this review is to discuss launch phase abort techniques which have changed significantly since the publication of the referenced techniques document, which had been written specifically for C' and D. The following list defines the major revisions:

a. Modification to the COI maneuver and expanded capability.

b. Use of a launch vehicle performance envelope for an abort cue.

c. Use of the exit heating limit as an abort limit.

d. Incorporation of the steerable LV manual capability to the abort techniques.

3. It is hoped that all groups associated with this area be represented to expedite this review. Draft copies will be available at the meeting.

Howard W. Tindall, Jr.

PA:EMHenderson:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 26, 1969
69-PA-T-35A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: F/G Mirror Image Targeting shall use a three-minute delay

As you know, we have established as a standard procedure during Apollo rendezvous having CSM backup LM maneuvers in order to retain the nominal relative motion during this critical mission phase. On the D mission these "mirror image" CSM maneuvers are targeted with a TIG delayed one minute after the LM TIG. One minute was chosen based on our estimate that it would be adequate for the crew to determine whether or not the command module should go active and to take the proper steps subsequent to that decision. John Young - the F mission CMP - was concerned that by using a one-minute delay he is forced to turn on his SPS trim gimbal motors for each of the mirror image maneuvers whether he has to execute the burn or not. Since there is no significant disadvantage in making the delay larger, we are changing it to three minutes for the F and G missions in order to avoid having to turn on those motors unnecessarily. Henceforth, all F/G analyses, simulations, procedures, and techniques will be based on that value.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

The PGNCS alignment against the CSM IMU should be within better than 1/2 degree around the y and z-axes and 1½ degree around the x-axis. If we add to this the maximum gyro drift we are willing to tolerate (i.e., 1.5 degree per hour) for the 2 hours between alignments, we can obtain the largest tolerable gyro torquing angles beyond which we say the IMU is broken. It seems to me that [illegible] 4 degrees should be that limit. However, since we have no real experience with LM IMU alignments of any sort this number must be tempered by real time judgment and thus becomes more of a guideline value than a limit.

Howard W. Tindall, Jr.

Addressees:
FC/E. F. Kranz
FC4/R. L. Carlton
FC5/W. E. Fenner

cc:
PA/G. M. Low
PD/A. Cohen
PD7/R. E. Kohrs
CF24/M. C. Contella
EG2/C. T. Hackler
C. F. Wasson
FA/C. C. Kraft, Jr.
FC/J. G. Renick
FC4/J. B. Craven
FM/J. P. Mayer
C. R. Huss
D. H. Owen
FM13/R. P. Parten
FM2/C. A. Graves
FM4/P. T. Pixley
FM5/R. E. Ernull
FM6/K. A. Young
R. W. Becker
FM7/R. O. Nobles
FM/Branch Chiefs
TRW/R. J. Boudreau
C. M. James
MIT/IL/M. W. Johnston, 7-279

PA:HWTindall, Jr.:js

APOLLO DATA PRIORITY COORDINATION
MEETING SCHEDULE

AS OF February 25, 1969

69-PA-T-33A

SUBJECT OF MEETING	3	4	5	6	7	10	11	12	13	14	17	18	19	20	21	24	25	26	27	28
F Lunar Orbit Attitude * Time History						■														
F Lunar Orbit Abort and ** Rescue											■									
F Earth Orbit Rendezvous																■				
F/G Launch Aborts				■																
F/G Contingency						■														
G Descent Monitoring			■										■							

SPECIAL MEETINGS

Meeting begins at 8:00 a.m.

Meeting begins at 1:00 p.m.

* Meeting in Room 378; Building 4
Starts at 8:30 a.m.

** Meeting in Room 378; Building 4
Starts at 10:00 a.m.

Howard W. Tindall, Jr.

MSC Form 1285 (Rev Sep 68)

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 24, 1969

69-PA T-37A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some things about MSFN orbit determination

A couple of interesting things came out of our Data Selection Mission Techniques meeting of February 14.

There had been concern that the last translunar midcourse correction (MCC_4) was being scheduled too late before LOI. You recall that it is at LOI - 5 hours. Math Physics Branch reported that the MSFN 1 sigma perigee prediction uncertainty at the time of LOI targeting (at LOI - 2 hours) is 1.4 n.m., assuming MCC_4 is executed to within .2 fps. It was also reported that if it was unnecessary to perform MCC_4 the uncertainty in perigee prediction is essentially constant from LOI - 5 hours through LOI - 2 hours; the 1 sigma value being .4 n.m. The significance of this, of course, is that our current midcourse correction logic makes it probable that MCC_4 will not be required and, therefore, it should be possible to perform LOI targeting as much as 5 hours before LOI without any additional error if it is operationally desirable to do so.

If you recall, on the C' mission we stated that MSFN ranging while the spacecraft was in lunar orbit was unnecessary unless orbit determination problems cropped up, which they never did. This same procedure applies to the F mission with one significant exception. In order to give us the greatest chance of solving our current lunar orbit determination and lunar gravitational problems, we would like to obtain as much MSFN ranging as possible during the landmark tracking exercise to be carried out on TEI day. Although not mandatory, we would like to assign it a priority high enough that it would be obtained even at some cost of voice communications and/or other things that might conflict with it. In other words, it is not trivial.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 24, 1969
69-PA-T-31A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Let's have no unscheduled water dumps on the F mission

During a recent Data Selection Mission Techniques meeting we were informed that the CSM has some sort of automatic water dump system. It was even rumored that it might be enabled on the F mission while the crew is sleeping during cis-lunar flight. This memo is to inform everyone that an unscheduled water dump can really screw up MSFN orbit determination. Accordingly, if we have a vote, this automatic capability, if it exits, should be inhibited and water dumps should only be performed as scheduled by MCC-H.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center
Mission Planning & Analysis Division

TO : See list below

DATE: February 20, 1969

69-FM-T-30

FROM : FM/Deputy Chief

SUBJECT: Results of the February 18 Apollo Spacecraft Software Configuration Control Board (ASSCCB) meeting

This is just a short note to inform you of the most significant actions taken at the subject meeting.

1. PCR 268 for both LUMINARY 1A and COLOSSUS 2A was approved. As a result, these programs which will be used on the G mission will be modified to speed up Programs P34 and P35 as recommended by Ed Lineberry, Bob Regelbrugge, etc. Specifically, this change to the TPI and MCC targeting programs is to use a Kepler prediction rather than the precision numerical integration since it is so much faster with no appreciable decrease in accuracy. It is estimated that about 80 seconds is saved each time these programs are called up. Since the command module runs through P34 three times between CDH and TPI, this represents a saving of about four minutes in that extremely crowded timeline. MIT intends to implement this such that it normally operates in the fast mode but they are providing a crew option to override that logic and use the old precision integration if it is deemed necessary. [Incidentally, no change is being made to the Stable Orbit rendezvous program (P38).]

2. PCR 273 to put the jerk limits used on the descent abort programs into erasable memory was disapproved. However, we were given the action item of determining the values which we feel are best to be put in fixed memory. These must be relayed to MIT on or before February 21.

3. PCR 274 for LUMINARY 1A and COLOSSUS 2A to modify the lunar potential was disapproved based on George Cherry's estimate that the impact would be substantial. MIT was asked to start a parallel effort in developing the formulation for the expanded lunar potential model for their programs but not to plan to implement it for the G mission. This obviously means we will have to develop workaround procedures for DOI and descent targeting to be used in the MCC-H/RTCC.

4. PCR 732 LUMINARY 1A to add rendezvous radar bias to the W-matrix input/output display was approved. As you recall, the crew was already given a convenient way to readout and update the position and velocity terms of the W-matrix but had to go through a special procedure for loading the rendezvous radar term. This change merely added that parameter to the standard display. There was considerable discussion regarding units

of these terms. MIT was given the option of changing them for crew convenience at no impact if they could do it to both COLOSSUS and LUMINARY. It should be emphasized this is just a nicety.

5. Several changes have been approved to the Descent programs of LUMINARY 1A. Probably the most significant deals with providing the crew with the capability of taking over manual control of spacecraft attitude and then returning to automatic control while in the terminal descent programs. If you are interested in this sort of thing I suggest you contact the experts to learn precisely what is being done. As I understand it, if the crew does take over attitude control, it is important that they maintain the computer recommended attitude as displayed in the FDAI error-needles, otherwise the throttle control by the LGC will get screwed up. Also, there is some concern that if the crew does not respond fast enough they may create an unstable situation.

Finally, I would like to confess a mistake I have been making, which I am going to try to avoid in the future. Namely, in the interest of expediency, I have been signing MPAD's PCR's which are not written up accurately or completely enough. From now on I am going to be looking for much more detail specifically describing the change and the advantages to be accrued.

Howard W. Tindall, Jr.

Addressees:
FM/J. P. Mayer
C. R. Huss
D. H. Owen
R. H. Brown
FM13/R. P. Parten
FM2/C. A. Graves
FM5/R. E. Ernull
H. D. Beck
FM6/R. R. Regelbrugge
K. A. Young
R. W. Becker
FM7/S. P. Mann
R. O. Nobles
FC5/C. B. Parker
TRW/Houston/R. J. Boudreau
MIT/IL/M. W. Johnston
NR/Downey/B. C. Johnson, AB46
FM/Branch Chiefs

FM:HWTindall, Jr.:js

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

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 25, 1969
69-PA-T-29A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Mission D Manuever Monitoring Document

Included in the D mission are some special propulsion and guidance system tests. They consist of unique maneuvers which are not discussed in either the Rendezvous or Entry Mission Techniques Documents. They required development of special mission techniques which are documented in the attached book.

Howard W. Tindall, Jr.

Enclosure

PA:HWTindall, Jr.:js

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 20, 1969
69-PA-T-28A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Descent Abort Mission Techniques

On February 13 we went over our Descent Abort Mission Techniques with the world. In general they were accepted as is. That isn't to say we didn't have some lengthy discussions resulting in some improvements and/or changes but we didn't make any substantial changes to the basic ground rules, philosophy, or overall procedures. I would like to list here some of the things we decided as well as some open items requiring work.

1. Although we didn't spend any appreciable time discussing this, it probably would be worthwhile to look into fixing the spacecraft computer program (LUMINARY) such that we could use the DPS and APS Descent Abort Programs (P70 and P71) before PDI (TIG). In other words, prior to PDI the crew and/or MCC-H may decide PDI is "no go." Since the descent abort programs have the capability of targeting and guiding an ideal maneuver to set up the standard rendezvous sequence it may be quite an advantage if we are able to call upon those programs without actually having attempted PDI as the program is currently constrained.

2. It was agreed that if the steerable S-band antenna lock-on is lost during a descent abort, the crew will not attempt to reacquire with that antenna but rather will switch to the omnis as soon as it is convenient for them to do so. Of course, this will only supply the ground with low-bit rate data but reacquisition with the steerable is considered to be almost impossible, particularly in an emergency situation like this. (Landing Analysis Branch was given the action item of determining if the initial descent abort attitude maneuver for any period in a nominal descent would cause the S-band steerable to loose lock.)

