Foreword

The enclosed collection of memoranda were written by Howard W. "Bill" Tindall, Jr., the former Director of Flight Operations at NASA's Manned Spacecraft Center in Houston. They document key technical decisions made between 1966 and early 1970 for all unmanned and manned flights through Apollo 13, and became widely know as "Tindallgrams." Astronauts, flight controllers, and engineers took part in this planning, and many have lamented that they had lost track of their copies, so we have bound this set together for them. As Buzz Aldrin remembered, "Bill had a brilliant way of analyzing things and the leadership that gathered diverse points of view with the utmost fairness."

In 1966, Apollo Spacecraft Program Manager George Low made Tindall responsible for all guidance and navigation computer software development by the Massachusetts Institute of Technology. Bill quickly grasped the key issues and clearly characterized the associated pros and cons, sometimes painfully for us, but his humor, friendliness, and ever-constructive manner endeared him to all of us.

In 1967, Low put Tindall in charge of a group called Mission Techniques, which was designed to bring together hardware development, flight crew procedures, mission rules, and spacecraft and control center computer programming. According to former MSC Director Christopher Kraft, "Those meetings were the hardened core of Apollo as far as operations planning was concerned. That's where the famous Tindallgrams came from." He continued, "It would be difficult for me to find anyone who contributed more individually to the success of Apollo than Bill Tindall."

Those of us who took part in those meetings and other interactions with Bill will always appreciate another aspect of his contribution. . . he made it a lot of fun!

May 31, 1996
Malcolm Johnston
The Charles Stark Draper Laboratory, Inc.,
Formerly the MIT Instrumentation Laboratory

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OPTIONAL FORM NO. 10
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UNITED STATES GOVERNMENT

Memorandum

RECEIVED
JUN 30 19
R. R. RAGAN

TO : See list below

DATE: MAY 12 1966

FROM : FM1/Assistant Chief, Mission Planning and Analysis Division

66-FM1-59

SUBJECT: Spacecraft computer program requirements for AS-207/208, AS-503, and AS-504

On May 13 and 14, 1966, a flock of MSC people met with MIT people in Boston to discuss the spacecraft computer program requirements for missions AS-207/208, AS-503, and AS-504. This memorandum is probably one of several on the subject you will be getting in the near future. My main purpose is to describe the situation as it exists on these important programs; it is not altogether a happy one.

Our basic problem seems to center on the time available to prepare the computer programs for these flights and on the fact that the computer is not big enough to contain all of the programs which appear to be either required or highly desirable for the mission. According to MIT estimates, the programs which had been identified as needed for the CSM on the AS-504 mission are in the order of 15,000 words in excess of the 36,000 word computer. The LEM computer storage capacity was exceeded by about 6,000 words for the LORS configuration and 4,500 words for the radar configuration.

Since we have assumed a basic ground rule that no routines would be included in the AS-207/208 programs which are not in the AS-504 program, our first task was to reduce the AS-504 program requirements to a point where the CSM and LEM programs would fit within the computer storage available. After doing this, we went through the AS-504 programs and determined which processors could be omitted from the AS-207/208 programs if the overall schedule situation would be improved by their deletion. Accordingly, our task at this meeting was to identify the lower priority routines with an understanding that no further work would be done on them and they would not be included in the computer programs for the AS-207/208, AS-503, and AS-504 flights. It was evident from the start that there were very few programs which could be easily deleted. In fact, it was a very painful process. For the most part, "requirements" could only be dropped at some cost in probability of mission success or by putting a greater workload on the crew or reliance on ground support. We did adopt a basic ground rule that obviously flight crew safety could not be impaired.

We were successful in our task to the extent that the program requirements were reduced to a point wherein a reasonable chance of their fitting into the computer storage was assured. In addition, we identified the next computer routines which would be deleted in the event storage was ultimately exceeded, forcing the removal of more routines. I would like to list a few of the programs which were deleted to give you a feel for the situation. For example, the following routines were removed from the command module computer program:

1. Concentric flight plan routines, which provide an onboard capability for computing the first two maneuvers of the coelliptic flight plan, setting up proper initial conditions for terminal phase, were deleted. Since flight crew safety is implicit in the rendezvous capability, we (MPAD) have accepted a task of identifying the various failure situations in which the command module must rescue the LEM to assure ourselves that this capability will still exist with these programs not available to the crew. This is not certain at this time.

2. Programs used for computing attitude maneuvers were deleted. These programs were used in the guidance system for automatically making minimum fuel attitude change maneuvers while avoiding gimbal lock. It is obvious that these routines would be used even in a nominal mission, but it is felt the pilot could do the job instead of the computer, although probably at some extra cost in our precious RCS fuel.

3. It was identified that deletion of the capability to take over launch guidance of the S-II and/or S-IVB stages of the Saturn by the command module guidance system would considerably relieve our computer storage problem. However, it has been directed by NASA Headquarters that this capability be provided. Accordingly, steps are being taken within MSC in an attempt to relieve this Headquarters requirement, which is primarily one of improving probability of mission success with indirect and hopeful acceptable implications on flight crew safety.

4. Programs were being supplied to enable guidance system to execute maneuvers necessary for inserting the spacecraft into orbit or for landing in a preselected launch abort area by use of a spacecraft SPS maneuver in the event of a late launch abort. These routines, which were originally scheduled for AS-204 but were deleted from that flight due to schedule problems, were also deleted from the AS-504 program. This is more serious, however, since ground support of Saturn V aborts is more limited than for the 200 series missions.

5. Several other actions were taken to relieve the storage problems, such as deleting some programs from the flight ropes which support preflight pad tests. (It is not intended to delete the tests but rather to support them in another way.) In addition, action designed to streamline the program was initiated.

6. Identified as the next programs to be deleted, if it turns out to be necessary, are the stored star catalog and the automatic star selection routines which the pilot would use routinely even during a nominal mission for platform alignment. Deletion of these routines would

force manual selection of which stars to use for this purpose and would require that their characteristics be manually keyed into the computer.

It is evident that the above programs would be extremely valuable during the lunar and AS-207 rendezvous missions, and the necessity of deleting these programs is probably the best indication of how critical the computer storage problem is.

Deletions in the LEM program were similar. It was interesting to note that the LORS configuration requires about 1,500 more storage locations than the radar. Thus, if the radar wins the guidance system olympics, we will recover this nice bonus. Generally speaking, however, it appeared that the computer storage problem was more severe on the command module computer than on the LEM at this date.

I would like to include a couple of remarks here regarding the programs for the AS-207/208 mission. Since it is intended to use only AS-504 programs and since it is possible to fly the AS-207/208 mission with a number of the CSM AS-504 programs omitted, by definition we do not have a storage problem for that mission. Our problem here--and it is a serious one--is that MIT maintains that we are considerably behind schedule. Although we intend to initiate action designed to improve this situation, it has been recommended by MIT that a number of the AS-504 programs be deleted which are not essential for the AS-207/208 mission. Some of us at MSC are concerned that, although this may improve the schedule situation for AS-207/208, it may damage the schedule for AS-504, which is probably even more undesirable. Accordingly, we intend to review very carefully the overall schedule situation before any of the AS-504 programs are omitted from the AS-207/208 programs. At the very least, it is intended that all internal program interfaces be provided to insure the maximum similarity between the AS-207/208 and AS-504 programs. In fact, it may even prove desirable to substitute dummy programs for each of those deleted from the AS-504 program. MIT was in complete accord with us on this matter.

MIT is still expressing concern over their ability to define, design, and implement the concentric flight plan routines in time for including them in the AS-207/208 LEM program. However, they indicated that they could continue with development of the Guidance System Operations Plan (GSOP) for the AS-207/208 with those capabilities included for at least six weeks without any schedule impact. Thereafter they feel that if they have not arrived at an acceptable solution, it may be necessary to drop these routines, which are considered mandatory by MSC, from the AS-207/208 program. I personally have every intention of making sure that they are not dropped, but there seemed to be no need to argue this point at this time since it has no influence on the current course of action.

At the conclusion of the discussions of the AS-504 programs, MIT agreed that there was nothing more MSC could do to enhance the schedule situation for the AS-504 program. That is, further deletions of the program requirements would not help in any way. This was stated and restated several times to insure that MSC would not subsequently be notified that schedules could not be met as a result of excessive demands by MSC in the area of program requirements.

Howard W. Tindall, Jr.

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FM2/R. O. Nobles

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UNITED STATES GOVERNMENT

Memorandum

RECEIVED
JUN 30 1966
R. R. RAGAN

TO : See list attached

DATE: MAY 16 1966

FROM : FM1/Assistant Chief, Mission Planning and Analysis Division

66-FM1-60

SUBJECT: Comments on the AS-207/208 Preliminary Spacecraft Reference Trajectory

TRW Systems released the AS-207/208 Preliminary Spacecraft Reference Trajectory during the first week of May. This report was put together on a compressed schedule, starting from rather hastily defined mission requirements. As a result, there are a number of things about it which were recognized as being in error even before release; however, since we have started so late in the development of this mission plan, it was felt the release of a rough cut such as this was better than to delay for a more polished one. This is not to criticize the TRW report; considering the conditions they did a good job. However, since a large number of directly concerned people were interested in learning about this mission plan in detail and since it was desirable to identify as many corrections as possible right away, I set up an informal presentation by TRW on May 11, to be attended by whoever was interested. At this meeting TRW reviewed the trajectory-oriented aspects of the AS-207/208 mission plan with primary emphasis on the four rendezvous exercises currently scheduled. The purpose of this memorandum is to document the discrepancies and open items discussed during the meeting. Assignment of action items was not the objective of this meeting and none were assigned.

I would like to start out with a personal observation about this mission: Beyond a doubt, this mission plan is presently at least an order of magnitude more complex than any mission we will have flown before it. It was designed in an attempt to satisfy an overwhelming list of mission objectives established to test out spacecraft systems and crew procedures, both for nominal and for contingency situations. It is my feeling that, unless these mission objectives can be considerably cut back, we may be embarking on an unrealistic undertaking, including the development of a nominal mission plan which can really satisfy all of these objectives, the development of complex crew procedures, both to carry out that plan and to handle contingency-contingencies, and, perhaps most significant, the dumping of an overwhelming, if not impossible, load on the flight crew, not only for preparation and training for the mission, but also its actual execution. This crew will be expected to check out the first Block II CSM, man and check out a LEM for the first time, perform three or four completely different rendezvous exercises with different guidance systems and procedures, carry out two EVA exercises, perform a number of contingency operations, such as switching over from one guidance system to another during primary engine burns, simulate crew rescue in terms of both rendezvous and crew transfer from one spacecraft to another by EVA, and so forth. It is to be noted that all of this is supposed to be done with spacecraft which have been designed for a specific mission--the lunar landing. That is, they have not been developed with operational flexibility as a design criteria.

And so with that introduction, I would like to record here a number of the specific comments of this discussion:

1. CSM/S-IVB Separation: The Preliminary Spacecraft Reference Trajectory has the command module separating from the S-IVB after 1 hour and 41 minutes of mission time. We were informed that agreements currently in effect with MSFC call for the CSM to stay with the S-IVB for at least two orbits and unless there is some problem associated with this, it would probably be preferable to retain that procedure.

2. S-IVB Venting: There was some question as to how we would handle the problem of spurious S-IVB venting in the event rendezvous is not carried out at the time scheduled. Of particular concern was the possibility of venting during the latter part of the rendezvous, with the problem becoming more critical during the braking and docking maneuvers. According to the Apollo Spacecraft Program Office (ASPO), MSFC is waiting for a set of ground rules from MSC defining how the venting situation should be handled.

3. Braking Gates: Based on mission requirements established by ASPO, TRW showed a maneuver being made at the first braking gate to reduce the closing velocity to 20 ft/sec. The consensus shows that this magnitude is somewhat too low in that it tends to undesirably stretch out the terminal phase, which increases the possibility of the situation deteriorating, as well as possibly costing more fuel.

4. Priority of Mission Objectives: Repeatedly throughout the meeting we came upon situations in which mission objectives were in conflict with each other and/or were undesirable in terms of excessive consumable usage or mission complexity. Accordingly, it seems highly desirable that the ASPO review the mission objectives and assign priorities defining the relative importance of the various mission objectives in order that meaningful mission planning can be carried out both in advance of the mission and in real time.

5. Recontact: Another problem area reidentified at this meeting dealt with the possibility of recontact of the spacecraft with either of the S-IVB's or the LEM nose cone. Obviously, attention must be given to the relative motion of all the many orbiting objects associated with this mission.

6. Stroking: When and how the stroking tests are to be carried out still remains ill defined with regard to such questions as the necessary propellant loading in the LEM at the time of the test, nature of network coverage required, etc.

7. Crew Rest: Ground rules associated with the crew rest periods, such as whether or not it is permissible or necessary that all crew members do sleep or do not sleep at the same time, has a heavy impact on the scheduling of the various activities. Accordingly, it is necessary that ground rules associated with crew rest be established at the earliest possible time.

8. CSM/LEM Separation for Re-rendezvous: In each of the re-rendezvous exercises, TRW included a considerable period of time between actual disconnection of the two spacecraft and the time at which the first major maneuver is made to establish the desired conditions for carrying out the terminal phase of each of the re-rendezvouses. It was agreed that the procedure TRW had included in the Preliminary Reference Trajectory seemed as good as any; however, prior to development of the follow-on documentation, it seems advisable to give further consideration to how we actually want to set up this procedure.

9. Minimum SPS Maneuver: A rather lengthy, but inconclusive, discussion centered on defining the minimum SPS maneuver which could be carried out. This has particular influence on RCS propellant usage in that the larger this minimum SPS maneuver is set, the more likely it will be necessary to carry out maneuvers with the RCS. On the other hand, it was noted that the capability of controlling the SPS engines for these small maneuvers leaves something to be desired in that large residual tumbling rates can result if the SPS thrust vector is not directed through the spacecraft c.g. and sufficient time is not given for the guidance system to compensate for it. RCS fuel would then be required to stop the rates.

10. Extra-vehicular Activity (EVA): The situation regarding EVA is still badly clouded. This is the case in terms of how many EVA exercises should be carried out, when they should be scheduled in the mission, whether the spacecraft should be docked or undocked, and, in fact, even includes what appears to be a need for re-evaluating the associated mission objectives. One thing that was clear, however, was that not enough time had been included for these exercises. TRW had provided about $1\frac{1}{2}$ hours, whereas the Flight Crew Support Division (FCSD) feels that 4 to 5 hours would be a more accurate estimate. It was also noted that, as scheduled by TRW, ground coverage was inadequate particularly considering the fact that this will be the first EVA carried out in the Apollo Program.

11. Spacecraft Guidance Switchover: Mission objectives have been established which call for switchover from the primary to the backup

LEM guidance system during powered maneuvers. In order to provide maneuvers of sufficient magnitude to evaluate this procedure, it was necessary to orient them such that much of the energy is dissipated out-of-plane. Simultaneously, an in-plane component is provided for establishing the initial conditions for the re-rendezvous terminal phase for each of the LEM active re-rendezvous exercises. This whole activity seems highly undesirable in that it increases the complexity of the mission to a great extent, has a good chance of fouling up the re-rendezvous exercise, and presents serious operational problems. For example, the platform alignment must be in an attitude different than would be used in an actual lunar mission in order to avoid gimbal lock. In addition to perturbing the navigation carried out by the primary guidance, it presents special problems with initialization of the abort guidance system which is programmed to assume that the primary inertial reference is aligned in the orbital plane. This is one example referred to in the previous note regarding relative priorities of the various mission objectives.