3. It was concluded that there is a significant advantage to having the AGS Mode Control switch nominally set to Attitude Hold during descent in order to permit the crew to complete a landing using the AGS if they have a PGNCS problem late in descent and consider it safer to land than to abort. Of course, this means that an extra switch setting must be made if it is necessary to abort on the AGS. Specifically the AGS abort sequence would be:

a. Set Guidance Control to AGS

b. Make a manual maneuver to approximately the abort attitude

c. Set Mode Control:AGS to Auto (This is the "extra")

d. Push Abort or Abort Stage

4. We had a lengthy discussion about whether or not the DPS should be run to propellant depletion. The Propulsion people (who are never in attendance in any meeting dealing with how their systems are going to be used) have stated that running the DPS to propellant depletion should not be done unless crew safety is involved. There are obviously times in the descent aborts at which crew safety is decreased if we turn off the DPS any sooner than we have to. Accordingly, in order to avoid some sort of complicated logic to guide the crew in determining when they can or cannot run to propellant depletion, we all agreed that the DPS will ordinarily be run to propellant depletion if the guidance system does not shut it off first. The crew took proper note that there is some hazard incurred in doing that and plan to manually shutdown the DPS when the propellant gauge reads 1 or 2 percent remaining provided they are clearly in the region that shutting down the DPS is not going to increase the probability of hitting the moon AND it is clear an APS burn will be required to achieve orbit. Implicit, of course, is that they are not so busy in treating the cause of the abort that they fail to monitor and take this action.

5. In the event it is necessary to use the APS to achieve orbit, it was concluded that the crew will not attempt to provide ullage prior to pushing the Abort Stage Button. Although this is not accepted practice for an in-orbit maneuver, we could see no reason why it should not be perfectly safe to do this following a DPS burn of any magnitude with completely full APS propellant tanks.

6. By far our longest discussion dealt with how to handle the situation at insertion following an abort during the first 300 seconds of powered descent. Specifically, we are faced with the problem of how to jettison the DPS conveniently and safely and at the same time trim the ΔV residuals in order to get on the desired rendezvous trajectory. The results of this discussion were so meager that I will not report them here. Particularly since subsequent to the meeting several new proposals have been made that appear better than anything we considered. What I'm saying is that our discussion was fruitful to the extent that it got a lot of people thinking about this problem but we probably need to get together again to discuss all the resultant ideas and choose our course. I will set up a get together just for that purpose.

Howard W. Tindall, Jr.

FA:HWTindall, Jr.:js

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 19, 1969
69-PA-T-27A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: All about F APS burn to depletion and landmark tracking

On February 14 we had a Mission Techniques meeting to pin down F lunar orbital operations between the end of rendezvous and TEI. Aside from a rest period, this consists of two exercises - the APS burn to propellant depletion and landmark tracking with the optics. I think we have a good understanding of how to do both of these things. We are recommending the addition of an extra rev in lunar orbit in order to complete them and to obtain one pass of strip photography on the sunlit part of the moon prior to TEI. This will make the time between wakeup and TEI approximately 12 hours which does not seem unacceptable, and does not increase total mission time.

1. APS Burn to Depletion

Although we went into considerable detail in planning this exercise I will only list here several of the most significant items. The detailed procedures, of course, will be documented elsewhere.

a. As you know, the APS burn to depletion is initiated at approximately zero degrees longitude in a horizontal, posi-grade direction. It occurs about 1¼ rev after docking.

b. After docking, the command module will be used for controlling attitude of the docked configuration. As soon as convenient after docking, the command module will reorient to near the burn attitude based on gimbal angles computed pre-flight and included in the flight plan.

c. The only data required from MCC-H is as follows:

(1) A P27 command load to the LM PGNCS of LM state vectors.

(2) Voice PAD message to the LM for PGNCS and AGS targeting. This will be the standard P30 PAD with a number of parameters omitted, which are only applicable to a manned burn.

(3) Voice to the CSM of the gimbal angles for the burn attitude. Having obtained these, the CMP is able to orient the CSM/LM accurately in burn attitude based on real time data and the LM crew is able to orient the steerable S-band antenna to achieve maximum signal

strength with MSFN.

d. Just prior to LOS, about 3/4 rev before TIG, the LM crew will update the state vectors in the AGS and will align it to the PGNCS. They will already have run through the SPS pre-thrust program (P30) and will leave the PGNCS in Program P00.

e. The CSM will jettison the LM $\frac{1}{4}$ rev before TIG and will null the relative velocity. They will then execute a 2 fps separation burn in a radially upward direction which will place the command module above and behind the LM at the time of the burn.

2. Landmark Tracking

Before C' we thought we knew how the optics tracking and MSFN orbit determination capability should be used for a lunar landing flight. Unfortunately we are worse off now since C' has proved we really don't know. At this time - with incomplete post-flight analysis, we have a dilemma. The optics data seems to indicate that spacecraft altitude was not changing while in lunar orbit; on the other hand, the MSFN data clearly shows a continuous change in altitude which was more or less what was expected based on Lunar Orbiter data. These two systems disagree with each other and yet both appear to be operating right. It may be possible eventually to figure out what is happening by further analysis of the C' data but unfortunately we are at a point when we must pin down the F mission flight plan. So what we were trying to do at this time, based on what we know now was to develop an exercise which we feel will give us the greatest opportunity to resolve our difficulties in time to support the G mission descent targeting accurately and dependently. Simply stated, we need as much data as we can obtain. Essentially, we are asking for a repeat of the C' lunar landmark exercise with some minor modification. Since the thing we are most concerned about is trends (i.e., the change in altitude) - it seemed that tracking on four successive revs is the minimum that would provide any kind of confidence in the results. I think everyone in attendance agreed with that. Secondly, although MPAD was asking for observation on four landmarks on each of these revs, we all agreed that three are probably adequate and so our proposal is to do landmark tracking on three sites on each of four successive revs.

To be a little more specific, we are currently recommending:

a. One of these be the same pseudo-landing site landmark we used on C'. It is called B1.

b. The first backside landmark as the spacecraft enters daylight (CP_1) should probably be chosen by the CMP in real time at about 20 degrees passed the terminator, the same as Lovell did.

c. The third landmark (CP2) can probably be moved closer to the sub-solar point than on C'. We are recommending a landmark about 25 degrees prior to local high noon.

Of course, we are specifying that all observations be made with the sextant and that they be spaced as far apart as possible - in the order to 25 seconds. It appears that it should be possible to use lunar orbit rate torquing during the landmark tracking period if that is easiest for the crew.

It is possible to include the exercise as described here in the current F mission timeline without affecting the rest period or the TEI burn currently scheduled at about 127:50. However, this would preclude obtaining strip photography desired on one pass over the entire sunlit lunar surface. In order to include that it will be necessary to delay TEI one rev to about 129:50. This will increase its magnitude by about 100 fps but does not change Pacific landing time. Of course, it is possible to retain the earlier orginal TEI as an optional maneuver time in the event of crew exhaustion to be utilized based on a real time judgment, if necessary. It appeared advantageous to us to put the strip photography after the more strenuous landmark exercise since it is less demanding on the crew, interferes less with TEI preparation and is of lower priority. The ASPO mission engineer, Bob Ward, will submit a Trajectory Change Request for this extra rev and everyone else I think will begin now to include it in their planning and documentation on the assumption that it will be approved.

Except for odds and ends, this pretty well finishes off the main line F Mission Techniques work.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center
Mission Planning & Analysis Division

TO : See list below

DATE: February 19, 1969

69-FM-T-27

FROM : FM/Deputy Chief

SUBJECT: Apollo spacecraft computer program newsletter

Christopher C. Kraft had a Joint Program Development Plan meeting at MIT on February 12. I would just like to pass on to you a couple of things that were interesting to me.

1. Fred Martin stated that there are 90 separate changes being made to the COLOSSUS 1A program in developing COLOSSUS 2. Altogether this involves a change of about 2,000 to 2,500 lines of code of which about 800 are the CSI/CDH addition and about 600 involve improvement to the TVC DAP. COLOSSUS 2 was released for rope manufacture on February 11. This release is called Comanche Revision 44.

2. COLOSSUS 2A will use Comanche 44 as its starting base line for the program which they plan for use in the G mission. Candidate program changes suggested by MIT to be included in COLOSSUS 2A are as follows:

a. New ephemeris and stars

b. V82 time input

c. Backup Mark Button

d. Provide countdown to .05 g in P61

e. Better definition of local vertical near sphere of influence where current formulation tends to break down.

f. Add PTC and Orbit Rate modes into DAP via extended verb.

g. Integrated stick during launch

h. V35 light test (?)

i. Lunar potential

j. P64 G maximum display

k. P34/35 speed up

l. Asteer

3. George Cherry also suggested a list of candidates of LUMINARY changes for post-G mission. They included:

a. Changes to the rendezvous braking phase to provide display of raw rendezvous radar data and line-of-sight rates as well as providing some automatic line-of-sight attitude control.

b. Some rendezvous navigation improvements including updating W-matrix through maneuvers.

c. An improvement to the alignment programs to make it more convenient for the crew to align the LM IMU to the CSM IMU.

d. Explicit descent abort variable insertion targeting.

In general, spacecraft computer program development certainly seems to be under control with very little frantic activity foreseen. Probably the programs requiring the most attention now are associated with powered descent to the moon. In fact, Mr. Kraft had MIT give an informal briefing lasting about two hours in which they presented their opinion of how the descent targeting should be done. I gather it is in close agreement with things Floyd Bennett's people have been recommending.

Howard W. Tindall, Jr.

Addressees:
FM/J. P. Mayer
C. R. Huss
D. H. Owen
R. H. Brown
FM13/R. P. Parten
FM2/C. A. Graves
FM5/R. E. Ernull
H. D. Beck
FM6/R. R. Regelbrugge
K. A. Young
FM7/S. P. Mann
R. O. Nobles
FC5/C. B. Parker
FM/Branch Chiefs
TRW/Houston/R. J. Boudreau
MIT/IL/M. W. Johnston
NR/Downey/B. C. Johnson, AB46

FM:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 11, 1969

69-PA-T-24A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: F/G Rendezvous Mission Techniques - mostly F

As part of F/G Torture Week, we spent Thursday, January 30 on the rendezvous. Overall, I would say this mission phase is in pretty good shape with only a few unresolved items that we know about right now. I would like to tabulate here a bunch of odds and ends we agreed to at this meeting - as well as my memory serves me. It's mostly trivia and if I were you I wouldn't waste my time reading anymore except maybe paragraph 3.