12. Ground Coverage Versus Lighting: The Preliminary Reference Trajectory was prepared such that all maneuvers were scheduled to occur over ground stations to the greatest possible extent. No consideration was really given to the lighting conditions for the rendezvous. This was intentionally done since the Preliminary Reference Trajectory was needed to supply the necessary information to make reasonable trade-offs prior to preparation of the Reference Trajectory. It is obvious that there will be a direct conflict between station coverage and lighting which must be resolved prior to preparation of the Reference Trajectory. Flight crew requirements associated with this are urgently needed.

13. LEM RCS Usage: It was noted by several of the participants at this meeting that the Preliminary Reference Trajectory as presented exceeds the LEM RCS capability in that ullage is only available when the down-firing jets are used since there is no planned interconnect on this flight. Did I say that right?

14. Docked DPS Burn: There was considerable discussion regarding the LEM Descent Propulsion System (DPS) maneuver in the docked configuration. In particular, there was concern as to whether it should be carried out as scheduled early in the mission or as part of one of the re-rendezvous exercises. Although there were problems associated with both, the consensus was to leave it as scheduled; that is, one of the Hohmann transfer maneuvers to place the CSM/LEM in the 180 n.m. circular orbit prior to the first re-rendezvous exercise.

15. Fire-in-the-Hole: It appears that requirements associated with camera coverage of the FITH should be established as soon as possible.

There are undoubtedly other items I should have included here that I either missed or forgot. At least they won't make this memorandum any longer than it is.

Howard W. Tindall, Jr.

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UNITED STATES GOVERNMENT

Memorandum

RECEIVED
JUN 30 19
R. R. RAGAN

TO : FM4/Chief, Mathematical Physics Branch

DATE: MAY 27 1966

FROM : FM1/Assistant Chief, Mission Planning and Analysis Division

66-FM1-64

SUBJECT: CSM orbit determination using the LEM radar

Apparently it is planned to use the LEM radar while that spacecraft is sitting on the lunar surface to determine the CSM's orbit. I am told that the radar angle data accuracy is so poor it will not even be used; the command module's orbit determination will be carried out with range and range rate observations. Considering the extremely slow rotational rate of the moon, I cannot for the life of me understand how it will be possible to accurately determine the orientation of the command module's orbital plane. I am told they intend to do this after the command module has made a plane change, which occurs a couple of orbits before LEM ascent, and the results will be used to establish orbital insertion conditions for the LEM launch targetting.

Could you analyze the situation, determining how well the various orbital elements may be determined for the following data gathering periods: (a) one-half pass, starting from horizon to directly overhead, (b) one complete pass from horizon to horizon, and (c) two complete passes from horizon to horizon. I am also interested in being informed about the correlation of the various orbital elements; for example, orbital period and orientation of the plane.

I may have this all messed up and perhaps they do not really intend to do the things in the way I understand it, but I certainly would appreciate it if you would make a rather abbreviated, order of magnitude type, analysis of this within the next couple of weeks in order to determine whether it is even reasonable to include such a program in the LEM computer or alternatively if it must be modified to make it insensitive to small bias and random errors in the radar data. I just can't help comparing this to a single radar station on the ground where conditions are far superior and our results are not red hot.

Howard W. Tindall

Howard W. Tindall, Jr.

cc:
(See attached list)

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
JUN 30 1966
R. R. RAGAN

TO : See list attached DATE: JUN 2 1966

FROM : FM1/Assistant Chief, Mission Planning and Analysis Division 66-FM1-70

SUBJECT: Spacecraft computer program status report

Tom Gibson and I went to MIT on May 25 and 26 with one of our primary objectives to determine exactly what the program schedule situation was for the AS-504 (AS-207/208) spacecraft computer programs. Although we had a number of very fruitful discussions with MIT people, such as Ed Copps, Dick Battin, John Dahlen, and Bob Mallard, on this subject, we really did not find out what we wanted to know. However, I am very encouraged to see the enthusiasm and vigor with which Ed Copps is attacking this problem.

Ed has set June 3, 1966, as a target for getting out the first cut at a Program Development Plan, which he is anxious to talk to us about during the following week. In fact, he intends to come down then not only to talk over the program as he has put it together but also to discuss its preliminary output regarding the AS-207/208, 503, and 504 schedule situation. Tom and I concluded that it would be better to accept this delay than for us to attempt to do the job ourselves, which is for all practical purposes the same thing he is trying to do. Our main objective, of course, is to find out what the pacing items are so that maximum attention can be given to these items in an attempt to bring what is expected to be an unacceptable schedule more into line. Possible lines of attack are as follows:

1. Review and, if possible, reduce or simplify our requirements involving the pacing programs.

2. Give top priority to programmers working on those routines for computer access.

3. Authorize somewhat inefficient use of computer storage by those programmers to speed up the coding process, even at the sacrifice of deletion of other routines.

4. Reassignment of personnel to the critical areas even though inefficient.

5. Reassignment of certain tasks from people working on the critical systems to other groups, such as AC Electronics, MSC, or other internal MIT units, etc.

It is not our intention to dispute MIT estimates of time required to carry out specific tasks, shortening the time to anticipate delivery, by telling them to do a job in two months which they feel requires three; although, of course, these estimates must be carefully examined to assure ourselves we are getting the correct picture.

It is to be emphasized that we must look at the overall schedule situation and not just the program for a specific flight. There are obvious interactions and trade-offs that could be made between the programs for AS-207/208 and those for AS-503 and AS-504. If all efforts to remain within the flight schedule fail and the programs do become pacing for these flights--as they very well could be--we must be in a position to understand the trade-off of flight schedule delays of one mission as compared to another.

A couple of items which Ed Copps did tentatively identify as problem areas which might be influencing the schedule are the following:

1. Special guidance programs are required to enable yaw steering during the lunar orbit insertion maneuver, providing for plane change in excess of 6°. Ed says the Design Reference Mission calls for a 12° capability, although he doubts that other spacecraft systems constraints would permit such great plane changes. Accordingly, he asked us to re-examine this specification to determine if we could live with a 6° plane change capability, thereby avoiding the necessity of formulating and including these special guidance programs.

2. Everyone at MIT seems to feel that the preparation of the Guidance System Operations Plan (GSOP) is the most critical of all items since so much of the work must be delayed until this final definition of program requirements is finished. Accordingly, we will attempt to take all possible steps to assist MIT in this work, including having MSC people stationed at MIT to assist in the development of the GSOP and, almost simultaneously, giving MSC approval of it. Also, it is intended to work on the more critical pacing items first as ones are identified and initiate procedures whereby official MSC approval can be obtained on these parts as they are completed rather than waiting for delivery of the entire package.

I'd like to make one final observation regarding the overall situation. It's probably terrible; I really don't know yet. But it's my feeling that everything that can be done to help has been done. We are reacting to the problem areas as fast as possible; MIT has reorganized in what seems to be the best possible way, and they appear to be getting things on a businesslike basis, which up to now has probably been our worst problem.

Bill T.

Howard W. Tindall, Jr.

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
JUL 18 19

TO : See list

DATE: JUL 11 1966 R. R. RAGAN

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-83

SUBJECT: Apollo rendezvous guidance computer program options

The purpose of this memorandum is to inform you of two special features of the Apollo spacecraft rendezvous guidance computer programs you may not be aware of since we just added them to the system.

First of all, you recall that both spacecraft--the CSM and the LEM--have rendezvous guidance systems. In order for the computers to determine what maneuvers are required to bring about rendezvous, the basic thing each of the computers needs is the state vectors--that is, orbital elements--of both vehicles. Up until now, all thought has apparently been given to the LEM program. Since the CSM is supposed to be passive, all radar data is used to update the LEM state vector, based on the assumption that the CSM it is tracking is in a well known, unchanging orbit. Also, as the LEM makes maneuvers, the guidance system senses them and so there is no need for a pilot input to the computer to inform it that they were made. However, when we consider what's going on in the CSM, or in the LEM during a CSM rescue, this doesn't look so hot.

First of all, the computer may really have a better defined state vector for its own spacecraft, making it more desirable to update the state vector of the other vehicle. Therefore, pilot control is needed over which spacecraft state vector should be updated based on the radar and optical observations. This will allow the pilot to exercise his best judgment as opposed to providing some sort of automatic logic built into the computer program. Also, if the other vehicle maneuvers, the computer won't know it unless informed by some external source, like the crew. For this reason and others, it is also necessary to include in both the CSM and LEM computer programs the capability for the pilot to input to the computer the fact that the other spacecraft is making a maneuver such that it can be taken into account in maintaining the best current state vector of each spacecraft in each spacecraft's computer.

Accordingly, both of these options are being provided; that is, the crew will inform the computer which spacecraft state vector should be updated and he shall also input to the computer all necessary information when the other vehicle makes a maneuver. Associated with this latter capability is the need to assure that the observational data is not improperly used. Therefore, in order to avoid complex and sophisticated computer logic, we have decided to again utilize the crew's capability to understand the situation and control the computer processing in the following way. The pilot will interrupt the computer program at the time it is planned that the other vehicle will make the maneuver, which will cause the computer to reject all tracking data until the actual ΔV of the maneuver is input. He will have to get this information by voice from the other spacecraft after the maneuver is executed, of course. This procedure will assure that the quantities which are input are the most accurate available and should assure that the observational data is used properly.

Howard W. Tindall, Jr.

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FM14/R. P. Parten
FM/Branch Chiefs
FM2/T. F. Gibson, Jr.

FM:HWT:ps

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
JUL 18 1966
R. RAGAN

TO : See list

DATE: JUL 11 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-84

SUBJECT: Capability to do orbit navigation in earth orbit will not be implemented for AS-207 or AS-504.

MIT currently has plans for supplying a number of different modes for using their basic orbit determination program. (MIT calls this process "navigation," so I will, too.) These modes differ in that there is a variety of types of observational data used during different mission phases.

In our attempt to simplify the AS-504 spacecraft computer program, we are reviewing the overall situation to determine that no unnecessary modes are included. For example, there is no need to perform orbit navigation while in earth orbit for the lunar mission or any recognized contingency situation. This particular orbit navigation mode was to utilize star/landmark observations along with other earth orbital service routines and special initialization capabilities to determine the spacecraft state vector prior to the translunar injection maneuver. Since this program is not required for the lunar mission, MIT will be directed not to include it in the AS-504 program. Since we do not intend to implement any programs especially for AS-207, unless directed otherwise, it will be dropped from the AS-207 computer program as well, which means that the CSM will not have the capability of determining its own orbital elements during that mission.

Accordingly, it will not be possible to satisfy that mission objective as referenced in TRW document 2132-H008-R8-000, "Mission Requirements for Apollo Spacecraft Development Mission AS-207/208," dated March 7, 1966, classified Confidential.

Howard W. Tindall

Howard W. Tindall, Jr.

MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6
UNITED STATES GOVERNMENT

Memorandum

RECEIVED
JUL 12 1966
R. R. RAGAN

TO : FM4/Chief, Mathematical Physics Branch

DATE: JUL 8 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-85

SUBJECT: Determination of relative CSM orbit

Jim, this is just a reminder of conversations with you and Emil about a job I'd like your people to do. In thinking more about this orbit determination task wherein the LEM determines the CSM orbit while sitting on the lunar surface, I wonder if perhaps MIT has lost sight of our primary objectives, thus leading them to the conclusion that they should use only range and range rate data.

The only purpose of this orbit determination, as you recall, is to determine the orientation of the CSM's orbital plane for use in targeting the LEM ascent guidance and to select a lift-off time which must be within a few seconds of optimum. It is not to obtain some sort of a precision total state vector of the CSM. Based on these ground rules, I just can't believe that the angular radar data, even with relatively large biases, cannot be useful if properly weighted, and I would think that it would provide a great strength or reliability to the process, which I would consider mandatory. That is, we are much more interested in assuring ourselves of getting a pretty good answer all the time rather than an excellent answer some of the time.

The questions to be answered are: should we or shouldn't we use the angular data, even with large biases, and how do we take maximum advantage of our external knowledge, such as the CSM's own orbit determination (though it's not with respect to the LEM). Don't forget, this data processing must be entirely automatic. The crew will never have time to learn how to operate all those statistical filters, etc., whatever they are.

Emil said he would start something here, but I wanted to make sure you were aware of it and concurred and, in particular, would give it some of your own personal attention. Perhaps these remarks belong at the top, but I'd just like to reiterate that as much as I distrust it, I'm afraid our best source of relative orbit determination for this particular mission phase may be by the LEM radar data. I doubt if the CSM will ever see the LEM on the surface, at least we'd better not count on it, and the MSFN tracking certainly can't figure out where the LEM is. Our other source is the G&N state vector T/M at LEM touchdown, which is probably the best, if the antenna are pointed at us.

Bill

Howard W. Tindall, Jr.

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
JUL 18 1966
R. R. RAGAN

TO : See list

DATE: JUL 8 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-86

SUBJECT: No special program available for targeting the CSM plane change in lunar orbit

As I understand it, it is currently planned to make a plane change with the CSM in lunar orbit within the last several revolutions prior to LEM ascent. The purpose of this maneuver is to optimize the sharing of maneuver (propulsion) requirements between the CSM and the LEM.

This memorandum is to inform you that there is no computer program currently planned for either the CSM or LEM spacecraft computer to carry out the targeting for this CSM plane change. In other words, in finalizing the onboard computer program requirements for the AS-504 mission, we are assuming that the targeting for this maneuver will be carried out by some source external to the computer, such as pre-mission planning in the form of crew charts or from the MCC in real time.

Of course, the programs needed to execute this maneuver will be available, although not provided specifically for it.

Howard W. Tindall, Jr.

UNITED STATES GOVERNMENT

Memorandum

Route to: ~~H. J. Honeycutt~~
R. N. Battey
~~L. E. Larson~~ 26 July

TO : See list

DATE: JUL 11 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-89

SUBJECT: LEM radar angle bias correction

As you know, the rendezvous orbit navigation process involves updating the spacecraft state vector based on the spacecraft radar data. However, the radar apparently has unacceptably large angular bias errors for some reason. Instead of fixing the damn radar, someone decided to include in the LEM spacecraft computer program the capability of computing these radar angle biases at the same time the spacecraft state vector is updated. Once these biases have been determined to the computer's satisfaction, they are not updated further; that is, they are assumed to remain unchanged thereafter.

There is a contingency, however, which would cause them to change, so I'm told, and that is if the LEM were to undergo loss of pressurization. It had been MIT's intention to provide an option in their rendezvous orbit determination program to reinitialize the computer such that it would redetermine the radar angle biases in this event. However, in line with our campaign to simplify the computer program, this option is being deleted, which means that, in the event of spacecraft pressurization loss, the radar angle bias may be in error by some fraction of a degree. This does not disable the rendezvous guidance system, but rather may cause some loss of efficiency in the use of propulsion fuel. Just how much depends on when it happens, of course, but the maximum extra cost is not expected to exceed about 50 ft/sec. We'll get a better estimate of this cost and make sure it's acceptable.

Ed Lineberry, how about you getting that done. In the meantime, we're telling MIT to take this option out unless we're directed otherwise.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
JUL 25 1966
R. R. RAGAN

Batson
Hoag

TO : See list

DATE: JUL 1 8 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-94

SUBJECT: Rendezvous terminal phase guidance program in the Apollo spacecraft computer

On July 7, 1966, a team of MSC and MIT "experts in rendezvous" (including Paul Kramer, Ed Lineberry, John Dahlen, and Norm Sears) met at MIT to discuss and review the preliminary Guidance System Operation Plan (GSOP) which MIT has unofficially distributed, covering the terminal phase and External ΔV programs for the AS-207/208 mission. This meeting was sort of a mile-pebble in the accelerated program development sequence we have established in an attempt to get all this business on schedule. That is, we are obtaining bits and pieces of the GSOP as they come off the MIT press rather than awaiting receipt of the formally published, final document.