1. On the D mission the CMP is prepared to make a so-called "Horizontal Adjust" maneuver if it is decided to stay in the mini-football in order to insure a closing trajectory. The F and G crews both felt this is an unnecessary complexity and so they will not make such a maneuver or be prepared to make one on these missions.

2. Everyone worries about overburning the DOI maneuver. Wait until they discover it just takes an extra 15 fps on DOI to cause a lunar impact. The LM picks up that much ΔV in about three seconds when operating at about 40 percent and so it is unlikely we will be able to establish a manual backup protecting against overburn which would provide a safe orbit. On the other hand, some sort of monitoring is required and Rick Nobles (MPAD) was given the action of establishing the limits for the crew to shut down the DPS manually when both the AGS AND the Burn Time have been exceeded by these amounts.

3. LM aborts due to a fouled up DOI maneuver are attracting a lot of attention. For the past year, everyone agreed that the best technique is to make a brute force burn right back to the CSM immediately. This probably works pretty well if it's done within five to eight minutes of DOI. After that it doesn't and the crew feels more time than that will be required for them to ascertain an abort is necessary and then to execute it. Ed Lineberry was given the action item of performing a parametric study to establish the best technique for aborts up to about 15 minutes after DOI with the maximum possible overburn based on our backup cut-off procedures. Whatever it turns out to be we are tentatively proposing to use the DPS at 40 percent thrust, controlled manually with the AGS maintaining attitude hold. The crew would shut down about

10 to 15 fps short and finish off the burn with 4 jet RCS while simultaneously jettisoning the DPS. Milt Contella ventured the opinion that DOI aborts are going to turn into the F equivalent of D's TPI_0 - Endless discussion and a mess in the end! I believe it already.

4. We decided to create a new PAD message which the CMP can use for loading his Target ΔV program (P76) for the ground computed maneuvers - DOI, Phasing and Insertion. It consists of Purpose, TIG, and ΔV's. In addition we decided to add burn time (BT) to the LM P30 PAD.

5. It was determined that it will not be possible for the F crew to use their descent program (P63) for the landing radar test as they had planned because MCC-H will not be prepared to support it with the necessary input data. Don't get excited. This is no great loss.

6. We pinned down the complete rendezvous tracking schedules for both spacecraft and established the following W-matrix values. The initial values shall be 10,000 feet, 10 fps, and 15 milliradians. The values for reinitialization shall be 2,000 feet, 2 fps, and 5 milliradians. (For the unique F rendezvous tracking period between the Phasing and Insertion burns, the W-matrix shall be initialized using 2,000 feet, 2 fps, and 5 milliradians.) MIT was asked why the PGNCS computer program (LUMINARY) does not provide a simple way for initializing the W-matrix value for radar bias as it does the position and velocity values. Perhaps a PCR should be submitted for that.

7. We had a lengthy discussion on rendezvous navigation during the phasing revolution. It was soon recognized that, since the LM has no tape recorder, it is only possible to evaluate its performance if we allow the rendezvous navigation to update the state vector. However, the flight controllers were concerned that if the rendezvous navigation in back of the moon fouled up the LM state vector they could have problems targeting the Insertion Burn which occurs shortly after AOS. On the other hand, it is possible that the rendezvous navigation could be useful in detecting dispersions in the Phasing maneuver. Accordingly, we reached the following agreements:

a. Rendezvous navigation by the command module will be used only to update the LM state vector.

b. Rendezvous navigation in the LM will be used to update the LM state vector until shortly before LOS. After that, the LM crew will switch the LGC to update the CSM state vector.

c. While the LM is in back of the moon the flight dynamics people will determine if the LM onboard state vector is acceptable for executing the insertion burn. If it is, it will be left alone; in fact, MCC-H will transmit it to the CSM after insertion. If it is not acceptable, the LM crew will be advised at AOS to terminate their navigation program (P20) immediately and the update program (P27) will be called so that the ground may send a good LM state vector for the Insertion maneuver. It is unlikely that they will have to do this but if they do it must be recognized that we will not get the rendezvous radar tracking data at the maximum ranges which we are so interested in.

d. As a standard procedure the ground will always update the CSM state vector in both spacecraft computers after insertion.

8. Rendezvous radar thermal study must be performed, I suppose, and we established the following profiles for that purpose listed here in order of our preference:

a. Rendezvous radar continuously operating from during the mini-football to completion of the rendezvous.

b. Same as "a" except turned off from DOI until just after Phasing.

c. Same as "a" except turned off during the platform alignment while in the phasing orbit.

If GAEC and RCA feel the rendezvous radar cannot support any of these profiles - we would rather fight than switch!

9. After a little merry-go-round we agreed on what the CSM should do for TPI targeting. He starts out running the P34 using the elevation angle option in order to obtain a TPI solution for comparison with the LM PGNCS. He then recycles using the time option with a TIG one minute later than the LM's in order to backup the LM TPI maneuver.

10. Both the F and G crews and just about everyone else who stuck it out to the end seemed to want to keep the LM active for TPI even if the rendezvous radar had failed. You recall the D mission rule says the CSM should go active for that failure. I guess that must be the right thing to do since so many people thought so and I was just too groggy to understand.

11. MIT was asked the following brief questions:

a. Does the CMC automatically inhibit VHF ranging data beyond the recycle range of 327 miles?

b. How does the crew request the half-period-between - CSI - and - CDH option in the rendezvous navigation program (P32).

c. Are these options in shared erasible memory or is it possible to load them pre-launch on the E-memory K-Start tape.

d. How should the crew handle the sign of the out-of-plane velocity display from R36 if: (1) the CMP requests the LM option for relay to the LM or (2) if he uses R36 to target his own plane change maneuvers.

Well, I warned you!

Howard W. Tindall, Jr.

PM:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 11, 1969

69-PA-T-23A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: F/G Mission Techniques - except for the lunar orbit phase - are ready to eat

Some of the decisions and open items that came out of our F/G Mission Techniques meeting in late January are listed in this memo. Basically, I would say that all mission phases aside from the lunar orbit activity are very well understood at this time - primarily as a result of the C' mission - and should be formally documented within the next couple of weeks.

1. Flight Control Division is going to establish the detailed procedures for manning and activating those LM systems required to establish communications in the unlikely event CSM communication is lost. They must include the techniques for orientating the LM steerable antenna toward the earth if the omnis are inadequate. It is also necessary to give some thought to when the crew should initiate these procedures. That is, what should be done with the CSM communication systems first after the total failure seems to have occurred.

2. As a standard procedure, MCC-H will update CSM state vectors on a more-or-less periodic basis - say every 10 hours or so when it is mutually convenient to the crew and ground, unless they have changed so little as to make it useless. Whenever the state vectors are updated, it will be to both the LM and CSM computer memory slots, CSM first.

3. REFSMMAT

a. The launch REFSMMAT will be retained until the IMU alignment after MCC_1 time whether the maneuver is made or not.

b. The same PTC REFSMMAT will be used translunar and transearth during the periods from the post-MCC_1 to pre-MCC_4 and from TEI plus two or three hours to EI - 5 hours.

c. The lunar orbit REFSMMAT to be used for the period between the PTC times defined in "b" shall be such that the LM in landing attitude, over the landing site after DOI would have 0, 0, 0 on the FDAI. This REFSMMAT will be computed by the MCC-H prior to MCC_4 for use in the CSM. According to my notes, the REFSMMAT will be updated on DOI day to compensate for prediction uncertainties. I can't remember why. (On the

G mission, of course, the REFSMMAT in the LM will be updated several times automatically while on the lunar surface by the LGC to correspond to the ascent alignment. Currently we plan to update the CSM more or less to the ascent REFSMMAT but we will not attempt to maintain it precisely the same as the LM.)

4. The only burn monitoring limit it is necessary to change from those used on C' is the one used for overburn protection on LOI_1. The extra mass of the LM makes this maneuver substantially longer in duration, so that limit has been made correspondingly larger. Specifically, it will be 10 seconds rather than 6 seconds.

5. Math Physics Branch was requested to determine if in order to maintain a good MSFN orbit determination capability, it is really necessary for the crew to reverse the orientation of the spacecraft x-axis every three hours during periods of venting. It seems as though the net effect of the venting is almost exactly in the least sensitive direction when using the PTC attitude currently proposed and it would certainly be nice to avoid unnecessary spacecraft maneuvers; perhaps even unnecessary awakening of the crew.

6. In order to insure that the crew never experiences CMC Program 65 during entry, MCC-H will make a real time selection of entry range to avoid P65 prior to targeting TEI. This should not be a difficult thing to do while in lunar orbit but cannot be done pre-mission to suit all launch opportunities.

7. The crew is looking for a recommendation as to whether the entry should be performed using one or two RCS rings. Claude Graves is said to be working on this.

D. Docked DPS burns in lunar orbit

a. It was established that, if a docked DPS burn is to be used for TEI, it should be carried out with one burn only as opposed to two as has been suggested.

b. In this event the LM platform will be aligned using docked AOT sightings of stars in order to determine platform orientation (P52). Given the accuracy of pulse torquing, it will be possible to reorient the IMU for the maneuver without additional AOT sightings.

c. The CSM will use the Average G Program (P47) for maintaining state vectors if we make a docked DPS burn.

d. It was estimated that the LM could be made ready for such a burn easily within 1½ hours.

e. MIT was asked to determine if the DPS gimbal trimming would work in the docked configuration at 10 percent thrust in the LUMINARY program.

f. It is evident that complete docked DPS check list must be prepared for the F and G crews by FCSD.

g. The crew was somewhat concerned with the technique MPAD has developed for the LOI-15 minute short. This short maneuver, you recall, is one the crew must target for themselves in the event of a premature SPS shutdown during LOI. The crew charts that MPAD has developed present the ΔV required assuming the maneuver will be executed exactly 15 minutes from the time of SPS shutdown. Since the spacecraft clocks are all keyed to LOI TIG, the crew feels it would be easier for them if the maneuver were scheduled to occur 15 minutes from LOI TIG. The point is, they were concerned that in the event of an emergency they may not note the time of shutdown or are more likely to make a mistake in determining when to execute the short maneuver. Flight Analysis Branch, MPAD, is looking into reworking these charts based on TIG rather than SECO.

10. Since there is concern over premature shutdown on either the LOI or TEI maneuver, the crew asked if it were not logical to protect against it, particularly in the unstable butterfly region, by use of the Thrust Direct On switch. For example, during LOI they suggest turning that switch On from TIG + 1 minute to TIG + 5 minutes and on the TEI maneuver they would switch it On from TIG + 15 seconds to TIG + 2 minutes. Flight Control and other guys are going to think about that! I think the greatest fear is what would happen if the crew neglected to switch it off in time.

That's all I can remember. Mostly trivia, you see which probably shows better than anything the status of F/G Mission Techniques for these mission phases.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 6, 1969
69-PA-T-19A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Apollo Mission Techniques Documentation Schedule

Attached is my guess as to when we will distribute some more Mission Techniques Documents. Except for the G unique stuff, we'll probably come pretty close to this schedule since it's primarily just updating C' books a little bit. It also gives you an idea of what we plan to do - if that's a help.

Howard W. Tindall, Jr.

Enclosure

PA:HWTindall, Jr.:js

[illegible] DOCUMENTATION SCHEDULE

as of February 5, 1969

SUBJECT		NOV [illegible] EST.	CURRENT EST.	ACTUAL
Saturn V/Apollo Launch Phase Aborts	 Update	- (If necessary)	- Mar 15	Oct 22, 196[8] -
D Retrofire and Reentry		Dec 16	-	Dec 16, 1968
D Rendezvous	Final Update	[illegible] -	- Feb 14	Dec 20, 1968 -
F/G Earth Parking Orbit & TLI*		-	Feb 17	-
F/G Translunar Midcourse & LOI*		-	Feb 17	-
F/G TEI MCC & Entry*		-	Feb 24	-
F/G Contingency Procedures*		-	Mar 3	-
F/G MCC-H/RTCC Data Selection*		-	Mar 17	-
F/G Lunar Operations	Draft Final** Update	Jan 13 Feb 17 -	- Feb 14 Mar 31	Jan 27, 1969 - -
G Descent	Final Update	- -	- Mar 31	Aug 23, 1968 -
G Lunar Surface	Final Update	- -	- Feb 24	Oct 6, 1968 -
G Ascent		-	Mar 24	-
G Descent Aborts	Draft Final	Jan 20 Mar 3	- Mar 24	Feb 3, 1969 -

* These are essentially updates of the C' documents

** Excluding period from post rendezvous to pre-TEI and rendezvous rescue

Enclosure

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 6, 1969

69-PA-T-18A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: F/G cis-lunar midcourse correction mission techniques

This memo is to document the cis-lunar midcourse correction mission techniques we agreed to January 27 and 28 at the F and G Mission Techniques meetings. The translunar maneuvers are based on the following assumptions and guidelines:

a. We are not concerned about getting substantially further off the free return trajectory than on C' - primarily because we have the DPS backup.

b. We are especially anxious to conserve RCS propellant, which led to the procedures of allowing the midcourse corrections to grow to SPS size if possible.

c. In order to maintain best control over the situation we decided to use MCC_3 (at LOI - 22 hours) as the prime MCC, leaving MCC_4 essentially for fine trimming if necessary.

d. The minimum SPS burn is 0.5 seconds which is equivalent to approximately 3 fps.

Based on all that, we established the following:

a. <u>MCC_1 (at TLI + 7 hours) and MCC_2 (at TLI + 24 hours)</u>

The need for these maneuvers will be based on how big MCC_3 would be if we did not make them. Specifically, MCC_1 and/or MCC_2 will not be executed as long as MCC_3 is less than about 25 fps without them. Furthermore, we will not make them unless we can use the SPS (that is, they must be bigger than 3 fps) and we will not trim residuals.

b. <u>MCC_3 (at LOI - 22 hours)</u>

This is the prime maneuver to achieve the desired trajectory around the moon. It will be made if the predicted MCC_4 is greater than about 3 fps in order to avoid using SPS for MCC_4. Residuals will be trimmed to within 0.5 fps on this maneuver, which will most likely be made with the SPS.

c. MCC_4 (at LOI - 5 hours)

By taking advantage of the significant flexibility provided with two-stage LOI maneuver in targeting the LOI maneuvers, we are often able to avoid making an MCC_4. That is, the LOI targeting can be done to achieve a 60 mile circular orbit in spite of substantial approach trajectory dispersions. This is done by rotation of the major axis of the initial 60 x 170 n.m. lunar orbit. However, we established that the apsidal rotation should be limited to less than [illegible] degrees. If it is necessary to use the SPS for MCC_4, the residual will be trimmed to within 1 fps.

Midcourse correction techniques on transearth leg phase of the flight were somewhat simpler. We are retaining the C' technique of utilizing transearth midcourse corrections only for corridor control. We have concluded that it is desirable to avoid making the last midcourse correction (i.e., MCC_7 at EI - 3 hours) if at all possible. Accordingly, we opened up the entry interface (EI) flight path angle limits a little more than on C'. Specifically, we will not execute MCC_7 if the flight path angle falls between 6.3 and 6.6 degrees ([illegible] degrees is nominal). In order to minimize the probability of that midcourse correction, we set the threshold for MCC_6 (scheduled at EI - 15 hours) at [illegible] fps which is close to the MSFN targeting accuracy at that time. The first transearth midcourse correction (MCC_5 at TEI + 15 hours) will not be executed unless it is greater than 1 fps.

The most significant change from C', of course, is brought about by the DPS backup which safely permits deviation from the free return trajectory. This makes the logic much simpler since we don't have to consider moving the maneuvers earlier to stay within RCS return-to-earth capability.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 6, 1969

69-PA-T-17A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: MCC-H Ascent Monitoring

This is a note primarily to myself to remind me of impressions obtained during the MCC-H Ascent Monitoring meeting of January 24, 1969. Although it appeared that the prime program for processing MSFN data was to be the "Lear," I feel quite strongly that the old, direct doppler-measurement technique should be retained for in-plane monitoring. The only situation it cannot support is ascent from the central landing site with a bad z-axis accelerometer. It seems to me, at least for now, that the Lear-Processor should only be used prime for out-of-plane - the situation the old technique can do nothing for. According to Steve Bales, their plans for RTCC program and MCC-H display implementation are in complete accord with this idea. It is only necessary to make the decision to do it this way on the G mission.

Another thing I am particularly concerned about is an apparent willingness to allow the trajectory to become badly dispersed before switchover from a failing PGNCS and thus to accept what could be a very poor rendezvous situation compounded by a failed PGNCS to do the rendezvous. In order to avoid this, two things must be done.

a. First, we must determine how serious it is to switchover to the AGS as soon as it is recognized that the PGNCS is not working as well as the AGS. This you see is not a question of pre-flight expected performance of the two systems but rather actual, observed performance in real time. The only reservation against switchover, it seems to me, is the hazard incurred by the actual operation of switchover itself.

b. Secondly, there appears to be a need to establish display action lines or techniques involving displays other than the predicted insertion display. This is necessary since the predicted perigee vs. wedge angle display do not reveal a problem until long after it occurs. It seems to me it should be possible to establish some technique which would result in taking action much sooner. One consideration which must be analyzed before adopting this technique, however, is to determine the effect of delaying the switchover action since, if the AGS is capable of returning the spacecraft to a near nominal trajectory at little ΔV cost, there is no point in taking the action early.

Howard W. Tindall, Jr.

UNITED STATES GOVERNMENT

Memorandum

[illegible]

TO : See list attached

DATE: February [illegible], [illegible]

[illegible]

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Notice of an F Mission Techniques [illegible]

This memo is to inform you of an [illegible] Techniques Meeting schedule. [illegible] Operation Mission Techniques [illegible], starting at 9 a.m. in Room [illegible] the activities between completion of [illegible]. You recall, this is the one period we did not cover in [illegible] and there are a number of open items [illegible] depletion burn, landmark tracking activities, [illegible].

Also at this meeting, we intend to [illegible] version of the F/G Lunar Orbit Mission Techniques [illegible] our meeting of late January which we will [illegible].

Happy Valentines Day!

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: February [illegible]

69-PA-T-14A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Two-stage LOI looks good after C'

Just like in other fields of endeavor, it always seems possible to use actual flight results to prove how smart you were before the flight. I am writing this note to crow about how C' proved we "done right" in planning a two-stage LOI.

As you recall we originally considered manually backing up the GNCS during LOI to avoid an overburn using both burn duration AND the EMS ΔV counter. However, when we got down to detailed planning on how to do this, we concluded that we had insufficient confidence in the ΔV counter to wait for it to clock out since the consequences of an overburn are catastrophic. Furthermore, although it sounds simple, monitoring three data sources simultaneously and taking proper action at this critical time turned out to be messy. As a result, the final C' procedure was to backup the GNCS by manually shutting down the SPS if it exceeded the LOI_1 estimated burn duration by more than six seconds. This value was consistent with the 60 x 250 n.m. initial lunar orbit. If we had been using a one-stage LOI our rule would have had to be for the crew to shut down manually just about at the nominal burn duration (no delay) in order to avoid an unsafe perilune in the event of a high thrust engine.

On C' LOI_1 we actually experienced a burn duration 4.9 seconds in excess of that expected. Therefore, given a one-stage LOI on C' the crew would have shut down the SPS manually even though the G&N was operating properly and then they would have had to make a second burn of about five seconds duration to finish it off. (In addition to that, we would have been unable to utilize the flexibility of the two-burn LOI targeting to compensate for the trajectory dispersion following the last translunar midcourse correction and we would have ended up with a 64 mile altitude on the back of the moon rather than a 60 circular orbit.)

Incidentally, our other pre-flight conclusion, that is, lack of confidence in the ΔV counter was also proven correct on this flight by several in-flight anomalies including an erratic accelerometer!

Weren't we smart?

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

APOLLO DATA PRIORITY COORDINATION
MEETING SCHEDULE

AS OF January 31, 1969

69-PA-T-13A

SUBJECT OF MEETING	3	4	5	6	7	10	11	12	13	14	17	18	19	[illegible]	21	[illegible]	25	26	27	28
	FEBRUARY																			
F Data Select													■					■		
G Lunar Surface			■																	
G Descent Aborts									■											
G Descent														■						
SPECIAL MEETINGS																				

■ Meeting begins at 9:00 a.m.

□ Meeting begins at 1:00 p.m.

Howard W. Tindall, Jr.

MSC Form 1305 (Rev Sep 68)

Memorandum

TO: [illegible]

DATE: [illegible]

FROM: [illegible]

SUBJECT: [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Δ	Δy	Δ	Δ
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible] fps	[illegible]
[illegible]	[illegible]	[illegible] fps	[illegible]
[illegible]	[illegible] fps	[illegible] fps	[illegible]

[illegible] have been changed or added since the previous [illegible].

[illegible] discussion as to how to handle the AGS gyro [illegible] check, we finally arrived at a rather simple procedure. The crew must note the <u>change</u> in the accelerometer bias from [illegible] to after the check. The AGS is considered failed if the [illegible] component is changed more than .04 fps^2; it is also considered failed if the (absolute) gyro drift in any component exceeds [illegible] hour. As you know, the AGS calibration procedure updates [illegible] compensation for both of these automatically. There had been [illegible] concern that if a large change occurred from the pre-flight values [illegible] be an indication that the calibration rather than the instrument [illegible] fault and, therefore, something should be done in [illegible]

[illegible]

Another [illegible]

[illegible]

[illegible]

When [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

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

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: January 21, 1969

69-PA-T-11A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: D Rendezvous Mission Techniques Meeting - January 20, 1969

This memo is to document the "results" of the gruelling session we had on the D Rendezvous Mission Techniques on Monday, January 20. This special meeting of FOD, FCOD, MIT people, and the prime and backup crews was called to try to reach agreement on a number of items not covered previously or uncovered in recent simulations.