It is our hope that, by reviewing and commenting on these pieces as they become available, the GSOP should be virtually acceptable without modification on the date of its publication and should permit the computer program development to proceed much more quickly than it has in the past. We had previously discussed these mission programs and our pilot input and display requirements for them in detail a month or so ago with MIT, and the pieces of the GSOP I am talking about here reflected that input very well. Therefore, most of the discussion was for purposes of clarification to assure a firm understanding on both MSC's and MIT's part as to what this program was really going to do and how we were going to operate it. Basically, very few modifications were considered necessary.

In my opinion, this meeting was highly successful; and, since these processors--the terminal phase and External ΔV--are the most significant new requirements and the most controversial of the mission programs, I feel we are probably over the hump as far as defining the program for the AS-207/208 mission.

I would like to point out here the two items given the most attention at this meeting since they serve well to describe the character of the terminal phase rendezvous guidance philosophy:

1. One of the capabilities of most interest which we have provided was the display of range, range rate, and the angle the spacecraft X-axis makes with respect to the local horizontal. It was decided to make these three quantities available at crew request at any time the data was available. (This stuff is used for carrying out the crew backup procedures.) Contrary to one of my previous reports, these quantities will

all be computed based on the current best estimate of the two spacecraft state vectors. (We had previously expressed an intention for the computer to display raw radar range and range rate in the LEM.) Our action in this case was based on our desire to make the CSM and LEM computer programs as much the same as possible, and, since the raw radar data is available on what is said to be a highly accurate analog display in the LEM, we have not really lost anything. In order to make this particular feature of the program as independent as possible from the automatic guidance system processing, we have divorced the display of these quantities from the activity associated with the primary guidance system to the maximum extent.

2. Based on Gemini experience, the crew has emphasized that there is no requirement for automatic execution of the braking maneuvers by the G&N system. As previously reported, it is felt that this task can be carried out just as well, if not better, by the crew if they are provided the proper information; namely, the range and range rate data. At least this is true in the case of the nominal mission and most contingency situations, and we want to take advantage of that. However, there are occasions when automatic control of these maneuvers by the G&N might be mandatory. For example, visual acquisition is required for the crew to carry out this task, and under some abort situations lighting conditions can be unacceptable. Also, there are abort cases in which the closing velocity is too high for effective manual control. Recognizing that procedures are available for utilizing the remaining computer processors to carry out the G&N controlled braking maneuvers by proper pilot manipulation of the computer, we deleted the requirement for automatic computer logic for this task. The point is, we felt that there was insufficient justification to carry out the extra programming, debugging, verification, and documentation, as well as using some 50 to 100 words of precious computer storage, for a program which was not needed, except in rather remote contingency situations, as long as procedures were available to handle all situations. And, they are.

The final GSOP shall reflect these characteristics; otherwise, it was accepted pretty well as is.

In the course of our discussions, I learned some rather interesting things about the command module which I must say didn't impress me very favorably. In fact, I really wonder (i.e., doubt) if it is possible for one crew member to carry out a rendezvous in the CSM. For example, the only observational data available to the computer is from the sextant, and that requires manual tracking and input of observations into the computer. (The LEM has automatic radar tracking with its data available to the computer as it periodically requests it.) And, of course, in order for the pilot to use this system, he has to be down in the navigation area of the spacecraft, which means he has to quit making observations sometime before any SPS maneuver to get strapped into his seat. On top of that, the sextant apparently can't be oriented along any of the major spacecraft axes, which makes it necessary to orient to some attitude not consistent with making RCS midcourse maneuvers.

I'll bet that when we finally get a crew timeline on a CSM one-man rendezvous, he has to do it without any observational data available to the computer after about 15 minutes before TPI. If my guess is right, in effect we have provided practically no CSM G&N rendezvous guidance system, and thus the job will end up being carried out pretty much using the crew backup procedures. Boy!

Howard W. Tindall, Jr.

UNITED STATES GOVERNMENT

Memorandum

D 6 4
Batten

~~R~~

RECEIVED
SEP 8 1966
RAGAN

TO : See list

DATE: AUG 30 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-100

SUBJECT: Notes regarding the AS-207/208 Guidance Systems Operation Plan (GSOP) meeting with MIT

During the week of August 15, we held a review of the AS-207/208 Guidance Systems Operation Plan (GSOP) at MIT. Some things interested me which I will pass on to you here. I will also include some of the more significant decisions--that is, direction to MIT--that were made at that time.

1. It is currently planned that the astronaut will freeze the rendezvous maneuver sequence by a manual input to the computer. This will be done at about twelve minutes before each of the maneuvers, including the TPI maneuver. It serves to prevent new observational (e.g., radar) data from changing the maneuver he intends to make next. It does this by causing the computer to completely ignore all new observational data obtained between the time of his signal and the maneuver. In fact, whatever data is collected during that period is never used, even after the maneuver has been executed.

2. Logic is being introduced into the rendezvous navigation program (i.e., the orbit determination used during rendezvous) which, in effect, edits the observational data automatically. Specifically, if the change in both the computed velocity magnitude and the computed position of the spacecraft is less than some pre-established amount due to the processing of new observational data, that data is adjudged to be good and is automatically included in the solution. If the change in either of these quantities is in excess of some larger pre-established amount, the data is not accepted (unless the crew permits it), and a program alarm light comes on. If the change in those quantities falls between these two limits, the data is accepted and used, but the alarm light would be lit.

3. MIT was directed not to provide a mode for utilizing Alignment Optical Telescope (AOT) data in the rendezvous navigation. This had been tentatively suggested for use in the event of a rendezvous radar failure but, based on the likelihood that the AOT data would not be of any value, it was decided not to complicate the program to permit its use.

4. Due to fear of some ambiguity, the computer program is designed to reject radar data when the estimated range to the target exceeds 400 n.m.

5. One of MIT's questions left unresolved was whether or not an automatic sextant search pattern is required as a lunar module acquisition aid. MIT intends to make a recommendation on this.

6. The flight crew people have requested that the display of duration of time in the terminal phase between TPI and TPF be in seconds. Since this is not one of the standard time display formats, MIT was directed to retain units of hours:minutes:seconds as they proposed, unless the crew has really good reasons to provide this new format. Tom Hardy has the action.

7. As usual, there was a discussion as to the reference to be used in the display of altitude. MIT was directed to compute and display all spacecraft altitudes referenced to a spherical earth with radius equal to that of the launch pad. This reference was determined to be best, although not perfect, for rendezvous missions after what seemed to be endless months of discussion. Coordinates of landmarks used for orbit determination, however, will be referenced to the Fischer Ellipsoid.

8. As a result of the crew's dissatisfaction with the fixed heads-down attitude forced upon them during SPS maneuvers on AS-204/205, MIT proposes to eliminate that constraint in the AS-207/208 programs. The computer will display a "preferred attitude," which is heads-up, but will not automatically orient the spacecraft to that attitude. As I understand it, it will hold whatever spacecraft "roll" attitude it happens to end up with when the thruster axis is properly aligned. It is possible for the crew to manually change this attitude if it is undesirable by deactivating computer attitude control, then manually changing the attitude and reinitiating computer control, which will then hold the new attitude.

9. No minimum impulse capability is to be implemented in the LGC since there appears to be no requirement for this, whatever it is.

10. As usual, the question of navigation (i.e., orbit determination) in earth orbit came up again. We previously had directed MIT not to include this capability in the AS-207/208 mission programs since it is not required for the lunar mission. However, they, and some MSC people, feel it is desirable to provide this capability in order to obtain further experience with the process prior to going to the moon. Thus, this is still an open item. It has been agreed, in any case, that orbit determination using unknown landmarks would not be included, and, although the provision is being made for star/moon horizon measurements, they will only be used to obtain CDU angles to be transmitted on the downlink and they will not be used in the navigation program.

Norm Sears estimates that the orbit determination process should be completed within about ten seconds of accepting an observation. Also, he would like to establish a procedure whereby data points are obtained at the rate of about one per minute.

11. MIT was directed to delete the guidance reference release (GRR) signal, its function to be replaced by the lift-off signal. As I understand it, there is some controversy over this which Aaron Cohen intends to resolve at MSC.

12. One feature of this program which particularly disturbs me, and many others, is the tremendous amount of work the astronaut must perform to use the computer program. Of course, much of this comes about as a result of the trade-off to provide mission flexibility by giving the crew the capability of controlling what the computer is doing as opposed to having it perform automatically. Another specific example is the amount of data which must be input to the computer prior to making a maneuver, including such things as spacecraft weight and inertia, engine trim angles, tailoff, spacecraft configuration (docked or undocked), and level of rate response to hand controller inputs. It would certainly be desirable, if possible, to eliminate as many of these inputs as possible, either by putting them in fixed memory--if that is a reasonable thing to do--or by deleting them altogether. There is some question in my mind as to how accurately some of them can be determined by the crew, and we may find that there is no significant advantage obtained by updating them. This will be followed up.

I'm sure there was something else interesting that came up there, but I don't remember it right now.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
SEP 8 1966
R. R. RAGAN

Bothwell

TO : See list

DATE: AUG 3 0 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-103

SUBJECT: Automatic rendezvous braking maneuver

As you know, MIT is currently designing the command module and lunar module computer programs without provision for automatic braking maneuvers. There has been some thought to reversing this direction. However, Don Cheatham, Aaron Cohen, and I agreed today to proceed as we are for the AS-207/208 programs--that is, do not provide automatic braking maneuvers in the computer programs--since we are fairly sure that this capability should not be required for that flight. We will review this decision later for the AS-504 programs, based on experience gained during the AS-204 mission and from crew training and simulations, after more complete crew procedures are defined.

Howard W. Tindall, Jr.

UNITED STATES GOVERNMENT

Memorandum

Faller

RECEIVED
SEP 9 1966
R. R. GILRUTH

TO : PA/Manager, Apollo Program

DATE: SEP 2 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-104

SUBJECT: Status of the lunar module "quick return" guidance capability

This note is in response to your query regarding the "quick return" capability being provided in the lunar module (LM) for aborts during the lunar descent phase. As you recall, I reported deletion of a program in the LM computer for generating coefficients to be used in an abort polynomial to retarget the LM powered flight to provide a direct intercept rendezvous trajectory. You asked how far this work had progressed since you felt such a capability would be "comfortable."

In answer to that question, MIT informed me that, whereas the concepts were well established, there was still a considerable amount of work required to complete this particular program. Furthermore, we have also deleted the direct ascent launch guidance, which is a necessary companion program. Certainly of more interest to you now is, what is our current capability.

The program is being written such that abort action by the pilot during powered descent will cause the guidance to retarget to the standard LM insertion orbit. Incidentally, it is necessary for the astronaut to select which engine, the Ascent Propulsion System (APS) or the Descent Propulsion System (DPS), is to be used, depending on the situation. In any case, following insertion into orbit, the crew has two choices: either to proceed with the concentric flight plan, or to use a processor which we have retained for just such situations as this, whereby the crew may obtain the two-impulse Lambert solution for rendezvousing with minimum ΔV--essentially a direct intercept. In effect, the latter provides very nearly the same capability as we have deleted, except that the maneuver must be carried out in two steps with some delay--say, five or ten minutes--between them, as opposed to a single maneuver.

If the concentric flight plan is chosen, the time between the abort action and rendezvous would be about $2\frac{1}{2}$ hours with the differential altitude varying between 42 nautical miles above to the standard 15 nautical miles below the CSM, depending on whether the abort took place immediately after initiation of the descent maneuver or at the end of the hover. The "direct intercept" approach would take about $1\frac{1}{2}$ hours but is only possible prior to initiation of hover since after that time the intercept trajectory, unfortunately, also intercepts the moon--first! Actual procedures have to be settled, but I feel we're in pretty good shape here.

Finally regarding current status, there are some unresolved problems associated with this retargeting which MIT is currently addressing. For example, if an abort occurs early in descent, the LM will be near 50,000 feet with orbital velocity. The current insertion altitude is 60,000 feet. Thus, the spacecraft would have to make a large altitude change with little increase in velocity, which would obviously demand some rather wild gyrations of the spacecraft--both highly undesirable and unnecessary.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

cc:
(See attached list)

R. Ragan

UNITED STATES GOVERNMENT

Memorandum

TO : FA/Director of Flight Operations

DATE: SEP 19 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-107

SUBJECT: Alternate rendezvous technique - mission planning status

Since our meeting in your office on the stable orbit rendezvous, Ed Lineberry and I have met on a number of occasions with other interested people in an attempt to lay out a schedule of work needed to arrive at the decision as to how to go on 278 and subsequent missions. This note is to let you know the things we (MSC) intend to do and when we expect to get them done. As you will see, most of the work is being done by the Flight Crew Support Division and Guidance Control Division since the most significant difference from the old Concentric Flight Plan (CFP) involves the terminal phase of the rendezvous.

1. Paul Kramer, FCSD, has assigned a task to McDonnell Aircraft Co. to perform man-in-the-loop simulations of both the stable orbit rendezvous technique and the CFP with comparable approach velocities. Simulation of both systems will be initiated with the transfer maneuver. The approach velocities will be equivalent to the CFP with differential altitude varying from about 5 to 15 nautical miles. All failures modes will be investigated. It is intended to start this three-week effort on about September 19.

2. GCD has two studies going. The first is an evaluation of the CSM optical rendezvous guidance system to determine its accuracies and performance when operating in a stable orbit type rendezvous. The prime objective of this study is to determine the magnitude of the dispersions to be expected in the on-board computed maneuvers starting with the transfer from the stable orbit point. It is anticipated that this analysis will be completed by mid-October.

3. The second GCD study concerns the braking phase. Ron Simpson is in charge of this investigation which is primarily an expansion of one previously carried out for higher closing rates. He intends to start with conditions corresponding to CFP differential altitudes of between 5 and 15 miles. As I understand it, his man-in-the-loop simulations are usually initiated at about a 10 mile range. The purpose, of course, is to determine if there is some preferred closing rate going into the braking maneuver. These runs will be performed both with and without a cockpit display of range and range rate. He expects to start this analysis in mid-September with the results to be available early in October.

4. We are doing some things in MPAD too, of course, but they are not as extensive as I indicated they might be during our meeting. Ed Lineberry's people are carrying out analyses aimed at selection of the optimum transfer angle(ωt) and trailing displacement for the stable orbit rendezvous technique. These two parameters are probably interrelated growing larger together to keep the closing rate meaningful in the face of dispersions. We still expect the preferred trailing displacement to be in the order of 15 to 20 nautical miles. At present the two prime candidates for ωt are 292° and 330°. 292°, you recall, has the advantage of providing the same approach conditions - primarily minimum inertial line of sight rates - as the CFP. This was the transfer angle used on the Gemini XI re-rendezvous which, in effect, checked out a ground controlled (perfectly!) CFP with braking without a radar simulating a differential altitude of 5 nautical miles. The 330° figure was jointly selected by MSC and MAC for the Gemini XII re-rendezvous based on lighting considerations and time available to make mid-course corrections. The objective was to provide as large a value of ωt as possible while avoiding the unique problems associated with a 360° transfer in the presence of out-of-plan and altitude dispersions. (Incidentally, McDonnell is carrying out a considerable amount of work both in terms of dispersion analysis and the preparation of flight crew rendezvous charts. Much of this work will be applicable to our effort.)