1. In order to provide an acceptable return trajectory in the mini-football, the CSM must make a "horizontal adjust" maneuver approximately at the nominal time of the LM Phasing Burn. Accordingly, the CSM shall be prepared to execute it if, for some reason, the LM fails to do the Phasing Burn. This provides an abort opportunity one-half revolution later from the mini-football if the real time situation dictates it. Nominally the CMP targets this maneuver for himself using a chart. Ed Lineberry was asked to look into what assistance the MCC-H might provide.

2. There shall be no "horizontal adjust" maneuver targeting done either at MCC-H or on-board for trimming the big football trajectory.

3. As usual, a great deal of time was spent on that damned TPI_0 football rendezvous. As expected, the analysis shows that MCC-H support for this abort is so poor that it must be considered "last ditch" only. (For example - the estimated ΔV error is 15 fps and TPI time error is three minutes - both three sigma.) Completely unexpected, however, was the conclusion that we should not intentionally delay aborts from the football to the second opportunity as we had previously recommended. This conclusion resulted from the realization that the situation must be degrading with time - particularly the lighting at braking and the ΔV costs - unless some sort of trim maneuvers were made. And, of course, trim maneuvers will foul up the MSFN which negates one of the prime reasons for going an extra revolution. Following is a detailed description of how we now think TPI_0 should be handled. It applies to the second opportunity too, if we somehow get into that situation.

a. <u>Both spacecraft shall use the "time option"</u> of the TPI targeting program (P34) rather than the "elevation angle option." The time used shall be the ground computed nominal TPI_0 time which <u>is</u> accurate, and which will [illegible] with [illegible] (The rationale for [illegible] most important - more so than [illegible] the nominal [illegible]. If the trajectory is nominal, the elevation [illegible] and it doesn't take much [illegible] to switch to the time option [illegible]. [illegible], why not simplify the procedure [illegible].) ([illegible] - what can MCC-H do to [illegible].)

[illegible] (ie [illegible] to [illegible]), [illegible] the LM [illegible] [illegible].

( ) [illegible] Δ < [illegible] Δ < [illegible] Δ < [illegible].

( ) [illegible]

( ) [illegible]

[illegible]

[illegible]:

( ) [illegible]:

( ) [illegible] CSM CMCS vs AGS at phasing [illegible] Δ [illegible].

( ) [illegible] evaluation of sextant input data.

( ) [illegible] LM RR range and range rate checks can [illegible] not to no go the CSM CMCS.

( ) [illegible] comparison with the MCC-H solution.

( ) [illegible] check is based on [illegible]

(a) LGC comparison with the RR/chart solution (of course the RR can affect both of these).

(b) A pilot evaluation of the RR and associated equipment.

(c) The CSM V83 vs LM RR comparison.

(d) A coarse comparison with the MCC-H solution.

4. Here's some more TPI_o stuff. That last paragraph was too long to include it there:

a. The TPI_o will continue to use $t = 130^{\circ}$ and nominal $E = 27.5^{\circ}$.

b. The out-of-plane DPS jettison technique previously agreed to will be retained.

5. Here's some other odds and ends:

a. The RR element of the initial W-matrix shall be .005 radians. Reinitializations shall use .001 radians. (MIT says initial use of .005 radians provides substantial improvement; MPAD says it doesn't either help or hurt; the crew procedures already include it; therefore, leave it in.) (Pixley to make sure .005 radians in on the pre-launch erasible load tape.)

b. It had been proposed that a special spacecraft attitude maneuver could improve the PGNCS estimate of RR bias. It is not considered worthwhile to add this into the D mission now. Maybe F, probably not.

c. MPAD has revised their recommended bias values used in the rendezvous maneuver targeting as follows:

(1) Δ TPI time in P32 - use 3 minutes

(2) Δ CDH time in P33 - use 1 minute 45 seconds

(3) The radial upward bias of 6.7 fps added to the CSM CDH maneuver to compensate for the 1-minute delay should be increased to 6.9 fps.

d. Following are the "approved" rendezvous maneuver solution comparison limits - PGNCS vs. MCC-H:

	$\Delta \dot{x}$	$\Delta \dot{y}$	$\Delta \dot{z}$	Δt
CSI	2 fps	2 fps	-	-

The rule is that if any component of the PGNCS solution disagrees with the MCC-H solution by more than these limits, the LM should use the entire MCC-H solution.

6. The last item, and it turned out to be a big one which we never were able to resolve very well, deals with CDH. As you recall, the MCC-H computes a CDH maneuver and relays it to the crew. It is used for three things: LM PGNCS solution comparison, LM execution if PGNCS comparison fails, and CSM mirror image targeting. Our problem comes about since the LM PGNCS computes the time of CDH (in the CSI - P32 program) which most likely will not coincide with the optimum time solution for CDH computed at MCC-H. Unless we want to send two CDH pad messages - which we do not - the MCC-H is forced to use the (non-optimum) LM CDH time. This is necessary to permit a decent solution comparison and to make sure the MCC-H targeted, CSM mirror-image maneuver does not occur before the LM CDH attempt. Of course there is a limit to how non-optimum we are willing to go - all of which led to the following procedure:

a. LM passes their computed CDH time via TAN or CRO to MCC-H.

b. MCC-H computes CDH ΔV's for that time to achieve coelliptic orbits (as in PGNCS computations).

c. MCC-H also computes acceptable, more optimum CDH by allowing CDH time to vary.

d. MCC-H makes go/no go in PGNCS CDH time.

(1) If okay - MCC-H sends CDH #b pad for on-board comparison.

( ) If fail - MCC-H sends CDH #c pad for the LM to execute. No on-board comparison is needed in this case.

We did not yet figure out the go/no go criteria for CDH time used in d.

There were a number of other things discussed wherein we concluded to retain previous decisions and agreements which I won't list here. All of this and anything else appropriate which comes from our January [illegible] D Rendezvous Mission Techniques world-wide meeting will be reflected in the upcoming revision to the D Rendezvous Mission Techniques document. We don't have any plans now to go over this stuff again after that unless special problems arise requiring attention.

Howard W. Tindall, Jr.

Enclosure
List of Attendees

PA:HWTindall, Jr.:js

D RENDEZVOUS MEETING

ATTENDEE LIST

H. W. Tindall, Jr.	FM
E. C. Lineberry	FM
P. Shannahan	FM
R. W. Becker	FM
R. R. Regelbrugge	FM
L. D. Hartley	FM
P. Pixley	FM
J. Garman	FS
D. W. Lewis	CF
M. C. Contella	CF
H. D. Reed	FC
W. E. Fenner	FC
M. P. Frank	FC
J. McDivitt	CB
R. L. Schweickart	CB
D. R. Scott	CB
D. Gordon	CB
A. Bean	CB
C. Conrad	CB
S. H. Gardner	CF
M. W. Johnston	MIT/IL
E. Muller	MIT/IL
S. Copps	MIT/IL
R. Larson	MIT/IL
G. Shook	TRW

Enclosure

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

Memorandum

TO : See list attached

DATE: January 21, 1969

69-PA-T-10A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: F and G mission cis-lunar and abort plan

On January 8 a gang of us FOD types got together to develop a proposal on how we should use the LM for cis-lunar and lunar orbit aborts. In other words, how should the C' techniques be modified due to having the LM DPS available to backup or use in place of the SPS. A great deal of work has been done and documented by Carl Huss, the Flight Analysis Branch of MPAD, and the Apollo Abort Working Group and the results belatedly reported here are heavily dependent on that work.

First of all I'd just like to state a few facts and assumptions upon which the Abort Plan given in the attachment are based.

a. Except in the case of aborts from lunar orbit, the SPS will always be the primary abort propulsion system. That is, the maneuver will be made with the SPS, bringing along the LM, when possible, so that the DPS can be used as a backup if the SPS fails.

b. Since the SPS does not have enough propellant for TEI with the LM attached, we must reverse the order for leaving the moon if we want a TEI propulsion system backup. And, I guess we do.

c. There is a period during translunar coast - from TLI until about LOI - 20 hours that the fastest return to earth can be made directly using a maximum SPS burn after jettisoning the LM. After that period there is no advantage to direct returns and we don't ever suggest making one.

d. There appears to be no period wherein it is faster to make a direct return using the DPS than it is to perform a post-pericynthion maneuver following a 60 mile flyby.

e. It is always preferable to perform a lunar flyby than a direct return using the SPS unless we truly have a time critical situation, in which case we would only consider use of the maximum available ΔV solution which, of course, includes jettisoning the LM.

f. The fastest return trajectory including a lunar flyby is with a pericynthion altitude of 60 n.m. If we maneuver to provide a higher altitude, the trip time is most likely going to increase. This accounts for the use of 60 n.m. in the time critical flyby modes. Of course, the procedure must include making the standard regularly scheduled translunar midcourse corrections to achieve 60 n.m.

g. Although the real time situation (particularly spacecraft configuration has an overwhelming bearing on what should be done), it seems like a good idea to place the spacecraft on a trajectory targeted to the prime CLA as soon as practical, even though that causes an increase in trip time, and perhaps a second maneuver after pericynthion to speed it up.

h. Although we always list the SPS maneuvers as the prime mode and only utilize the DPS as a backup to the SPS, it is recognized that the crew and ground must be trained and prepared to carry out a docked DPS burn. Accordingly, numerous additional options are available to be agreed to either pre-flight or in real time wherein the DPS is used instead of or in addition to the SPS. For example, the desire to make a DPS system test may justify its use in a non-critical time situation or the use of both the DPS and SPS may provide a significant advantage given certain spacecraft system failures to provide greatest crew safety.

Finally - we briefly discussed how to handle partial LOI_1 Burns. First of all we are recommending the same procedures as C' in the event of guidance or control problems during LOI_1 - namely SCS MTVC rate command takeover and burn completion. This is proposed for all the same reasons as for C' - basically it results in a better situation. For SPS failures prohibiting completion of LOI_1, Flight Analysis Branch recommends ground targeted aborts using the DPS as preferable to the C' type "15 minute abort" SPS burn using on-board chart targeting. This is probably the best thing to do and I'm sure we'll talk about it a lot more before it finally is resolved. One thing to be emphasized though is that, since we have the DPS backup we don't have to be in such a hurry to take action after SPS troubles show up as we were on C'.

All of this will be thoroughly reviewed at a slam-bang Mission Techniques meeting scheduled for January 29.

Howard W. Tindall, Jr.