5. In addition, the mission planning for the Gemini XII re-rendezvous is being constrained as much as possible to duplicate the AS-278 initial CSM rendezvous conditions. In particular, we are trying to duplicate the ground tracking orbit determination capabilities as well as the relative motion trajectories to simulate the stable orbit rendezvous technique.

6. As you may recall, we originally estimated development of ten reference trajectories was required to provide information for the big decision. We have concluded that it is virtually impossible to do that much work in a reasonable length of time, regardless of how we redistribute our manpower. However, RAB is developing a reference trajectory for the nominal lunar rendezvous assuming an on-time LM lift off. It will be a two-impulse, minimum Δ V trajectory to the stable orbit position. Once this is completed they intend to perturb the LM insertion conditions up to the 3 Sigma performance of the Abort Guidance System and the Ascent Propulsion System in order to determine the effects of these dispersions on the Delta V. Their work will be based on the assumption that there is a perfect knowledge of the situation at the time of the maneuvers and that they are executed perfectly. Ed anticipates that this work will be completed around the middle of October.

Finally, we are issuing a program change notice to MIT to provide an offset rendezvous target capability - trailing position only. I should point out that some resistance is expected to this program change, primarily from the FCOD since there are many other capabilities they give much higher priority which we have not agreed to implement so far. I am not certain how ASPO will react either since, as I understand it, TRW has reported to Joe Shea that they see no significant advantage to this technique.

Also associated with all this, the AS-207/208 Reference Trajectory is to be issued on about September 23. As you are probably aware, there are a large number of unresolved areas on this complex mission primarily due to the uncertainty associated with the AS-206 mission; thus, the quality of this Reference Trajectory is going to be questionable in any case. Unfortunately it will continue to show the initial CSM active rendezvous as a CFP type with a differential altitude of 20 nautical miles. Although it does not correspond to the planned documentation schedule, I really expect another Reference Trajectory will have to be issued prior to the release of the Operational Trajectory. Therefore, if we change to the stable orbit rendezvous, that will either be reflected in the new Reference Trajectory, or we will issue an addendum of some sort such as an internal note documenting the change.

Chris, this has been a tough problem and, believe it or not, we have spent a lot of time developing this plan for getting the answers you and Sig want. If there is something else you think we should be doing, please let me know.

Howard W. Tindall, Jr.

cc:
FA/S. A. Sjoberg
FA/R. G. Rose
FC/J. D. Hodge
FL/J. B. Hammack
FS/H. E. Clements
FM;J. P. Mayer
FM/C. R. Huss
FM/M. V. Jenkins
FM12/J. F. Dalby
FM/13/J. P. Bryant
FM14/R. P. Parten
FM/Branch Chiefs
CA/D. K. Slayton
CF/W. J. North
CF/P. Kramer
EG/R. C. Duncan
EG/D. C. Cheatham
EG23/K. J. Cox
PA/J. F. Shea
PM2/C. H. Perrine

FM:HWT:cm

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MAY 1962 EDITION
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K. Kagan

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
SEP 2
R. R. RAGAN

TO : EG/Chief, Guidance and Control Division

DATE: SEP 2 1 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-109

SUBJECT: Mission rules needed for use with AGC self-check

As you probably recall, we have had an exchange of views and memoranda regarding the usefulness of the Apollo computer program known as self-check. This exchange was started by our attempt to cut the spacecraft computer program down to an acceptable size for the lunar mission. Current status is that the self-check programs are still in; however, I intuitively feel the 504 programs have probably again grown to a point that we have again overflowed storage and will eventually have to have another paring down session. I would like to request that your people who expressed an interest in preserving self-check assume the task of formulating applicable mission rules which could be used on the lunar mission in conjunction with the self-check programs. These mission rules would specify exactly what action is to be taken during the 504 mission, probably as a function of mission phase and type of computer failure detected by self-check.

The point is, I would like to make sure that this program really serves a useful operational function as opposed to a pre-flight function before we decide to carry it to the moon at the exclusion of some other program someone wants. And, of course, if we do retain it in the system, these recommended mission rules should be very useful to the Flight Control Division and to the flight crew in establishing the operational procedures.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

cc:
CA/D. K. Slayton
CF/W. J. North
CF/C. C. Thomas
EG/D. C. Cheatham
PA/J. F. Shea
PD4/A. Cohen
FA/C. C. Kraft, Jr.
FA/S. A. Sjoberg
FC/J. D. Hodge
FM/J. P. Mayer
FM/C. R. Huss
FM/M. V. Jenkins
FM/Branch Chiefs
FM2/T. F. Gibson, Jr.
FM:HWT:cm

5010-108

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UNITED STATES GOVERNMENT

Memorandum

RECEIVED

R. R. RAGAN

TO : FM/M. V. Jenkins

DATE: SEP 2 1 1966

66-FM1-110

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: LGC computer requirements to provide DPS backup of SPS

During our discussion at MIT last week, the question came up as to whether it is necessary to have trajectory integration techniques in the LGC for the trans-earth phase of the mission as well as the lunar phase. The argument is that if we are serious about using the LM descent propulsion system to back up the command module SPS during the trans-earth phase, it will be necessary to have this integration capability as a service program for such things as platform alignment and maneuver targeting. In fact, this capability would also be required for trans-lunar aborts using the DPS, I suppose. The more I think about it, the more I am convinced that this capability should be included and I am interested in your comments on the subject. Of course, if you agree I assume you will include it in the 504 LGC program requirements.

Howard W. Tindall, Jr.

cc:
CF/C. C. Thomas
EG/R. C. Duncan
EG/D. C. Cheatham
PA/J. F. Shea
PA/W. A. Lee
PD/R. W. Williams
PD4/A. Cohen
PM/O. E. Maynard
PM2/C. H. Perrine
FA/C. C. Kraft, Jr.
FA/S. A. Sjoberg
FA/R. G. Rose
FC/J. D. Hodge
FC2/E. F. Kranz
FC3/A. D. Aldrich
FC4/M. F. Brooks
FC5/G. S. Lunney
FM/J. P. Mayer
FM/C. R. Huss
FM13/J. P. Bryant
FM/Branch Chiefs
FM2/T. F. Gibson, Jr.

FM:HWT:cm

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
SEP 27 19
R. R. RAGAN

TO : FM2/Flight Software Branch
Attention: T. F. Gibson, Jr.

DATE: SEP 21 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-111

SUBJECT: Rendezvous search modes of various types

According to the notes I made during the 278 GSOP review at MIT last August, there was apparently still some question as to whether an automatic radar search mode was needed. Sears also questioned whether an automatic sextant search mode was needed on the command module.

Has anything been done to answer either of these questions? If so, what? If not, what can we do to close out these items?

Howard W. Tindall, Jr.

cc:
EG/D. C. Cheatham
PD4/A. Cohen
FM/M. V. Jenkins

FM:HWT:cm

0

UNITED STATES GOVERNMENT

Memorandum

TO : See list

DATE: SEP 21 1966

66-FM1-112

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: Apollo rendezvous navigation data edit is too complicated

In my notes of the AS-207/208 GSOP meeting with MIT, reference 66-FM1-100 of August 30, I indicated that MIT was including an automatic data edit scheme in the rendezvous navigational program for both the LM and the CSM. As you recall, this scheme was to accept radar or SXT data automatically if its effect on the spacecraft state vector is less than some pre-established amount and would reject it if its effect is greater than some other (larger) pre-established amount. Data falling between these two criteria was to be accepted but a warning light was to be turned on. Dr. Shea commented that this seems unnecessarily complicated - that really there is no apparent sense in having three conditions when two would do just as well. I must say, although I was foolish enough to argue at the time, I certainly agree now that we really should make this a simple binary decision. Use the data or don't use the data based on some pre-established level of quality - probably light a light when the computer is rejecting the data and do away with that central region altogether. I have searched my memory and can't recall why MIT proposed to do it that way, but unless someone can find a good reason, we should direct MIT to simplify the decision logic as noted above.

Flight Office Branch personnel please take appropriate action immediately.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED

TO : See list

DATE: SEP 21 1966

R. R. RAGAN

FROM : FM/Deputy Chief, Mission Planning and

66-FM1-113

SUBJECT: There are differences in the descent guidance programs on AS-503 and AS-504

It is currently intended to include some sort of tests of the LM descent propulsion and guidance on the AS-503 mission. However, it is not possible to use the same guidance equations on AS-503 as will be used on the AS-504 lunar descent. This is due to obvious differences of an earth orbital mission compared to an actual descent to the moon's surface. The gravitational potention is different; the objective of the maneuver is different; there is nothing for the lunar landing radar to bounce signals off of, etc. Accordingly it is MIT's intention, with our concurrence, to omit certain vital parts of the AS-504 descent guidance program from the AS-503 mission. The purpose of this memo is to make sure that you all know this.

It is my understanding that there are four main processers of the AS-504 descent guidance program which are not to be included in the AS-503 program:

1. processing of the landing radar data
2. landing point designation
3. x-axis override
4. automatic rate of descent control

In addition, there is likely to be a change in the coordinate system of some sort needed.

I certainly do not claim to be an expert in descent guidance; in fact, quite the opposite. If anything above interests you, I would suggest you contact someone who really knows what they are talking about like Don Cheatham, Floyd Bennett or Tom Price.

Incidentally, we are currently in the midst of an exercise designed to make the AS-278 spacecraft computer programs identical to those for AS-503. Although I don't expect this to have any influence on the descent guidance, I just mentioned it here to cover that possibility.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

R. Ragan.

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MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
SEP 2 ...
R. R. RAGAN

TO : See list

DATE: SEP 2 2 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-114

SUBJECT: Apollo spacecraft guidance navigation modes currently planned for AS-503 and AS-504

I am afraid there is a bit of confusion as to what navigation modes are being provided in the AS-503 and AS-504 Apollo spacecraft computer programs. I am sure I have contributed to this confusion myself, and the purpose of this memorandum is to try and clear it all up.

According to Norm Sears, it is intended to provide the following navigation; that is, onboard orbit determination programs in the AS-504 command module computer program:

a. During earth orbital operations there shall be no onboard navigational capabilities at all.

b. During the trans-lunar and trans-earth phases the navigation program is being formulated to process both star/landmark and star/horizon measurements. The landmarks and horizon may be either earth or lunar at the choice of the flight crew. That is, there is no interlock governing which is used depending on position of the spacecraft relative to those two bodies. The pilot must manually key in location of the earth landmarks and it is probable that he will also have to key in lunar landmarks since those stored for lunar orbit navigation are likely to be of a size not readily observable during these phases of the mission.

c. In lunar orbit the navigation program will utilize only lunar landmarks referenced to the platform. Twenty-eight landmarks will be stored in the computer program, but I am certain others may be keyed in if the crew desires.

For the AS-503 mission, it is currently intended to have only one navigation mode - namely, use of star/landmark or star/horizon observations. The landmarks and horizon used are restricted to earth only since it is not intended to have such routines as the lunar ephemeris, lunar rotation, etc., programs available. Earth landmarks must be keyed in manually by the crew. Norm Sears (MIT) points out that use of this data in orbits of the type currently planned for AS-503 may actually result in degradation of the onboard state vector, and as a result it may be necessary to restrict this process to a spacecraft system test rather than an operational procedure in support of the mission.

I suppose, to make this entirely complete, I should also list here the processing of the command module sextant data for rendezvous navigation, which will be in all Block II computer programs currently planned.

Other than rendezvous navigation utilizing the spacecraft radar, there is no navigational capability planned to be included in the LGC program for any mission.

We are currently in the midst of an exercise to make the AS-278 programs identically the same as AS-503. Since we have a difficult schedule situation on AS-278, there may be implications on the navigation modes available for the AS-503 mission as noted above; however, at this time I do not expect that to be the case and will certainly inform you if the situation changes.

Howard W. Tindall

Howard W. Tindall, Jr.

Addressees:
(See attached list)

L. E. Larson
Sears

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MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
OCT -3 1966
L. E. LARSON, JR.

TO : See list

DATE: SEP 27 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-115

	Action	Info
R. RAGAN		
D. HOAG		✓
L. LARSON		✓
CENTRAL FILES		

SUBJECT: LGC program development for the AS-278B

This note is intended to document my understanding of the situation with regard to the spacecraft computer programs for the alternate AS-278 mission. In particular, I would like to record how we are responding to the current programming needs in this area.

Although it was originally stated as a ground rule that alternate missions would be flown using the same programs developed for the primary missions, it appears that that will not be possible in this instance; e.g., there are two contingencies the Apollo Program Office feels it is mandatory to be prepared for. One is an extended schedule slip on the delivery on the first LM spacecraft, and the second is the failure of the AS-206 mission of such a nature that it is not possible to carry out the AS-278 mission as currently planned. The alternate mission (AS-278B) in both of these instances is to rendezvous the AS-207 command module with a LM, man the LM, perform certain spacecraft systems tests and then to initiate a programmed sequence very similar if not identical to the current AS-206 mission after returning the crew to the command module. We are now attempting to determine precisely which additional processors must be added to the AS-206 program in order to permit making such a flight. Of course, the additional requirements depend on precisely how this mission is to be flown, which in turn depends on the guidance system capabilities; e.g., we are in the familiar little cycle. At the least, it appears that the capability must exist to power up the system and align the platform in orbit; however, even these things are not certain.

DUE DATE

I have asked Paul Stull and Tom Price to contact the various ASPO and MPAD personnel involved in this mission planning to pin down the possible alternatives for flying this mission, leading to a precise definition of additional program requirements to the 206 program. It is our intention to direct MIT to give the identified processors, which theoretically are already needed in the AS-208 program, highest possible priority such that they may be added to the 206 program at the most opportune time. It appears certain that they will have to be added at some time; e.g., it appears certain a program must be developed to support this type of a flight. There is some question, however, as to whether the 206 program as currently defined is needed since the modified program should be able to fly both the 206 mission and the AS-278B mission. Our basic problem is providing this augmented program in time to support the 206 mission if it is flown; i.e., it depends on the schedule of that flight and the program development required for it.

Accordingly, it is our intention to continue working on the present AS-206 program as currently defined until the latest time at which a decision can be made, probably in the latter part of November or early in December. It is at this time that the final 206 program integration and flight acceptance verification testing will be going on. If, at that time, it is apparent the 206 flight has slipped sufficiently to permit adding the additional processors to support the AS-278B mission, work on the 206 program would be terminated and only this augmented program would be developed for use both on the AS-206 and AS-278B. If the current 206 schedule is maintained, however, we would be forced to complete flight qualified 206 program ropes to be followed later by the augmented AS-206 program for support of the AS-278B mission.

Although some preliminary information has been obtained from MIT regarding over-all schedule impact, it is my intuitive feeling that it is probably not particularly accurate. Therefore, it is my intention to obtain program development plans for the augmented AS-206 program which will include the effect of work on this program on the AS-278/503 and 504 program schedules.

This will be done as soon as the additional program requirements for the AS-278B mission have been defined.

Howard W. Tindall

Howard W. Tindall, Jr.

Addressees:
(See attached list)

J. Sears

UNITED STATES GOVERNMENT

Memorandum

TO : See list

DATE: OCT 4 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-118

SUBJECT: No extra memory for the Apollo Spacecraft Computer

One of the most significant decisions coming out of the AS-278 computer program review with the Apollo Spacecraft Program Manager on September 15 and 16, was his absolute assurance that the spacecraft computer memory would not be augmented for the AS-503 or AS-504 flights. Accordingly, all program development should proceed on that basis for those flights.