Enclosure

PA:HWTindall, Jr.:js

CIS-LUNAR ABORT PLAN

Categories depend on when the need for the abort is recognized as follows:

CATEGORY I

From TLI until abort LOI - 20 hours (The actual time will be approximately at the equi-return time - direct return using the SPS vs flyby. This tradeoff will be biased as described in Note I.)

A. Time Critical

1. SPS direct return without the LM, to any CLA (ΔV less than about 8,000 fps). (See Note II)

2. DPS maneuver at pericynthion + 2 hours to any CLA following a 60 mile flyby. (1500 fps ΔV max.)

B. Non-time Critical

1. SPS (or RCS) burn at convenient time before LOI - 5 hours, to flyby pericynthion between 60 and 1500 n.m., to the prime CLA.

2. DPS (or RCS) burn at convenient time before LOI - 5 hours, to flyby pericynthion between 60 and 1500 n.m., to the prime CLA.

CATEGORY II

LOI - 20 hours until the last translunar coast midcourse correction at LOI - 5 hours.

A. Time Critical

1. SPS burn at pericynthion + 2 hours to any CLA following a 60 n.m. flyby.

2. DPS burn at pericynthion + 2 hours to any CLA following a 60 n.m. flyby.

B. Non-Time Critical

1. SPS or RCS burn at convenient time before LOI - 5 hours, to flyby pericynthion between 60 and 1500 n.m. to the prime CLA.

2. DPS or RCS burn at convenient time before LOI - 5 hours, to flyby pericynthion between 60 and 1500 n.m. to the prime CLA.

Enclosure

CATEGORY III

After LOI - 5 hours - or when propulsion system failures are recognized too late to do Category II.

A. Time Critical

1. SPS burn at pericynthion + 2 hours to any CLA following a 60 n.m. flyby.

2. DPS burn at pericynthion + 2 hours to any CLA following a 60 n.m. flyby.

B. Non-Time Critical

1. SPS or RCS at earliest practical time before MCC 5 (about TEI + 15 hours avoiding sphere of influence) to the prime CLA as fast as practical. (See Notes I and III)

2. DPS or RCS at earliest practical time before MCC 5 (about TEI + 15 hours avoiding sphere of influence) to the prime CLA as fast as practical. (See Notes I and III)

NOTE I : There is an important real time judgment factor influencing the non-critical abort techniques trading off reduced return time vs. large maneuvers which may modify the priorities.

NOTE II : The LM is jettisoned only in the case of Category I, time critical, SPS direct return aborts.

NOTE III : Normal return velocities shall be limited to less than 36,323 fps. Time critical aborts must provide entry velocities of less than 37,500 fps.

[illegible] C' MISSION TECHNIQUES DOCUMENT."

F and G MISSION TECHNIQUES MEETING

Building 4; Room 378 January 27 - 30, 1969

AGENDA

The first three days will be devoted to everything - nominal and contingency - except the lunar orbit activities. The discussion will be more or less in the sequence listed below. Of course, Items 1 through 8 will be based on the Mission Techniques prepared for C' and the actual experience gained during the flight. In fact, we shall use C' documentation with change pages, where available, to help guide the discussion. We will proceed as fast as we can with no particular goal set for each day - except to finish items 1 through 8 during the first three days. Hopefully we'll be able to put most of this part in the freezer after this bash since we start from such a good foundation in C'. "Lunar Orbit Operation" (Item 9) will be the sole subject of January 30 and we'll be lucky to finish it. Furthermore, it would be truly naive to think we won't have to get together again on that complex sequence of operations. Unique G operations (Descent, Descent Aborts, Lunar Surface, and Ascent) will be worked later in separate meetings.

1. <u>Earth Orbit</u>

   IU, GNCS, and SCS monitoring and performance evaluation

2. <u>TLI</u>

   Preparation for TLI and burn monitoring - Maneuver "Preparation" here and under later items includes such things as:

   a. Targeting (when sent and based on what?)

   b. State vector updating

   c. REFSMMATS

   d. Pad data formats

   e. Burn attitude checks

3. <u>Translunar Coast</u>

   a. Midcourse correction scheduling and targeting

   b. Cis-lunar navigation

   c. Abort Block Data

4. LOI 1 and 2

Preparation for LOI and burn monitoring

5. TEI

a. Lunar Orbit Block Data

b. Preparation for TEI using SPS or DPS

c. Burn monitoring

6. Transearth Coast

a. Midcourse correction scheduling

b. Cis-lunar navigation and on-board return-to-earth targeting

7. CM/SM Separation and Entry

a. Entry initialization

b. Entry monitoring and backup procedures

8. Aborts and/or Contingency Techniques

a. TLI partial burn aborts

b. Cis-lunar abort modes

c. LOI partial burn aborts

9. Lunar Orbit Operation

a. Pre-DOI LM activation and checkout

b. Lunar landmark tracking

c. Preparation for DOI and burn monitoring

d. F mission phasing and insertion burns

(1) preparation
(2) burn monitoring
(3) CSM backup procedures

e. Rendezvous (LM and CSM)

(1) System preparation and performance evaluation
(2) Navigation
(3) Maneuver targeting comparisons
(4) Burn execution and monitoring

APOLLO DATA PRIORITY COORDINATION
MEETING SCHEDULE

AS OF January 20, 1969

69-PA-T-9A

SUBJECT OF MEETING	January					February														
	27	28	29	30	31	3	4	5	6	7	10	11	12	13	14	17	18	19	20	21
F/G Earth Orbit, TLI, Trans-lunar, LOI, TEI, Trans-earth, Entry, Aborts	■	■	■																	
F/G Rendezvous				■											■					
G Lunar Surface (not EVA!)								■												
G Descent Aborts														■						
SPECIAL MEETINGS																				

■ (upper half filled) Meeting begins at 9:00 a.m.

■ (lower half filled) Meeting begins at 1:00 p.m.

Howard W. Tindall, Jr.

MSC Form 1285 (Rev. Sep 68)

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: January 15, 1969

69-PA-T-8A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: F and G Lunar Orbital operations - mostly pre-DOI LM activation stuff

On January 10 we had an F and G Mission Techniques meeting dealing mostly with Lunar Orbital operations, which I would like to record with this thing.

In our continuing effort to figure out the best way to minimize the DOI day timeline, I think we have finally converged on the best basic procedure for getting the LM checked out. As usual we went over the three most popular ways proposed - namely:

a. All at one time on DOI day

b. Two work periods - one prior to LOI and one on DOI day

c. Two work periods - one on DOI day and one after LOI_2

We finally selected the last of these, basically by the process of elimination. Trying to do everything on DOI day not only lengthens that day by at least one hour but it also sets up a situation which is completely intolerant of even the most minor trouble as the crew goes through the process of manning, powering up, and checking out the LM. And, it should be emphasized that although it may be possible in real time to slip DOI a revolution, it will be by no means a simple procedure to get all squared away again in preparation for the most complex operation we have ever attempted in flight. What I am trying to say is that we want to avoid perturbing the timeline around DOI at almost any cost and, splitting up the LM preparation into two periods helps to do this.

Having accepted the two period technique, the question remains - where to put the first period? Although the pre-LOI period of checkout was attractive for a number of reasons, it seemed to us questionable in terms on what it might do to the spacecraft thermal situation and more seriously to what might happen to the LM steerable S-band antenna if it were unstowed prior to the big SPS LOI maneuvers. Except for the fact that this time period provides continuous MSFN coverage, all other advantages are also obtainable if we schedule this activity after LOI_2. The thing we like about putting a two or three hour checkout period after LOI_2 and before the crew rest period is that it provides an opportunity for the crew to get the LM squared away - that is, things stowed and other housekeeping chores done before DOI day. It also provides an opportunity to add an additional activity which might be discovered during the D mission or as a result of continued detailed planning of the F and G missions without perturbing the complicated pre-DOI timeline. (It also provides a place to stick in some F unique DTO's.) Of course, this checkout period is much more tolerant of problems than DOI day. For example, it can be extended although at the cost of some crew rest. And, perhaps more important, will provide more time for the MCC-H to evaluate and digest the checkout data. Charlie Duke is going to head a tiger team mostly composed of FCD and FCSD people to develop a detailed timeline for LM preparation including all those systems tests considered essential and no more than that. They will integrate these into the total timeline which includes the crew suiting and eating and all of the other LM activation activity as well as the CSM landmark tracking which now consists of only one tracking time period.

We will review the results of their work at a later Mission Techniques meeting so that everyone in the world can criticize it and finally bless it.

In addition to that one big item there were a pot full of little things we discussed and resolved as follows:

a. There is a minor difference of opinion between the F and G crew as to whether the landmark tracking should be done in the pitch or roll mode. John Young, who favored the pitch mode, is going to try out the other technique in an attempt to resolve this.

b. Most of us have pretty well agreed that docked AOT IMU alignments are expensive to do and are not necessary. Accordingly, we now propose to use the same procedure as D for docked LM alignments referenced to the CSM platform using the known relative orientation of the CSM and LM navigation bases. This does mean that an accurate LM IMU gyro drift check can not be made although we expect it will be good enough for a go/no go of the system. Just how good it is will depend on how stable the relative orientation of the navigation bases is over a two hour period. We must get this information from ASPO as soon as possible.

c. Prior to and during DOI we want the LM radar turned on to check it out and if necessary to verify PGNCS performance of the DOI burn. After that the rendezvous radar may be turned off since there appears to be no strong requirement for its use until after the phasing burn on the F mission or until about five minutes before powered descent on the G mission.

d. In lieu of some other positive proposal we stated that the DPS would be separated from the ascent stage 10 minutes prior to the insertion maneuver by executing a 2 fps horizontal retrograde RCS burn. AGS control will probably be used for that.

e. It has been stated that there is very little difference in the accuracy of the results obtained using the sextant rather than the scanning telescope for landmark tracking therefore until C' it was proposed to use the telescope because acquisition and tracking was expected to be easier. However, the C' crew informs us that it is actually easier to track a given lunar feature using the sextant once it is acquired and so that is what will be done on the F and G flights.

f. Since there seems to be time available following LOI for the CMP to get some practice landmark tracking, it will be included in the timeline. Of course, the actual landing site will be in darkness then so some other feature located to the east must be used instead. It is our intention to select a landmark which will be at a 3 degree sun elevation angle on a nominal mission since this experience would give us a little more confidence of tracking at a low sun elevation angle. This benefit is not important enough, however, to make any real time change in the landmark to be used like we were prepared to do on C'.

Howard W. Tindall, Jr.