On the other hand, I would hope and expect that work will continue on the auxiliary memory for follow-on missions, and I feel we should offer whatever assistance MIT can provide on a non-interference basis to that effort.

Bill

Howard W. Tindall, Jr.

Addressees:
(See attached list)

N. Sears

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MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

	Action	Info
R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
CENTRAL FILES		
R. Millard		✓
E. Copps		✓
J. Miller		✓
Dahlen		✓
N. Sears		✓
Nevins		✓
R. Battin		✓
~~DUE DATE~~ Eldon Hall		✓

TO : See list

DATE: OCT 11 1966

66-FM1-123

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: Procedure for obtaining Apollo Spacecraft Computer Program schedule information

In our (MSC) attempt to establish the most meaningful flight development schedule for Apollo including, as it must, adjustments to conform with the continually varying mission constraints as well as providing backup missions for contingency situations, many people have legitimate need to know the effect of their ideas and proposals on the readiness of the spacecraft computer programs being developed by MIT. On the other hand, the exact schedule of these programs is still ill-defined. As a result, on occasion recently, people attempting to get this sort of information directly from their MIT friends have obtained uncoordinated and, thus, inaccurate information upon which decisions have been made, sometimes distressing to MSC and MIT both.

To avoid this problem in the future, we are immediately establishing a procedure wherein Mr. Tom Gibson of the Flight Software Branch and Mr. Bob Millard of MIT, or their authorized representatives, are to serve as the single point contacts in their respective organizations for the procurement of schedule-type information. It will be their job to poll all influenced parties to assure the information obtained is the best possible under the circumstances. Spacecraft computer program schedule information obtained by any other route shall be used at the user's own risk; certainly with no obligation on our part to comply.

Howard W. Tindall Jr.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

J. Sears

MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

	Action	Info
R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
CENTRAL FILES		
R. Pollard		✓
E. Copps		✓
Dan Lickly		✓
J. Dahlen		✓
J. Sears		✓
Kernan		✓
R. Battin		✓
Eldon Hall		✓
DUE DATE		

RECEIVED
OCT 13
R. R. RAGAN

TO : See list

DATE: OCT 11 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-124

SUBJECT: Program Development Plans are coming!!

September 29th shall probably go down in history, at least in my diary, as the day of a major breakthrough at MIT. On that date we had an all day meeting attended by all key MIT management personnel involved in spacecraft computer program development. I expect it to be the first of similar weekly sessions for as long as they are required. The purpose of these meetings is to establish detailed program development plans for the spacecraft computer programs. This basic information is required for the obvious purposes of understanding the schedule situation, of evaluating the impact of program changes and additions, of assigning priority of effort - both manpower and facilities - in the optimum manner, of providing vital information to NASA program management for consideration in their decisions, etc.

I must say I was tremendously impressed with the cooperative, earnest support all of these MIT people gave to this effort this time and have every hope that it will continue for the four to six weeks of hard, weekly meetings I expect will be needed to reach our objectives.

At this meeting, most of our attention was spent on two items which I will discuss in some detail. First was the availability and adequacy of the computer facilities needed for computer program development, and the second was our investigation into the use of the AS-278 computer programs with minimum change for the AS-503 mission.

At present MIT has two 1800 digital computers on which all program development and verification is carried out. These machines have been and are currently completely saturated. There are no other facilities in the entire universe, to our knowledge, of proper configuration to relieve this situation completely. This is identified as a major problem area particularly during the months of November and December. However, an IBM 360 is to be installed at MIT very soon and it is currently estimated that it will be on line no later than February 1st. As you recall, we have funded AC to the tune of about $300,000 to develop a facility in Milwaukee for use on Block I program development, i.e., for AS-501/502. It was emphasized that maximum utilization of this facility is essential.

It was discovered during program development for AS-204/205 that the hybrid facility at MIT was an extremely valuable tool for program debugging. This is apparently because it is so easy to get on and off this machine;

in addition, it runs considerably faster than the digital computer. Thus, it is possible for the programmers to check program fixes quickly and determine whether they seem to be working before committing the program to the all-digital tests. Phil Felleman of MIT presented a complete schedule of the tasks currently planned for the hybrid computer through calendar year 1967. This schedule showed that almost continually there are a number of vital tasks which must be carried on simultaneously, or at least on a time sharing basis. This is expected to present serious problems and we are currently looking into the possibility of augmenting the facility to relieve it. In particular, an almost ideal set of hybrid equipment is available at Beckman - a system which had been under development for MPAD - which MIT can obtain immediately at a "bargain price". Additional pieces of equipment such as a Block II AGC and a core rope simulator must also be obtained from some, as yet, unknown source. MIT is continuing to formulate plans for augmenting this facility including obtaining for us the influence it would have in improving the computer program development schedule. Specifically, this augmentation would make possible the simultaneous use of the command module and LM cockpit simulators at MIT. In addition, it would give the unique capability of being able to run data flow tests and simulations of these two spacecraft in conjunction with each other, which will certainly be highly desirable for preparation of the AS-278 mission. It was strongly emphasized that the purpose of this facility is not flight crew training, but rather is for the development of the spacecraft computer programs and associated crew procedures.

The second half of the day was spent in discussions of how the AS-278 programs could be used in support of the AS-503 mission. A number of routines were considered for beefing up the AS-278 program, but after lengthy discussions only two candidates were left outstanding. One was the lunar orbit insertion (LOI) program which is certainly not needed to fly the AS-503 mission, but which it might be advantageous to test on it. The second and more important processor which we probably must add to AS-278 is the trans-lunar injection (TLI) steering of the SIVB. This program will probably be needed to obtain the experience of AGC steering the SIVB on AS-503 before it is used for the actual TLI maneuver on AS-504. Of course, it is not yet certain that the AGC will be used for this purpose on AS-504, but its likelihood is great enough that we should be prepared for this important spacecraft systems test.

Our next meeting will be Wednesday, October 5th during which, among other things, we expect to review program plans MIT is preparing based on the following ground rules:

1. Schedules should show influence of augmenting the hybrd facility.

2. They should be based on the assumption that the AS-503 will be flown using the AS-278 programs. The AS-278 programs will be augmented

as necessary to do this, but it is expected that no more than the two processors noted above shall be added for that purpose.

Finally, I expect we will review open items remaining regarding the "final" definition of the AS-278 program. Stand by for the next exciting episode.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

J. Sears

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

UNITED STATES GOVERNMENT

Memorandum

	Action	Info
R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
CENTRAL FILES		✓
		✓
		✓
		✓
		✓
		✓
		✓
DUE DATE		

TO : See list

DATE: OCT 12 1966

66-FM1-129

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: Cursory definition of Spacecraft Computer Program capabilities currently planned for AS-503 and AS-504

One of the possible actions which has been identified to help our spacecraft computer program development schedule is to fly the AS-503 mission with the AS-278 programs. I have indicated in previous memoranda that in order to do this we would probably have to add several routines to the AS-278 program to make it applicable for AS-503. However, as we have studied this matter in more detail, we have arrived at a point where only one routine is still considered a candidate -- some guidance of the SIVB simulating TLI. This is a command module program. There are no additions contemplated for the LGC. Those interested in exactly what capability would be available are referred to the AS-278 GSOP.

I am sure if we proceed in this way that it will have some impact on establishment of the final mission requirements, and in turn will influence how certain of the spacecraft capabilities for the lunar mission must be tested prior to making the AS-504 flight. I would like to call your attention particularly to the fact that we shall have no navigation (orbit determination) capability other than that associated with rendezvous for the AS-278 and AS-503 missions, nor will we have the ascent or descent guidance equations in the LGC. There has been much discussion on the testing of all of these. Based on recent discussions with ASPO mission planning people, I really don't expect that any mission requirements affected by this decision are of such a mandatory nature that we would be directed to proceed other than I have indicated above. Obviously, if this is incorrect, the sooner we find out about it the better.

Somewhat associated with this, it seems worthwhile to me to provide a list of the additions to the AS-278/503 program which will have to be made for 504. This list, presented below, is MIT's current best estimate and is by no means final, official or definitive, but perhaps it will serve to let you know what the job we have before us is as well as giving you some idea of the capabilities we intend to provide for AS-504.

<u>CMC</u>

1. Return to earth
2. LOI guidance
3. Direct intercept targeting routine

<u>LGC</u>

1. Descent Holman Injection guidance
2. Lunar landing guidance
3. Ascent guidance

CMC

4. Navigation
   a) SXT star/horizon and star/landmark
   b) Lunar landmark
5. Boost monitor
6. Orbit integration additions for
   a) Trans-lunar operations
   b) Lunar operations
7. Lunar ephemeris program
8. Lunar rotation routine
9. Lunar landing prediction routine
10. LGC initialization
11. Lunar landmarks (28)

LGC

4. Direct intercept targeting routine
5. Orbit integration
   a) Remove earth orbit
   b) Add Lunar
6. Lunar rotation
7. Lunar landing time prediction
8. LGC initialization program changes
9. Post landing service programs such as IMU angle storage
10. Lunar surface IMU alignment
    a) Normal
    b) AOT failure
11. Launch time determination
12. AGS initialization program changes

Finally, I suppose I ought to add the following remark based strictly on my own intuition -- namely, we have almost certainly got a computer storage problem on the AS-504 programs again if all the above items are added to the AS-278 program, particularly with all of the special flexibilities and options which will be suggested. Therefore, the fact that your favorite processors are listed above does not necessarily mean that we will be able to get them all in.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

J. Sears

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

UNITED STATES GOVERNMENT

Memorandum

	Action	Info
R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
		✓
E. Copps		✓
John Miller		✓
J. Dahlen		✓
J. Sears		✓
J. Nevins		✓
R. Battin		✓
Eldon Hall		✓
DUE DATE		

TO : See list

DATE: OCT 1 2 1966

66-FM1-130

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: Altitude and velocity limits imposed by the spacecraft computer program on the AS-503 mission

As you know, we are currently figuring on using the AS-278 spacecraft computer programs for AS-503. Ed Copps called me the other day to state that the orbital integration routines in the AS-278 program are scaled such that they will only work for altitudes less than about 5,400 nautical miles above the surface of the earth and velocities no greater than about 32,700 feet per second. (I am told the maximum values to be encountered in a nominal mission are about 3,900 nautical miles and 29,500 feet per second). He was looking for reassurance that this scaling would not present a constraint on the AS-503 mission, and I told him that I didn't think it would but I would check here at MSC. In the meantime, MIT is proceeding, assuming that these limits are not unacceptably restrictive for the AS-503 mission. If anyone knows a reason why this is not satisfactory, please let me know immediately.

Bill

Howard W. Tindall, Jr.

Addressees:
CA/D. K. Slayton
CF/C. C. Thomas
EG/R. C. Duncan
EG/D. C. Cheatham
PD4/A. Cohen
PM/O. E. Maynard
PM2/C. H. Perrine
FA/C. C. Kraft, Jr.
FA/S. A. Sjoberg
FA/R. G. Rose
FC/J. D. Hodge
FL/J. B. Hammack
FM/J. P. Mayer
FM/C. R. Huss
FM/M. V. Jenkins
FM13/J. P. Bryant
FM/Branch Chiefs
FM2/T. F. Gibson, Jr.
FM2/R. O. Nobles

FM:HWT:cm

N. Sears.

GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

R. RAGAN
D. HOAG
L. LARSON
~~CENTRAL FILES~~
DUE DATE

TO : See list

DATE: OCT 1 0 1966

66-FM1-131

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: More on Program Development

On October 5th, we had the second of our weekly all day program development plan meetings at MIT. Most of our attention was given to the open items on the AS-278 program which I will discuss later, but first I would like to pass on some general comments regarding the work at MIT. Based on their intensive planning over the last couple of weeks, it appears that staffing for program formulation (Norm Sears' area) and for program coding, integration, and check out (Ed Copps' area) is now adequate. They foresee no problem in the development of the AS-278/503 and AS-504 programs in these areas. In fact, they expect to be in a position to handle follow-on mission programming in a routine fashion. There is a shortage of people in John Dahlen's area. These are the guys who prepare the detailed program sequencing -- Chapter 4 of the Guidance Systems Operations Plans, for those who are familiar with that. They have several more people scheduled to move into this who they consider to be highly qualified and experienced which should help to relieve the situation. However, this relief will only be for programs developed after AS-278 since that GSOP is currently scheduled for release on about October 17th.

The other problem areas, as I have noted before, are the computer facilities used for program development -- namely, the 1800's soon to be augmented with a IBM 360/75. How quickly the new IBM computer will be on line continues to be problematical. The pacing item for this is the so-called MAC compiler necessary for running AGC programs on the IBM machine. And the hybrid computer facility is also constraining as noted previously. Phil Felleman has done a considerable amount of excellent work in laying out the projected schedule of its use based both on the current facility and in the augmented facility which I have described previously. It is our intention to continue the development of the justification for augmenting this facility for presentation to our management at MSC, probably around October 22nd. It is Phil Felleman's estimate that this equipment could be operational by about February 15th, provided they get the go-ahead by the first of November.

Following is a list of the open items associated with the AS-278 mission programs:

1. Manual takeover of the Saturn guidance during boost into orbit. The AS-278 GSOP presently includes this capability; however, it was hastily assembled and a considerable amount of further thought and planning has been carried out at MSC leading to the desire to change that

formulation. It is my understanding that Guidance and Control Division has dispatched the additional information MIT needs to develop this spacecraft capability to MSC's satisfaction. MIT has been directed to prepare an MDRB -- our change control document defining the work to be done and the schedule impact if it is to be done.

2. Trans-lunar injection (TLI). Guidance of the SIVB by the command module computer for a simulation of the TLI maneuver on AS-503 has been proposed. The objective here is to test the interfaces of the spacecraft with the SIVB; it is not considered essential to check out actual TLI guidance equations, although that would be desirable. Since this is the case, it is possible to utilize to a large extent either the external ΔV or Lambert guidance programs already available in the AS-278 program. The question as to which of these was to be used was finally resolved in favor of the Lambert, even though it requires an additional uplink and pre-thrust program. The reason the Lambert was chosen was that it is expected to be very much closer to the TLI final formulation than the external ΔV, and it is not expected that the development of these two extra processors is a particularly large job. MIT was requested to prepare an MDRB for Lambert steering of the SIVB with a request that if they encounter some problem which use of the external ΔV processor would relieve, they would inform us immediately. Incidentally, associated with providing this capability in the AS-278/503 program, we are informed that the all-digital simulation to support testing of the Saturn steering is in pretty good shape as a result of the work they had done previously. They feel they have a good model of the Saturn steering with the IBM guidance equations, gimbal dynamics, etc. This is a rigid body representation including no fuel slosh or bending, of course.

3. Lunar orbit insertion (LOI). MIT will prepare an MDRB to include the LOI guidance if they desire. We informed them that MSC was not particularly concerned whether this was included or not.

4. Stable orbit rendezvous. Jerry Bell (RAB) was scheduled to discuss the changes required to the rendezvous guidance with MIT on October 7th. We decided to delay initiation of the MDRB for this until our meeting next week, at which time, hopefully, the definition of this program change will be more definite.

5. LGC DSKY/eight ball discrepancy. MIT was requested to prepare an MDRB for the addition of the necessary transformations to make the computer and FDAI displays compatible.

6. APS and DPS minimum impulse. Aaron Cohen accepted the action item of reviewing within MSC the need for providing these capabilities in this program. MIT was told not to prepare MDRB's yet.