Enclosure
List of Attendees

FA:HWTindall, Jr.:js

F MISSION LM CHECKOUT
ATTENDEE LIST

H. W. Tindall, Jr.	FM	E. B. Pippert	CF
R. J. Carr	FM	T. R. Lindsey	CF
D. D. DeAtkine	FM	L. J. Riche	CF
K. Henley	FM/MR	C. O. Lewis	CF
G. Michos	FM/GAEC	E. E. Aldrin, Jr.	CB
R. C. Wadle	FM	E. A. Cernan	CB
M. Alexander	FM	J. W. Young	CB
R. D. Duncan	FM	T. P. Stafford	CB
R. T. Savely	FM	C. M. Duke	CB
R. D. Nelson	FM	N. A. Armstrong	CB
F. V. Bennett	FM	B. D. Pinkston	TRW
C. A. Graves	FM	W. G. Marley	TRW
G. S. Lunney	FC	C. R. Skillern	TRW
P. Shaffer	FC	J. W. Wright	TRW
T. E. Weichel	FC	J. R. Scott	TRW
C. F. Deiterich	FC	J. H. Pass	TRW
K. W. Russell	FC	J. R. Owen	TRW
S. G. Paules	FC	C. R. Hunt	TRW
J. B. Craven	FC	V. W. Simmons	TRW
G. C. Watros	FC	E. C. Howell	TRW
M. L. Windler	FC	G. M. Kingsley	GAEC

Enclosure

APOLLO DATA PRIORITY COORDINATION

MEETING SCHEDULE

AS OF January 14, 196[illegible]

6[illegible]-IA-T-7A

SUBJECT OF MEETING	January										February									
	[illegible]	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	6	7	[illegible]	11	[illegible]	13	14
[illegible]			■																	
[illegible] Orbit, TLI,						■	■	■												
[illegible], LOI, TEI,																				
[illegible], Entry																				
[illegible]									■											■
[illegible]				■																
[illegible]													■							
SPECIAL MEETINGS																				

[illegible]

[illegible]

[illegible] W. [illegible], Jr.

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: January [illegible], 19[illegible]

[illegible]-PA-T-[illegible]

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: D Rendezvous Mission Techniques

The final review of the D Rendezvous Mission Techniques will be held on Wednesday, January [illegible], starting at 9:00 a.m., in Room 333, Building 4.

We intend to go through the subject document, a copy of which you were sent in late December, 19[illegible], to make sure everyone understands and agrees to what it says or to settle on necessary additions, deletions, and modifications to make it right. Based on this discussion, it will be revised and redistributed in final form.

At this same meeting we will review the D Mission Maneuver Monitoring Techniques based on a draft to be distributed at that time with the same objectives noted above for the rendezvous.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:[illegible]

UNITED STATES GOVERNMENT

Memorandum

TO : See list below

DATE: January 14, 1969

69-PA-T-5A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Procedures for LM aborts immediately after landing are terrible!

Clarke Hackler of Guidance and Control Division uncovered a rather alarming situation which we've discussed a little at our Descent Abort Mission Techniques meetings. He briefly states the problem quite nicely in the attached memo, which I thought should be brought to your attention.

The four switch settings involving three switches which Clarke refers to are:

a. The ENG STOP switch is set at probe contact.

b. The ENG ARM switch is placed from the DES to OFF position.

c. The ENG STOP switch is reset.

d. The ABORT STAGE switch is set (after raising a plastic overlay).

Howard W. Tindall, Jr.

Enclosure

Addressees:
PA/G. M. Low
C. H. Bolender
FA/C. C. Kraft
FC/E. F. Kranz
CB/N. A. Armstrong

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

TO : CF/Chief, [illegible] Support Division
PD/Chief, Systems Engineering Division

DATE: DEC 3 0 1968

FROM : EG/Deputy Chief, Guidance and Control Division

SUBJECT: Crew operational procedures during [illegible] abort (Like the LM legs break at time of landing impact)

A review [illegible] that the crew [illegible] go through [illegible] procedure to Abort St[illegible]. [illegible] separate actions, in proper sequence, [illegible] taken to [illegible] ascent engine. [illegible] separate switches, [illegible] in three different locations, [illegible] in abort stage. This appears to [illegible] large number of actions and switches to be concerned with during a time critical period.

A description of our understanding of [illegible] system works [illegible] in the enclosure to this memorandum. [illegible], the primary [illegible] the large number of actions and switches involved in ascent engine ignition stem from two basic factors: (1) The computer engine [illegible] crete is not reset until the crew calls P[illegible], the Landing Confirm Program, and (2) the ABORT STAGE switch, which normally overrides the ENGINE ARM switch, is disabled through the ENGINE STOP switch when [illegible] STOP switch is in the set position (which it is after the crew stops the DPS)

From an operational viewpoint, we believe the number of actions and switches should be reduced to assure a better chance of executing a safe lunar surface abort. Procedurally, it would seem that the crew should be required to make only one action following shutdown of the descent engine in the event of an abort decision—that [illegible] the ABORT STAGE switch. This could be made possible by [illegible] ENGINE STOP switch circuitry breakpoint in the abort stage wiring [illegible].

No further action on this matter will be taken in [illegible] Guidance and Control Division. At your request, we will [illegible] rate on the [illegible] fix suggested above. Please contact Mr. [illegible] Ha[illegible] at [illegible].

Robert G. Chilton

Enclosure

cc:
[illegible]/R. A. Gardiner
CB/C. Conrad
FM/H. Tindall
FM[illegible]/F. Bennett

EG[illegible]:[illegible] 12/[illegible]/68

Enclosure

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: January 14, 1969

69-PA-T-4A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: F and G cis-lunar midcourse correction scheduling

This memo is to make sure everyone is aware that we are scheduling the final midcourse corrections before LOI and Entry differently than on C'.

The final translunar midcourse correction shall be scheduled at LOI - 5 hours since that provides optimum midcourse correction effectiveness and confidence in subsequent MSFN tracking for LOI targeting. You recall on C' this maneuver was at LOI - 8 in order to provide a longer crew rest period after that. This is not required on the F and G missions at this time.

The basic criteria for selecting EI - 2 hours as a last transearth midcourse correction was to make it as late as possible while still providing adequate MSFN tracking for entry initialization. On the C' mission it was found that although two hours is adequate, an additional hour would be advantageous. Since there appears to be no disadvantage to moving this maneuver one hour earlier to EI - 3 hours we propose to do so. One associated item North American is going to check out is with regard to the effect of this on the RCS quads. There is a slim possibility that this schedule may present a thermal problem.

I would like to emphasize that the intermediate cis-lunar midcourse correction schedule is not based on trajectory considerations but rather will be selected to fit most conveniently in the crew work/rest cycle just as it was done on C'. Accordingly, the scheduling of these maneuvers must await development of the flight plan after which they will be shuffled in at the most convenient times.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: January 14, 1969

69-PA-T-3A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Operations required for communication loss on F and G are sure better than on C'

I think we have pretty well established how to handle a communication loss situation on the F and G missions. In effect, we have defined which Block data must be sent and what onboard cis-lunar navigation needs to be carried out. In both cases, of course, it is possible to cut back substantially from the C' techniques. This is because we feel it is reasonable to assume that the LM provides a "perfect" backup for the CSM communications.

BLOCK DATA

We established a ground rule that it is only necessary to send Block data for abort situations when either the LM is not available or if sufficient time to use the LM is not available. Following is a table of all the Block data transmissions planned for F and G giving the time of transmission for the abort opportunity which it would be used for:

Time of Transmission	Time of Abort Maneuver
During earth orbit	TLI + 90 minutes. CSM only, direct return
LOI - 15	PC + 2 for fast return following flyby
Pre LOI_1	$TEI_{1 \& 2}$ assuming perfect LOI_1
Pre LOI_2	TEI_2 Update and TEI_3 assuming no LOI_2
Post LOI	For TEI after sleep
Pre LM Jettison	TEI 6 revs from jettison
After LM Jettison	C' rev by rev technique except during sleep

In addition, remember the crew has the capability of using the GNCS (P37) to compute their own return-to-earth maneuvers in the event of a communication loss. In order to simplify the crew's procedures, we intend to transmit a small amount of additional information for use a first guess in the operation of P37. Specifically MCC-H will periodically send the crew values of the landing area (CLA), the maneuver magnitude (ΔV), and the burn ignition time (TIG) for possible future abort times.

CIS-LUNAR NAVIGATION

As you recall on C', the onboard capability for cis-lunar navigation using P23 was thoroughly exercised and proven to be an excellent system. Furthermore, it appears that Jim Lovell was able to do his job just about as well in the beginning as he was later in the mission, indicating that inflight training is not particularly necessary. Based on this experience, only two batches of P23 star/earth horizon navigation sightings shall be scheduled on the entire F and G flights. In order to get the most from these two periods, one should be scheduled before TLI + 5 hours and the other after TLI + 14 hours, if it is convenient to do so. The advantage of making the first batch that early is that it will permit the MCC-H to make an accurate determination of the actual horizon altitude the CMP is using in order to update the CMC in real time just as we did on C'. To do this it is necessary that the observations be made in altitude less than 50,000 n.m. and preferably lower than 35,000, which is the altitude at TLI + 5 hours. I would like to point out that the horizon Jim Lovell used so successfully was sort of a nebulous one of his choice and was not well defined making it unreliable to use the "C'" horizon altitude for the F and G missions. Although not disasterous, a good knowledge of the horizon substantially improves navigation prior to entry which is when it is most important in the event of communication loss. Whatever that is.

Recognize that implicit in this plan of scheduling only two batches of observations early in the translunar coast is that there can be no independent onboard confirmation of the MSFN navigation which was considered so important to insure that we miss the moon on C'.

Math Physics Branch of MPAD has been requested to develop a P23 tracking schedule to be used for transearth navigation in the event of no communication. This schedule will be included in the Flight Plan labeled "loss of communication contingency."

As you recall, the primary purpose of onboard navigation during transearth coast was for conditioning the W-matrix. We have selected a procedure for F and G which makes it possible to eliminate that operation. Specifically, we have concluded that a crossover point exists at 30 hours before entry, which has the following characteristics. If communication has been lost prior to that time, the onboard system is capable of providing acceptable navigation, maneuver targeting, and entry initialization starting from scratch with no special W-matrix conditioning. (The flight path angle error at entry should be no greater than 0.5° under the worse conditions.) In addition, it has been shown that the MSFN will be sufficiently accurate at EI - 30 hours that in the event of subsequent communication loss there is no need to perform onboard navigation but rather the crew may safely return to earth using the data supplied for that purpose at EI - 30 by the MCC-H. In other words, the same procedure used on C' at EI - 15 will be carried out on F and G at EI - 30. Namely, spacecraft state vectors will be updated and the crew will be provided with midcourse maneuver targeting and entry pad data needed to complete the mission without further communication.

In summary, F and G operations associated with communication loss are being considerably simplified from those used on C'. Utilization of LM communications makes it possible to markly reduce the number of short Block data pad messages; the onboard and MSFN navigation performance experienced on C' permits us to reduce onboard navigation to a total of only two batches of star/horizon observations. No special procedures are required for W-matrix initialization. I'd call that a giant step in the right direction!