7. DPS "30 second" maneuver constraint. MSC is also to review the need for eliminating the current constraint on DPS maneuvers within the 26 to 30 second burn range which are not accurately controlled by the AGC

due to automatic throttling at that time. MIT was asked to delay preparation of an MDRB until MSC could establish its need.

8. IMU alignment backup. It has been requested that a capability be provided to align the IMU through use of the rendezvous reticle in the CSM and the LPD reticle in the LM. This capability is most desirable for the lunar mission where loss of the primary alignment systems would be extremely serious. MIT was requested to prepare MDRB's for both of these.

9. Reentry landing point targeting. MIT is continuing their investigation as to the earliest time it is possible to load the latitude and longitude of the reentry landing point. It is still hoped that procedures may be available for input and verification of these parameters at an acceptable time in the mission. If this investigation proves negative, MIT will be requested to prepare an MDBR.

10. Universal update. Action on this item had somehow been overlooked. It has been our intention to have MIT prepare an MDRB on this for some time, but apparently we had failed to request it. Accordingly, we did so.

11. Earth orbit navigation. Our old friend was discussed as usual. MIT was informed that our direction to delete this capability had been recently forwarded to them. MIT stated that they felt it their responsibility as the G&N contractor to formally bring to our attention their concern that this action is improper. We jointly agreed that their best course of action was to prepare a letter for the ASPO Manager stating their position on this matter. I must say I don't feel very strongly one way or the other about this, but it certainly is evident that MIT has a unanimous, sincere opinion. So do some MSC people.

I felt this meeting was quite fruitful and the MIT participation was again very cooperative. We have scheduled the next meeting for October 13th, and after that one, I might even start to tell you what the program delivery schedule actually is. How's that for suspense?

Howard W. Tindall, Jr.

Addressees:
(See attached list)

N. Sears

UNITED STATES GOVERNMENT

Memorandum

TO : See list

DATE: OCT 14 1966

66-FM1-132

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: LGC program requirements and mission constraints on alternate mission AS-278B

Following our AS-206 spacecraft computer program status review at MIT on October 6th, we launched into a discussion of the AS-278B mission and its demands on the guidance system. This alternate mission, you recall, is one in which the LM and command module are launched separately followed by a CSM active rendezvous. The LM would then be manned and a number of spacecraft systems tests would be carried out, perhaps including a LM active station keeping exercise and docking. This would be followed by an unmanned sequence of LM maneuvers basically the same as currently planned for the primary AS-206 mission.

After considerable discussion to establish what seemed to us to be reasonable mission constraints, we arrived at the following list of programs needed to augment the AS-206 program for use on the AS-278B mission. You will note that all of the changes are associated solely with the function of determining the orientation of the platform or aligning it prior to the AS-206 maneuver sequence.

1. Platform orientation determination is required and maybe a platform alignment program is also required, although we don't think so.

2. Star catalogue and associated data handling routines must be added.

3. Modifications to the routine providing pilot interface with the computer, i.e., input and displays will probably be required.

4. Preparation of an addendum to the GSOP would be needed and it is to be emphasized that this work would be applicable to the AS-278B mission only.

The following routines were also considered but are apparently not needed for the reasons listed.

1. G&N power-on and power-off programs. These programs, which are routinely provided on manned spacecraft to assist the pilot in turning on and off this equipment, are probably not needed since it is thought this process can be carried out manually, and it is strictly a one-time affair; i.e., as far as we could tell it is only necessary to turn on the equipment one time and never to turn it off.

2. Some thought was given to adding special digital auto pilot modes for RCS translation and rotation using the hand controller. Here again it is MIT's impression that processors are available in the current AS-206 program which can be utilized in the station keeping and docking exercise.

3. LGC initialization primarily associated with state vector and clock alignment updating. Apparently is is already possible in the AS-206 program to input these quantities both via uplink and DSKY.

4. Special programs to initialize and start the AS-206 maneuver sequence. Apparently the present AS-206 program already has these capabilities by means of uplink and DSKY inputs.

As you can see, the list of programs required has really been reduced to a minimum. In addition, these programs are probably required in very nearly the same form for the later missions, which means work on them is not entirely wasted. The list was kept this small by assuming that certain constraints on the mission were acceptable. In large part, this was done by carrying out a number of functions, manually by the crew, which are ordinarily under computer control. This will be apparent by glancing through the following list of constraints which I certainly don't claim to be complete, and in fact, some of the items listed may not even need to be there.

1. No provision is made for re-rendezvous in the LGC. In this category, note there is no processing of the LM rendezvous radar by the LGC nor is there attitude control in the LM program for aligning its rendezvous lights toward the CSM.

2. It is assumed that no change will be required to the AS-206 maneuver sequence program. I would like to point out, however, that considerable flexibility exists in the targeting and timing of the maneuver as the program is presently formulated.

3. Platform alignment to within about 5° of the preferred orientation about all 3 axes is acceptable for the AS-206 maneuver sequence. The intent here is to provide a coarse alignment of the platform while docked through use of the command module G&N. Of course, it would then be necessary to determine precisely the resulting orientation of the LM platform.

4. There will be no provision in the LGC to assist the astronaut in locating stars in the AOT. This must be done manually with whatever assistance is possible from the CSM.

5. It is probable the crew must check contents of the erasable memory word by word via the DSKY to insure that all critical parameters are stored properly after the LGC is turned on the first time. I am referring here to quantities such as accelerometer bias, scaling factor, etc., equivalent to those loaded by the K-start tape prior to

launch. This is probably not unique to AS-278B.

6. The only DSKY display programs to be implemented will be associated with the platform orientation determination program and those required for the crew to check out the contents of the erasable memory.

7. The G&N power-on and power-off sequence will be carried out manually by the crew.

8. An LMP will be available and in operation.

9. The RCS will be manually purged and pressurized.

10. The S&C band will be turned on manually.

11. The ECS primary water coolant valve will be manually activated.

12. No C or S band antenna steering will be provided.

13. No LGC AGS initialization will be provided.

14. If LM cold soak is required in the docked configuration, the CSM shall do it.

15. The LM shall always be extracted from the SIVB by the CSM even if LM 1 spacecraft changes are required [I am not certain this is a constraint imposed by the computer program].

16. The LM will be powered down during launch and until manned [here again I am not certain this is a program constraint]. This implies

a) There will be no launch T-M

b) There will be no launch abort or contingency orbit insertion capability.

[If it is determined that the LM can be launched powered-up, I should point out that the AS-206 program does provide these capabilities.]

Of course, the status of the AS-278B alternate mission is still quite confused. As I have indicated previously, it is our intention to do nothing now at MIT in support of this mission except to make sure the programs identified above, currently being prepared for the AS-278 program, are given enough priority to assure their readiness when the decision must be made around the end of November as to what we are going to do. In addition, we will attempt to determine what, if any, impact this activity would have on the AS-278/503 and the AS-504 spacecraft computer program development schedule. I would be very interested to hear from those of you concerned with this matter if you feel that either the list of programs or constraints given above are not accurate or adequate in some way.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
CA/D. K. Slayton
CB/A. B. Shepard
CB/J. A. McDivitt
CB/E. E. Aldrin, Jr.
CF/W. J. North
CF/C. H. Woodling
CF/D. Grimm
CF/P. Kramer
CF/C. C. Thomas
CF/J. B. Jones
EG/R. C. Duncan
EG/D. C. Cheatham
EG23/K. J. Cox
EG25/T. V. Chambers
EG26/P. Ebersole
EG27/D. Gilbert
EG42/B. Reina
EG43/R. E. Lewis
EG/43/M. Kayton
EG43/C. Wasson
ET/71/T. R. Kloves
EX/N. Foster
KA/R. F. Thompson
PA/J. F. Shea
PA/W. A. Lee
PD/R. W. Williams
PD4/A. Cohen
PM/O. E. Maynard
PM2/C. H. Perrine
PM2/K. L. Turner
PE7/D. Lockard
FA/C. C. Kraft, Jr.
FA/S. A. Sjoberg
FA/R. G. Rose
FC/J. D. Hodge
FC2/E. F. Kranz
FC3/A. D. Aldrich
FC4/M. F. Brooks
FC4/R. L. Carlton
FC5/G. S. Lunney
FC5/C. E. Charlesworth
FC5/P. C. Shaffer
FC5/J. C. Bostick
FC5/H. D. Reed
FC5/J. E. I'Anson
FL/J. B. Hammack
FM/J. P. Mayer
FM/C. R. Huss
FM/M. V. Jenkins
FM12/J. F. Dalby
FM13/J. P. Bryant
FM14/R. P. Parten
FM/Branch Chiefs
FM2/T. F. Gibson, Jr.
FM2/ R. O. Nobles
FM13/J. R. Gurley

FM:HWT:cm

D. Kears

MAY 1962 EDITION
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UNITED STATES GOVERNMENT

Memorandum

TO : See list

DATE: OCT 1 4 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-138

SUBJECT: AS-206 LGC program status

DUE DATE

On October 6th at MIT, we held a review of the AS-206 computer program which they have romantically christened "Sunburst". Our primary objectives were twofold; first, to make certain that the formulation of the program was consistent with the way we intend to fly the mission, and second, to determine the current status of the program development. Generally speaking, I would say we are in good shape on the AS-206. We appear to be on schedule with some tolerance for problems of a nature you ordinarily expect to encounter in this type of work, and with a few exceptions, the program as currently defined should be entirely adequate to support the mission.

It is still planned to release this program for rope manufacture on December 26th. This date has held firm for a number of months now, and Jim Miller, who has taken over direction of this program at MIT in the absence of hospitalized George Cherry, presented fairly detailed program development plans upon which he based his confidence of staying on that schedule. He identified as the two most critical items:

a) The descent guidance for Mission Phase 2 (i.e., the second DPS maneuver), and

b) The digital auto pilot which is also the major processor remaining to be completed. Jim pointed out that a number of processors have been coded and unit tested which are now awaiting the availability of the DAP for integrated systems tests.

Jim Miller has beefed up the manpower in both of these areas recently.

There was one item requiring immediate attention if anything is to be done about it. This involves the manner in which the LGC is set into action at Saturn launch. Apparently, the program is started by the receipt of a guidance reference release (GRR) signal sent some 3 minutes and 10 seconds prior to liftoff by the Houston MCC command system. There are two things that sound kind of lousy to me; one is the desirability of having to send a command from a remote site to start the system working, and the second is the fact that it is currently planned to send this signal so long prior to liftoff. Obviously, the problem here is that if a hold in the countdown is encountered after it is sent, it is necessary to recycle the launch countdown back as much as 2 or 3 hours which sounds completely unacceptable. I wouldn't be surprised if

I have this all confused. If you are concerned with this type of thing, I suggest you get ahold of someone who knows what they are talking about for a precise description of the situation. Incidentally, if program changes are required associated with this GRR problem, there is a possibility of schedule implications.

Another item on which we spent a considerable amount of time had to do with the implementation of two jet ullage, which is desired on AS-206 in order to make the DAP for that mission consistent with the DAP for AS-208. A question arose as to whether there should be some sort of interlock to inhibit the main engine start signal based on onboard sensing of ullage, or rather lack of it. It was finally decided that we should leave the program essentially as it is with a fixed duration of ullage and an engine start signal issued by the LGC at a particular time in the sequence. This was primarily to insure that the tests performed on AS-206 are applicable to AS-208. MIT did request that we direct Grumman to provide RCS jet fail indications to the LGC for use in their automatic jet select logic in a somewhat different way than is currently planned.

Other matters receiving consideration at this meeting were:

a) The possibility of utilizing the LGC to keep track of RCS fuel used and remaining -- a job which apparently cannot be done accurately in any other manner. MIT expressed reservations that the LGC would be able to do this accurately either. In addition, there may be computer cycle time problems since this processor would have to operate simultaneously with the DAP which is already heavily loading the computer.

b) The matter of increasing the size of the downlink lists from 100 to 200 words on the AS-206 program since FCD expects that this will be necessary for the later LM's.

MIT indicated that they intend to issue a new, complete GSOP around the end of November. The last one, R-527, was dated June 1966. MIT intends to release certain parts of this earlier since it is badly needed by some parties right now.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

J. Sears

GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

	Action	Info
R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
~~CENTRAL FILES~~		✓
[illegible]		✓
R. Battin		
E. Copps		
[illegible]		
[illegible]		
[illegible]		✓
[illegible]		✓
[illegible]		✓
DUE DATE		

OCT 22 1966

R. R. RAGAN

TO : See list

DATE: OCT 17 1966

66-FM1-135

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: Verification of LGC when powered-up in space

The other day at MIT, when we were discussing the alternate mission AS-278B, the question came up of how the astronaut assures himself that the contents of the erasable memory is as it should be when he first powers-up the computer in space. Since there seemed to be some confusion or uncertainty at MIT, I suppose that situation is the same throughout the universe. We were told, or at least I think we were told, that when first turning on the computer after it has been completely powered-down there is no assurance that the contents of the erasable memory will be the same as it was when powered-down. Since on every manned LM mission the computer must be brought on line from a completely dormant state, some procedure must be established for checking this portion of memory, I suppose. Is anyone within the sound of my voice working on that? In fact, who is supposed to? I guess we ought to ask MIT to do something, and we will.

Bill

Howard W. Tindall, Jr.

Addressees:
(See attached list)

N. Sears

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Memorandum

OCT 20 19..

R. R. RAGAN

R. RAGAN	✓
D. HOAG	✓
L. LARSON	✓
~~GENERAL FILES~~	✓

TO : See list

DATE: OCT 1 7 1966

66-FM1-136

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: Apollo Spacecraft Computer Program Schedule

DUE DATE

Since last week I promised to start quoting some delivery dates, here goes. We are currently planning release of the flight programs for rope manufacture as follows:

MISSION		DATE
AS-501/502	(CSM)	October 24
AS-206	(LM)	December 26
AS-278/503	(CSM and LM)	April 15
AS-504	(CSM and LM)	November 15

Accuracy of these dates, of course, decreases with how far they are in the future. Actually, I am quite confident that we can meet this schedule with the possible exception of AS-278 which still has on open item a number of additions that could impact the schedule. I am hopeful that it will be possible to improve or make earlier the AS-504 delivery. As you know, rope manufacture is expected to take on the order of 5 or 6 weeks which, if added to the above dates, will give you the readiness date of the actual flight configuration of the computer program.

We have requested that MIT prepare schedule delivery dates next week for the various sections of the GSOP's for the flights before us. The list is to include both preliminary and final versions as well as specifying the manner in which MIT proposes to segment the GSOP's. I'll pass these on when we get them.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

5010-108

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Memorandum

R. RAGAN	✓
D. HOAG	✓
L. LARSON	✓
CENTRAL FILES	✓
R. Battin	✓
E. Copps	✓
J. Fehr	
J. Lawson	
Eldon Hall	✓
J. Dahlen	✓
J. Fellema	✓
DUE DATE	

G. Sears

OCT 22 1966

R. R. RAGAN

TO : See list

DATE: OCT 1 7 1966

66-FM1-137

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: Another AGC program development report

Just got back from the northlands and couldn't resist sending out another note, although I really don't have much to report. The program development planning at MIT seems to be progressing nicely. We did pick up a couple of items that require attention; e.g.,

a) It is necessary that NASA provide specifications on the characteristics of the command signals from the AGC to the SIVB for the translunar injection simulation maneuver in the AS-278/503 computer program. Rick Nobles (FSB) has the action on this.

It was re-emphasized by MIT that they were not developing the capability of confirming stability of the over-all system. Their model of the SIVB is strictly rigid body and is not adequate for that purpose. It is my understanding that MSFC will perform whatever studies are necessary to confirm adequate stability for this maneuver mode. This will be discussed at the MSC/MSFC Flight Mechanics Panel meeting next week.

b) Studies continue at MIT on the formulation of the offset targeting to support the stable orbit rendezvous technique. This simulation work is required to prepare the framework of an MDRB [program change request]. This work should be completed within about two weeks, at which time they will prepare the MDRB. MIT is proceeding on the assumption that this capability shall be provided on both the LM and command module with an option available for each to compute the maneuvers necessary if the other vehicle is active.

c) An investigation is currently underway at MSC to determine the advisability of starting the LM descent propulsion system at 10% thrust rather than 30% thrust. It will simplify the LGC program, but since the formulation and coding must be completed very soon, we will derive very little benefit from this change if a decision is not made very soon. In fact, there will come a time where the change will make our job more difficult.

d) Since so much concern has been expressed, both at MSC and MIT, with regard to the need for star/landmark and/or star/horizon navigation on the AS-503 mission, I have requested MIT to prepare an MDRB for including that capability in the AS-278/503 program. Since the formulation of these programs has been pretty well completed, I expect the major impact will be in having to finish all the coding in time for initiation of program systems integration which is scheduled to begin early in December.

MIT reported that their work on the action items assigned them at the AS-204 CAR are essentially complete.

a) Procedures for manual computer re-start will be available October 14th. [Incidentally, MIT feels this action should never be carried out and certainly don't guarantee it; however, in accordance with our request they have laid out the best procedures they could for manually forcing the computer to re-start from a known location].

b) On October 14th they will provide a list of parameters which must be input into the erasable memory if a complete loss of erasable memory occurs. Procedures for carrying out this process will be ready by October 21st.

c) A complete description of the Flag Word will be available October 14th.

d) A description of how to correct the PIPA bias, etc., will be available on October 14th. Documentation of detailed crew procedures will be completed by October 21st.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

D. Sears
#73

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Memorandum

R. RAGAN
D. HOAG
L. LARSON
CENTRAL FILES

RECEIVED
NOV
R. RAGAN

DUE DATE

TO : PA/Manager, Apollo Spacecraft Program Office — DATE: NOV 3 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division — 66-FM1-141

SUBJECT: AGC program for AS-501/502 - Final status report

The attached memorandum lists all of the program changes required to the AS-202 program to fly AS-501 and AS-502. As you can see, there are quite a few, although most are quite simple. For example, some of these changes are merely corrections to bugs that were known to be in the AS-202 program when we flew it. We made a strong effort to minimize the changes, and it's my impression that all of these are really required with the possible exception of a couple that were put in to provide the flexibility we felt might be needed to make the program usable for the AS-502 mission which was not then completely defined.

As you recall, certain mission changes were required which took some time to negotiate, both here at MSC and at Marshall. Carl Huss, from our division, deserves a lot of credit for his work in getting these missions revised and thus minimizing the program changes required. (By the way, Carl is writing a note to explain the differences in the AS-501 and AS-502 missions in response to the question you penciled onto one of my memos). We know of no reason at this time why the AS-501 program will not do the AS-502 job. Some program verification may be required to check such things as the differences in the targeting, but it is our intention to keep this to an absolute minimum.

This program has gone together very nicely. Dan Likely and his team of AC and MIT people are to be commended for the professional manner in which they handled this job. The program was frozen October 11th - one day behind schedule. It completed test verification and was released to Raytheon for rope manufacture October 24th - on schedule. This program has no known bugs or deficiencies at this time. If development of all the AGC programs went like this, we'd be out of a job.

Howard W. Tindall
Howard W. Tindall, Jr.

Enclosure

cc:
EG/R. C. Duncan
FA/C. C. Kraft, Jr.
FA/S. A. Sjoberg (w/out enclosure)
FC/J. D. Hodge
FM/J. P. Mayer (w/out enclosure)
FM/C. R. Huss (w/out enclosure)

FM:HWT:cm

J. Sears
#73

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Memorandum

R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
~~CENTRAL FILES~~		✓
		✓
		✓
		✓
		✓
J. Sears		✓
		✓
		✓
DUE DATE		

RECEIVED
NOV
R. R. RAGAN

TO : See list

DATE: NOV 1 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-142

SUBJECT: In which some items of interest regarding the AS-206 LGC program status are discussed

Quite a number of things have been going on with regard to AS-206 mission plans, spacecraft configuration, and the LGC computer program development. I would like to take a couple of minutes here to let you know about the latest developments in the latter.

Ed Copps indicates that the program development is proceeding on schedule as far as he can tell, and that the next valid schedule check-point will occur in about three weeks. I suppose we will schedule a review about that time. MIT has been studying the effects of the spacecraft equipment deletions on the program and to date has found nothing that is not acceptable. They did point out that it is necessary for the ground to send certain commands which previously were optional. We did not take time to examine this particular subject in detail, but I would suggest that someone from the Flight Control Division should get in touch with Tom Price of our Flight Software Branch to learn more about this in detail.

One program change requested by ASPO was for the LGC to issue some additional commands in order that redundant relays could be used in two mission critical circuits. MIT indicated that this program change could be implemented without schedule impact since we had already indicated to them that it would be okay to delete several processors from the AS-206 program which were no longer required. Specifically, we dropped out the 3rd and 4th APS maneuvers and the RCS cold soak since they are no longer a part of the mission. We also indicated that we could probably omit the DPS cold soak phase from the mission if that provided a significant saving in program effort or, if it permitted, the use of a more desirable platform alignment. Apparently the alignment which has been chosen for the AS-206 has been somewhat constrained by this cold soak phase and makes necessary special prelaunch processing of some sort. MIT is to let us know if dropping this mission phase would be beneficial to them.

Currently there are no open items on the AS-206 program, although MIT is concerned about a couple of things. One is they are not happy about our one-second downlink. They feel that this will not provide enough data for post-flight analysis and are concerned that MSC will soon request additional downlink formats. The second item is associated with the LM spacecraft separation from the Saturn. Apparently we have requested that a constant attitude rate be maintained as opposed to an inertial attitude hold which would be simpler to provide. I gather they just honestly don't understand why anyone wants this constant rate mode, although they are programming it. Carl Huss was going to look into this a little bit. Apparently he was not even aware that was the way it was to be. Weird.

Two items were closed out as follows:

a) We have instructed MIT to implement 4-jet ullage in the AS-206 program; i.e., the computer program will command all 4 jets on for the duration of time which would be required if only 2 jets were used. This is to insure that the ullage will be sufficient for the main engine start in spite of jet failures which have been protected against by the jet select logic in the program. Implementing the 4-jet logic means there is no need for the ΔV monitor nor the changes to the spacecraft jet failure systems which had been suggested. The ΔV monitor, you recall, was a proposed program change [i.e., MDRB #206-19] which was to inhibit the main engine start signal if sufficient ΔV had not been detected by the LGC.

b) MIT was informed to change the DPS engine start sequence to 10% thrust rather than 30% thrust. This change is beneficial to program development and to the engine people - a rare occurence.

I might also point out we had a highly successful meeting with Grumman on October 20th where we discussed their requirements for program tapes and data packages for use on their simulation facilities. As I understand it, everyone agreed that we could provide tapes at any time Grumman requested them with the understanding that they would certainly not be flight qualified - in fact, their quality will likely be unknown at the time of delivery. We also indicated that the deficiency reports accompanying these tapes might be rather crude and incomplete. As a possible work around, it was suggested that Grumman could provide a knowledgeable resident at MIT for the last couple of weeks prior to their acquiring a tape. This person should then be aware of the status of the program when they get it. Actually, Grumman has taken steps to do this - two of their guys were up there just last week to get their feet wet.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT NOV 23 1966

Memorandum R. RAGAN

R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
~~CENTRAL FILES~~		✓
J. E. Miller		✓
John Dahlen		✓
Ed Copps		✓
Alex Kosmala		✓
Norm Sears		
Eldon Hall		✓
DUE DATE		

TO : See list

DATE: 1966

66-FM1-148

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: AGS program status for AS-278

I guess enough things have happened affecting the status of the programs for the AS-278 mission that I ought to issue another status report. According to MIT, work is progressing along basically on schedule. The major effort is currently in Ed Copps' area where coding of the program is going on which should be completed early in December. At that time all of the basic components of the program will have been compiled into a single working assembly. It is this assembly which Alex Kosmala's Program Integration Group puts through systematic debugging and then finally, when all of the systems are working together, through the final program verification. It is to be noted that this work is done with an assembly made up of the entire flight program - it is not broken down into subsections which are later assembled together. Of course, during the initial stages of this program integration the major task is to get the subroutines, which have been individually debugged and are running in this master assembly, to work with each other. That is, the task is to get these individual processors to run in sequential strings - the output of one serving as the input to the next - with astronaut inputs and displays all working properly.

As of last week all MDRB's [i.e., program modifications] under consideration were acted upon. Specifically, it was agreed to add the so-called universal update in both the CMC and the LGC. This was the only modification to the CMC and resulted in slipping the program delivery date about one week. Other LGC MDRB's approved were a GASTA transformation which was required in order to provide DSKY displays consistent with the FDAI eight ball and addition of a minimum impulse mode for the APS.

The affect of these modifications was to delay LGC program delivery approximately a week and a half. Thus, our best current estimate of program delivery for the AS-207 program is April 28 and the AS-208 program is May 5. Of course, every effort will be made to improve this delivery schedule.

Since work is proceeding again on the orbit rate eight ball, I suppose there may be some special processor required to compute and display initialization quantities for that black box. Paul Stull is checking into that, as well as what spacecraft this would be needed for, if any.

MDRB's which were not approved for the AS-207 program were those providing the capability for AGC steering of the SIVB simulating translunar injection and manual takeover of the Saturn during launch into earth orbit. These two routines would have resulted in an additional four weeks' impact on the AS-207 delivery, which was judged unacceptable. However, since a test of the AGC-SIVB interface is considered mandatory prior to the lunar landing mission, we have had no choice but to provide a unique program for the AS-503 command module. You recall it was our desire to fly both the AS-278 and AS-503 missions with the same programs, but this apparently is not possible for schedule reasons for the CMC. The LM programs will be the same. Since there is very little difference in the launch schedule of AS-278 and AS-503, we will have to maintain tight control on new programs to be added to the AS-207 program for AS-503.

As I see it right now, the additional programs consist of:

a) Simulation of the TLI steering of the SIVB.

b) Manual Saturn steering into earth orbit. (Holy waste-of-time, Batman!)

c) Use of star/horizon and star/landmark observations in the on-board navigation process.

MIT has been directed to proceed as noted above and will assemble a program development plan for the AS-503 command module program. I assume that soonest possible delivery will be in the order of a month after AS-207 - say, May 26.

Howard W. Tindall

Howard W. Tindall, Jr.

Addressees:
(See attached list)

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NOV 23 1966

UNITED STATES GOVERNMENT

Memorandum

R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
~~CENTRAL FILES~~		✓
R. H. Battin		✓
Ed Copps		✓
		✓
J. S. Miller		✓
		✓
John Dahlen		
Thomas Lawton		
Alex Kosmala		✓
DUE DATE		

TO : See list

DATE: NOV 14 1966

66-FM1-151

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: Ground rules for MIT man loading for AGC programming

This is really for my own records, but in case you are interested, we presented the following ground rules to MIT with Bill Kelly's (ASPO's MIT Contractual Officer) concurrence. These ground rules were to cover the work they are doing in revising their man loading estimates for contract negotiations which are coming up in the next couple of months covering their work for calendar year 1967.

1) Unique programs, both hardwire and erasable, are required only for:

a) AS-204, AS-206, AS-207, AS-208, AS-208B LM

b) AS-501, AS-503 CM, AS-504 LM, AS-504 CSM

2) Aside from AS-208B (i.e., AS-278B), no special programs are currently planned for any backup or contingency missions.

3) Although follow-on flights are scheduled, no unique hardwire programs are to be developed in their support.

4) However, for scheduled missions not listed above, it is recognized that work is required of MIT which must be man loaded, such as:

a) Generation and verification of erasable memory.

b) Update of documentation.

c) Additional verification and perhaps error analyses associated with differences in the mission plan from that for which the program was originally developed.

d) Etc.

5) MDRB action is certain. MIT shall man load to support this activity, defining the extent to which they plan to be able to respond; i.e., number and complexity of MDRB's anticipated per mission.

6) No AAP or EMPO (e.g., AS-504C) missions are to be included in the man loading.

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7) It is recognized that a number of missions will be transferred from main line Apollo to AAP or EXPO which will require programming support from MIT. This work will be covered by contract changes based on negotiations with MIT at a later date.

Incidentally, Larry Fry and I made a rough estimate of the probable decrease of the MIT proposal as a result of deleting AAP effort from the original proposal. It came out to be in the order of $500,000. We are also doing a certain amount of trimming in other areas which may yield up to another $500,000 or so, but I expect that will be about the limit.

Howard W. Tindall, Jr.

Addressees:
EG/R. C. Duncan
EG/R. A. Gardiner
EG44/W. J. Rhine
KA/R. F. Thompson
PD4/A. Cohen
PP7/W. R. Kelly
FA/C. C. Kraft, Jr.
FA/S. A. Sjoberg
FM/J. P. Mayer
FM/C. R. Huss
FM/M. V. Jenkins
FM12/J. F. Dalby
FM13/J. P. Bryant
FM14/R. P. Parten
FM/Branch Chiefs
FM2/T. F. Gibson, Jr.
FM2/R. O. Nobles
FM2/P. J. Stull
FM2/L. A. Fry

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Memorandum

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DEC 5 1966
R. R. RAGAN

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R. RAGAN		✓
D. HOAG		✓
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TO : See list

DATE: NOV 25 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-168

SUBJECT: Small program change needed in the AS-501/502 AGC program

In the course of development of the AS-206 computer program at MIT, a coding error was discovered which was immediately recognized as being common to the AS-204 and AS-501/502 programs. It is a scaling error, if you know what that means, which imposes the operational constraint of not operating one of the integration programs (i.e., Average G) at an altitude in excess of about 3,000 n.mi. Whereas this should pose no problem on AS-204, we have some concern about AS-501 and AS-502. Specifically, during the nominal mission, the Average G program is set into operation when the spacecraft is at an altitude of approximately 2,500 n.mi. Errors in the state vector update sent prior to the previous maneuver which places the spacecraft in this high altitude trajectory, or failure to get that update into the spacecraft computer for some reason, could result in dispersions wherein the Average G would be called upon at an altitude above the 3,000 n.mi. limit. Of course the guidance system would not recognize it was at the higher altitude except that a second state vector update is transmitted just before Average G is turned on in order to provide acceptable reentry conditions and landing point control. The whole problem results from poor quality updates or none at all.

In examining this problem with MIT, it was determined that approximately eight words of the program would have to be changed to eliminate it. Of these, six words are three double precision constants and two are program steps of some type, I think. They are all located in a single rope module and since they are so completely isolated, a minimum re-verification effort is required to certify the changes for flight.

Ropes for the AS-501 program are currently being manufactured by Raytheon. It would be unwise both in terms of schedule and cost to interfere with their completion. The rope modules which they are now producing will be perfectly adequate for verification tests and could even be used in flight if we are willing to accept the danger of an erroneous state vector update or the failure of it to be received. On the other hand, it is currently our consensus that we would be wise to manufacture a single new module to be substituted in the spacecraft when it's available. It will cost about $15,000 and will take about 30 days to make starting after delivery of those now in process. The cost in effort and treasure is justifiably small to procure the insurance the new rope would provide for possible update problems, particularly considering the current level of confidence we have in that business. It is our intention to proceed unless directed otherwise.