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: January 10, 1969

69-PA-T-2A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some decisions regarding lunar landmark tracking on the F and G missions

We had an Ad Hoc Mission Techniques meeting on January 9 to talk over lunar landmark tracking. In particular, we wanted to discuss what we thought had been learned from the C' mission and what we want to do on the F and G missions. This memo is to outline all that briefly. The specific things we were trying to decide were:

a. Whether special tests of any sort should be included on the F mission which might permit us to broaden the acceptable sun elevation angle constraints associated with the lunar landing and

b. To decide if optical observations (SCT or SXT) of the landing site are required on DOI day for descent targeting and if so how many, when should they be taken, and how should they be used?

Jack Schmitt has probed extensively into the landing sun elevation angle constraints problem both before and after C' and probably has a better understanding of this overall situation than anyone else I know. He has intensely debriefed all of the C' crewman on this specific subject and is confident that the visibility will be acceptable for landing if the sun elevation angle is no less than about 3 or 4 degrees. The upper constraint he feels is in excess of 20 degrees and the actual limit will probably be based on heating considerations on the spacecraft or the crew during EVA rather than visibility during descent (we'll find out what that limit is). In other words, it looks like we have a sufficiently wide band of acceptable sun elevation angles that this imposes no real constraint on G launch opportunities! Furthermore, there appears to be no reason to provide special tests on F designed to broadened these limits or give us greater confidence in them. One interesting point he emphasizes, though, is that we should avoid landing with a glide path within about 2 degrees of the sun elevation angle since there is a definite degradation in visibility along that line which would impair the crew's capability of evaluating the landing site. This means that we should avoid sun elevation angles between about 14 and 18 degrees - a little band of unacceptable lighting conditions within the much larger acceptable limits. He feels that this band may be avoided in the few instances we encounter it by delaying launch somewhat or by adding an extra revolution or two in lunar orbit. It is also evident that by the use of the hybrid flight plan we can extend the translunar coast time with the same effect.

In summary, it appears that the sun elevation angle constraint on G mission launch opportunities is not significant at this time and there is no need to provide special tests on F to confirm this opinion.

The question of optical tracking of the landing site is not so clearly understood. However, [illegible] it would be a serious mistake at this time for the [illegible] not to include optical observations of the landing site [illegible] targeting operations. [illegible] located and track [illegible] the landmark on their first opportunity [illegible] to be no reason not to eliminate the first [illegible] of [illegible] tracking, which we [illegible] previously included primarily for [illegible] training. Accordingly, we intend [illegible] the [illegible] ground targeting operations previously developed in our [illegible] techniques meeting except that the first of the two tracking [illegible] will be deleted or moved to LOI [illegible] in the timeline. [illegible] will be [illegible] located [illegible] or 1. [illegible] session would [illegible] to [illegible] of the landing [illegible].

[illegible] optical [illegible] important [illegible] of course, [illegible] which will [illegible] also [illegible] or the [illegible] confirms [illegible] or [illegible]

Our discussions included [illegible] performance [illegible] requirements [illegible] However [illegible] support the [illegible] I left them out [illegible] simply because it is too [illegible] to discuss [illegible]

Howard W. Tindall, Jr.

[illegible]

orbit. It is also evident that by the use of the hybrid flight plan we can extend the translunar coast time with the same effect.

In summary, it appears that the sun elevation angle constraint on G mission launch opportunities is not significant at this time and there is no need to provide special tests or P to confirm this opinion.

The question of optical [illegible] is not [illegible] clearly understood. [illegible]

[illegible]

[illegible]

Howard W. Tindall, Jr.

[illegible]

[illegible]

[illegible] D. E. Clayton

CF/A. F. Shepard ([illegible])

CF/W. J. North

CF[illegible] D. F. Grimm

CF[illegible]/C. Jacobsen

CF[illegible] W. Haufler

CF[illegible] Hinton

CF[illegible] J. Bilodeau

CF[illegible]/C. C. Thomas

CF[illegible]/I. L. Bentley

CF[illegible]/R. L. [illegible]

CF[illegible]/M. C. Gremillion

CF[illegible] Kramer

CF[illegible] J. [illegible]

CF[illegible] M. C. Costello

CF[illegible] Lewis

CF[illegible] D. K. Morel

CF[illegible] C. H. Woodlin

CF[illegible] J. J. Van Bockel

CF[illegible] M. F. Griffin

CF[illegible]/M. Brown

CF[illegible]/C. Nelson

CF[illegible] Flippen

CF[illegible] Holloway

[illegible] J. W. [illegible]

[illegible] G. Colton

[illegible] M. A. Faget

[illegible] J. F. Lee

[illegible]/J. Chamberlin

[illegible] I. M. Deane

EE[illegible] I. Vavra

EE/L. Packham

EE/R. Sawyer

EE13/M. J. Kingsley

EE13/R. G. Irvin

EE[illegible]/R. L. Chicoine

EE[illegible]/G. E. Gibson

EE[illegible]/R. G. Fenner

EE[illegible]/J. R. McCown

EG/R. A. Gardiner

EG/R. C. Cheatham

EG[illegible]/M. Kayton

EG[illegible]/C. T. Hackler

EG[illegible]/K. J. Cox

EG[illegible]/E. E. Smith

EG[illegible]/T. V. Chambers

EG[illegible]/I. E. Ebersole

EG[illegible]/W. J. Klinar

EG[illegible]/H. E. Smith

EG[illegible]/J. Hanaway

[illegible]/R. Reina

[illegible] Turley

EG[illegible] C. W. Frasier

EG-MIT/T. Lawton

HA/R. F. Thompson

[illegible]

IA/C. H. Bolender

PA/K. S. Kleinknecht

PA/M. S. Henderson

PP/A. Hoboken

FC/W. T. Gray

PD/O. E. Maynard

[illegible]/C. D. Perrine

PD/R. V. Battey

PD[illegible]/J. G. Turnock

PD[illegible] L. J. [illegible]

PD[illegible]/R. [illegible]

PD[illegible]/M. R. von Ehrenfried

[illegible]

[illegible]

[illegible]

[illegible] J. [illegible]

[illegible]

[illegible]

[illegible]

CO[illegible] J. [illegible]

FA/C. C. Kraft, Jr.

FA[illegible]

F[illegible]

FA[illegible]

F[illegible]

FC[illegible] F. Kern

FC/M. F. Franz

FC/G. S. Lunney

FC/C. F. Charlesworth

FC/M. Windler

FC[illegible]/C. [illegible]

FC[illegible] H. M. Hutchinson

FC[illegible] J. H. Temple

FC[illegible]/C. S. Lewis

FC[illegible]/W. E. Platt ([illegible])

FC[illegible] Aldrich

FC[illegible] N. [illegible] Hutchinson

FC[illegible] Willoughby ([illegible])

FC[illegible]/J. E. Hannigan

FC[illegible]/R. L. Carlton ([illegible])

FC[illegible]/J. C. Bostick

FC[illegible]/T. C. Sheffield

FC[illegible]/J. S. Llewellyn

FC[illegible]/C. F. Deiterich

FC[illegible]/J. E. I'Anson

FC[illegible]/E. L. Pavelka ([illegible])

FC[illegible]/C. R. Parker ([illegible])

FC[illegible]/H. G. Miller ([illegible])

FL/J. B. Hammack

FM/L. C. Dunseith

FC/J. C. Stokes ([illegible])

FM/J. P. Mayer

FM/C. R. Huss

FM/[illegible] H. Owen

FM/[illegible] F. Parten ([illegible])

FM/C. A. Graves ([illegible])

FM5/[illegible]

FM4/[illegible] ([illegible])

FM4/R. E. Savely

FM4/W. R. Wollenhaupt

FM[illegible]/R. E. Ernull

FM[illegible]/H. D. Beck

FM[illegible]/K. A. Young ([illegible])

FM[illegible]/R. W. Becker ([illegible])

FM[illegible]/R. S. Merriam

FM7/S. P. Mann

FM7/R. O. Nobles

FM7/R. H. Brown

FM/Branch Chiefs

[illegible] L. Allen ([illegible])

[illegible]

[illegible]

Bellcomm/H[illegible]/A. V. [illegible]

Bellcomm/H[illegible]/J. [illegible]

Bellcomm/H[illegible] Corey

Bellcomm/Hdq./MAO/A. Merritt

GAEC/Bethpage/M. Pollack

GAEC/Bethpage/J. Marino ([illegible])

GAEC/Bethpage/R. Mancuill

GAEC/Bethpage/[illegible] Pratt

GAEC/Bethpage/Cognizant Pilot's [illegible]

GAEC/Bethpage/R. Pratt

MIT/IL/R. R. Ragan ([illegible])

MIT/IL/E. Copps

MIT/IL/M. W. Johnston, IL [illegible]

NR/Downey/M. Vucelic, FB[illegible]

NR/Downey/R. Zermuehlen, FB[illegible]

NR/Downey/J. F. Roberts, FB[illegible]

NR/Downey/[illegible] C. Johnson ([illegible]), AE[illegible]

NR/Downey/W. H. Markarin, FB[illegible]

NR/Downey/E. Dimitruk, FB[illegible]

NR/Downey/J. E. McIntyre, FB[illegible]

GSFC/[illegible]/F. O. Vonbun

GSFC/[illegible]/E. Kimmer

NASA/Hdq./MAO/E. P. Sheridan

NASA/Hdq./MAOI/F. O. Allen ([illegible])

TRW/Redondo Beach/R. Braslau

TRW/Houston/W. J. Klenk

TRW/Houston/D. J. Gordon

TRW/Houston/R. J. Boudreau

TRW/Houston/M. Fox

TRW/Houston/K. L. Baker

OPTIONAL FORM NO. 10
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UNITED STATES GOVERNMENT

Memorandum

TO : FL/Chief, Landing and Recovery Division

DATE: January 7, 1969

69-PA-T-1A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Let's move the recovery force a little

Jerry, I've done a lot of joking about the spacecraft hitting the aircraft carrier, but the more I think about it the less I feel it is a joke. There are reports that the C Prime command module came down right over the aircraft carrier and drifted on its chutes to land 5,000 yards away. This really strikes me as being too close. In other words, I realize the probability of the spacecraft hitting the aircraft carrier is very low but there is absolutely no advantage in having the ship within five or ten miles of the aim point - with the possible exception of the PAO requirements for good commercial TV. It certainly does not improve the recovery operations at all. And, the consequence of the spacecraft hitting the carrier is truly catastrophic.

In summary, I seriously recommend relocating the recovery force at least five or ten miles from the target point.

Howard W. Tindall, Jr.

cc:
PA/G. M. Low
PA/C. C. Kraft, Jr.

PA:HWTindall, Jr.:[illegible]