Incidentally, it is my understanding that one of the maneuvers on the AS-502 mission is carried out at an altitude in excess of 3,000 n.mi. and thus we will have no choice but to make this correction for that flight.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

OPTIONAL FORM NO. 10
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UNITED STATES GOVERNMENT

Memorandum

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DEC 5 1966
R. R. RAGAN

R. RAGAN	✓
D. RGAN	✓
L. LARSON	✓
~~CENTRAL FILES~~ R.H. Battin	✓
Ed Copps	✓
John Miller	✓
Eldon Hall	✓
Dave Dahle	✓
Jim Lemons	✓
Dan Lear	✓
Alex Kosmala	✓
DUE DATE George Cherry	✓

TO : See list

DATE: NOV 28 1966

66-FM1-169

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: LGC program status for AS-206

We spent a lot of time at MIT last week wrestling with the AS-206 problem. Although in a previous note I expressed some optimism regarding possibility of recovering some of the one month slip MIT draped on us, they have convinced me now that there is really not much chance. As a result we pretty well convinced ourselves that it will be necessary to release a tape on December 27th, our old flight program release date, for manufacturing ropes to be used for spacecraft systems tests at the Cape. At least this "B-release" will be needed unless the Aurora 88 programs can satisfy that requirement. MIT points out that if it is necessary for them to test the B-release assembly and determine it's deficiencies, that effort will result in a further delay in release of the flight program. We are looking into the possibility of doing that sort of program checkout on the Bit-by-Bit simulator here at MSC if it can be made ready in time. It appears to me we can't do much more to improve the situation.

MIT has brought in superstars Alex Kosmala and George Cherry on a part-time basis even at the detriment of program development for the AS-278 mission; we have reduced the program requirements to the limit even to the extent of deleting thorough restart protection - a subject which I shall discuss in a little more depth later. We are retracing the AS-204 footsteps almost exactly and as we did that time will attempt to derive maximum benefit from whatever flight schedule slips are experienced, although right now we certainly can't count on anything like that.

Regarding the elimination of restart protection, I would like to point out that this isn't a closed issue since G&C have expressed much concern over this. Apparently in the design of the Block II computer, decisions were made based on the assumption that restart protection would be provided in the software. They feel the probability of encountering restart situations on Block II flights is relatively high and could result in disaster if not handled properly. Ed Copps made a guess that to provide complete restart protection would cost another couple of weeks for program delivery, but it must be emphasized that that is just a guess. I gather that it really is a rather complex process to go through the program and make it completely insensitive to interruptions which can occur at any time. Our current direction to MIT is to provide restart protection for those periods during which the probability of occurence is very high, such as staging from the descent to ascent power. At other times,

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in the event of an interruption, the computer will send the engine-off signal and will release the digital auto pilot. Protection of the state vector and current time is also provided and mission phase registers are cleared such that no further activity will be called for by the computer. What this amounts to is that things are put into a more or less dormant state which will be known to the ground pre-mission such that it should be possible to issue new commands in an intelligent manner to get things going again. It probably will be a major undertaking in the MCC and may have implications on the RTCC program. Obviously it's not a good substitute for restart protection. Therefore, we have requested MIT to examine this subject in more depth, first of all identifying to us procedures to be carried out if we stick with the program as described above, and second to let us know with somewhat more precision the schedule impact associated with more complete restart protection.

Part of our meeting at MIT included participation by Grumman, which resulted in a couple of things. First of all, in response to our strong recommendation, they have finally agreed to send one of their men to MIT on an almost full time basis for the next month or so in order to provide themselves with a first-hand knowledge of the program status as it develops. MIT is completely in accord with this. Another matter discussed concerned Grumman's recommendation that a third APS maneuver be carried out. An on-the-spot assessment of this indicated that it should be possible to initiate such a maneuver from the ground using the APS-2 mission phase processors and that no program additions would be required if Grumman were successful in talking the ASPO office into doing it.

And that's about it -

Howard W. Tindall, Jr.

Addressees:
(See attached list)

Norm Sears
#73

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
DEC 5 1966
R. R. RAGAN

	Action	Info
R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
~~CENTRAL FILES~~ [illegible]		✓
[illegible]		✓
[illegible]		✓
Eldon Hall		✓
[illegible]		✓
[illegible]		✓
Norm Sears		✓
DUE DATE		

TO : See list

DATE: NOV 28 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-170

SUBJECT: More interesting things about our work with MIT

I always start out these MIT newsletters with the hope they will be short enough that you'll be willing to read 'em. A couple of things came up at our Program Development Plan review on November 16 there that I thought I would pass on.

1. It's becoming more and more obvious that the program development facilities at MIT - both digital and hybrid - are going to be severely saturated during the first 3 or 4 months of next year. During that period we will be working simultaneously on the AS-206, 207, 208, 503 CM and two 504 programs, and we certainly will not have the second hybrid on the line. And so all this work will be dropped on the two 1800 digitals and the single hybrid facility until the IBM 360 digital computer is made operational. Since I am convinced the 360 readiness will not come early, I have asked MIT to set up a special task force specifically to keep the development of that facility progressing at the greatest possible speed. In addition we propose to help as much as we can by doing such things as preparing programs here at MSC for use in checking out the vital MAC compiler being developed by one of their contractors.

2. It is my understanding that all AC effort on program development being carried out at Milwaukee shall be terminated upon delivery of the AS-501 documentation which is scheduled for delivery on about December 5. The nine AC people who were sent to MIT for work on AS-501 are all being retained and are now working on AS-206.

3. It looks like we will be able to have a meaningful computer storage review in January. Ed Copps pointed out it is not only lack of storage that's going to trouble us, but also other things like the limit to the number of verbs and nouns, whatever they are, that are available.

4. Rick Nobles and his guys struck a vein of gold the other day up at MIT in the form of detailed flow charts of some parts of the program. These flow charts are the form of documentation everyone felt in their bones must be available somewhere 'cause you just can't program without something more definitive than the GSOP. Now that we have discovered them, MIT has agreed to let us use them with the understanding that they are not controlled documents and that MIT retains no responsibility for their accuracy and quality. We are delighted to accept the flow charts under those terms and will be responsible for reproducing and distributing them

to whoever has need to know. I would like to reiterate that we have always maintained that the MIT documentation is inadequate, particularly in the area of flow charts and I have every intention of emphasizing that battle as soon as we get our program development plans in shape.

5. Some weeks ago we discussed the possibility of having several MSC people associated with flight crew working in residence at MIT with Jim Nevins' merry band on the development of Chapter 4 of the GSOP and associated crew procedures. Our objective was twofold - to speed up completion of that work for AS-504 as well as training these people to service the flight crews in their training for these tough Block II missions. MIT is still anxious to have these people come, but I understand from a brief discussion with Joe Loftus, who is handling this matter at MSC, that he has run into some problems. I certainly hope he is able to overcome these soon because it sure looked like a good idea to make MSC as independent as possible of MIT in the training of flight crews.

6. It looks like our biggest schedule problem will be delivery of the AS-207/208 programs. Although we have been meeting our AS-278 milestones with regard to GSOP delivery and program coding pretty well, MIT has recently revised their estimate of how long it takes to perform program integration and verification. It seems to me that the only way to improve the delivery schedule is to get the facilities MIT needs as soon as possible, as noted above, and to reduce the amount of work that is required. We are pursuing the idea of establishing processor priority lists both here and at MIT with the intent of carrying along all of them (including those unique for AS-503) in the AS-278 program assemblies, but giving maximum emphasis on the debugging and integration to those with the higher priority. For example, it's evident that it is not necessary to have the entire concentric rendezvous flight plan operating to perform the AS-278 mission, since the maneuvers in those re-rendezvous mission phases will be established pre-flight and/or by ground control a la Gemini with the need for onboard maneuver determination starting only at TPI. I'm sure there are a number of other processors which could also be labeled not mandatory for the mission. It is our intention to see just how far we can back off in an effort to help the schedule. It is rather depressing that we have to take steps like this, but the advantage of this approach is that if the program integration proceeds faster than anticipated, or if more time becomes available for one reason or another, it will only be necessary to start working on processors which are already in the assembly, which is a much easier thing to do than to add them in when a reprieve occurs. And of course it gives us the option of accepting delivery of a flight program in which some of the lower priority processors are not working in order to obtain it sooner.

Wasn't very short was it, or interesting either, but I'll be darned if I'll throw it away after getting it to this stage.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

J. Sears

UNITED STATES GOVERNMENT

Memorandum

R. RAGAN	✓
D. HOAG	✓
L. LARSON	✓
~~CENTRAL FILES~~	✓
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DUE DATE	

TO : See list JAN [illegible]

R. R. RAGAN

DATE: DEC 22 1966

66 FM1-188

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: DAP initialization simplification

Ken Cox, Rick Nobles, Charley Parker and I got together to see what could be done about reducing the number of crew displays and inputs associated with the digital auto pilot (DAP). As you recall, the DAP's require initialization by the crew who specify the spacecraft configuration, choice of RCS quads to be used, dead-band, RCS jet failures, etc. These quantities are displayed to the crew prior to each maneuver and must be overridden if unsatisfactory. We see no way around those displays and inputs.

It was our desire to attempt to reduce or eliminate the requirement for input of additional quantities such as spacecraft weight, moments of inertia, initial engine gimbal angle settings, etc., prior to the initiation of main engine maneuvers. It has been noted on numerous occasions that all of these parameters could be determined by the computer itself to well within the degree of accuracy required. For example, it should be sufficient that the final engine trim angles experienced during the previous maneuver be used at the start of the next; the weight and moments of inertia are more-or-less dependent upon the amount of main engine propellant which has been expended. A running account of the propellant expended could be continuously carried in the computer probably based on ΔV_m, which is computed during each maneuver. Ken Cox has prepared curves of each of these quantities as functions of weight which can be used to prepare linear approximations as functions of the summation of ΔV_m to be supplied to MIT.

It is to be emphasized that the only reason these parameters need be computed on board is to provide a backup for communication failure or lack of a ground station at the time it is needed since it is the intention of the Flight Control Division to update these parameters from the ground routinely. Therefore, it is our desire that these quantities be computed and stored away in the computer at the conclusion of each main engine maneuver rather than just before the next so that the ground supplied data is not wiped out by the less accurate values computed o[illegible] board.

It is our intention to tell MIT that there is no [illegible]irement to display these quantities to the crew, and the program w[illegible] designed that way unless we are informed that this is unacceptabl[illegible] representatives of the flight crew. If they feel it's necessary to see [illegible]se displays, then it must be with the understanding that there will be no special automatic updating of these quantities. Rick Nobles is going to check this out.

MIT was requested to prepare an MDRB based on a description of the requirements noted above given to them over the phone on December 19. We'll attempt to get it in AS-258 but if the schedule impact is too great (as it probably will be) we'll get it in AS-504.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

K. Lears

UNITED STATES GOVERNMENT

Memorandum

R. RAGAN
D. HOAG
L. LARSON
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DUE DATE

JAN ...

R. R. RAGAN

TO : See list

DATE: DEC 2 8 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

~~66~~ FM1-189

SUBJECT: We've bit the bullet on GRR

The fact that the 206 LM is the only LM to be powered up when launched presents a requirement for some unique manner for the G&N to detect or at least be informed that liftoff has occurred. In the absence of a hardwire liftoff signal, it had been intended to transmit a guidance reference release (GRR) discrete by means of an RF link to the guidance system at a pre-determined time prior to liftoff. Most recently this value was at T-30 seconds in the countdown. Once this signal was sent there was no way to stop the platform from being released and the computer transmitting commands on its preset sequence. This has caused a great deal of concern everywhere, - at MIT, at the Cape, and here at MSC since Saturn countdown history includes some rather weird holds. Our problem was that any interuption in the countdown occurring after GRR was transmitted would force a recycle of about 2 hours to get the G&N squared away again and could very likely result in scrubbing that launch attempt. MIT has proposed a fix for this by a change in the spacecraft computer program which we have decided to implement. It is the purpose of this memorandum to inform you of this rather significant programming chance.

In place of a hardwire or RF signal of liftoff, we intend to detect the chance in accelleration that occurs at liftoff by the guidance system itself. Since the platform is activated long before this time, it is merely necessary to provide a small, relatively simple program for monitoring the ΔV which, when a pre-established threshhold has been exceeded, could provide a discrete to be treated precisely as the GRR signal. Obviously this is not any gigantic breakthrough except in the sense we have decided to do it. Although the concept seems well founded, I'm sure there will be some continuing discussions as to the th[...]d to be selected. MIT is currently proposing 1.[...] g's. (Recall the [...]is experiencing 1 g prior to engine ignition). I[...]rder to permit [...]on to rage on on this subject, the threshhold [...]be located [...] storage. Another choice to be made but which [...]ot influen[...]mentation of the program is what system shoul[...]stablished [...]rationally. MIT would prefer using the ΔV mo[...]as backup [...]al sent within the last several seconds pri[...]liftoff. [...]se the liftoff may not be detected for as much a[...] seconds w[...]sult in small spacecraft state vector error[...] I am sure t[...]ble for the control of the flight will insist that the G&N ΔV monitor be prime and the GRR discrete via RF would be sent only as a backup in the event some G&N failure has been detected immediately after liftoff.

It is probably worth pointing out that MIT is anxious to make this change and are confident that it is something they can really do without running into trouble. They feel the impact on program delivery is negligible and in fact point out that their effort required for this programming change and its verification will probably be less than that required for the development of workaround procedures involved in the recycle countdown. If we run into some sort of insurmountable problem not unforseen at this time, it should be a relatively simple matter to retreat to the system we had before this change, at least insofar as the spacecraft computer program is concerned. The basic programming to handle the GRR signal is not being changed. Accordingly, if we revert to the procedure of sending GRR at T-30 seconds it will only be necessary to change the value of this time in the erasable load.

Well, that's about it. I hope everyone will be happy about this. I know I am, if it only cuts down on the number of telephone calls on this horrible subject.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

J. Sears

GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

	Action	Info
R. RAGAN		✓
D. HOAG		✓
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DUE DATE		

JAN 9 1967

R. R. RAGAN

TO : See list

DATE: DEC 22 1966

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

66-FM1-191

SUBJECT: MIT's digital computers are saturated until the IBM 360 becomes operational

I guess I ought to record the saga of the MIT 360 computer, if only so that it may take it's proper place in history. It is a little adventure which has been going on in the shadow of the more dramatic crises at MIT and is now rising to the surface in it's own right. Although it looked as though there was not much we could do about it except watch in fascinated horror, we have taken some steps which I hope will be effective and which might interest you.

As far as I can tell, somewhat less than a year ago MIT foresaw that the two Minneapolis Honeywell 1800 digital computers they are using for spacecraft computer program development would be inadequate at some time in the future. In the absence of good programming plans, it's hard to know how they either predicted this would be the case or were able to convince anyone of it. In fact, I guess they did have a bit of trouble since it wasn't until June that they were finally given the go-ahead to procure an IBM 360 by MSC. Installation of this computer has proceeded, along with training of MIT personnel to use it. IBM contracted to supply some important special programs, which they have apparently delivered on schedule, and MIT has prepared some others to permit use of this facility. But the one which now appears to be the most critical of all is the MAC compiler - a complicated service program which translates symbolic programs into computer language. MAC is the MIT equivalent of IBM's Fortran, except that it is said to be superior. The development of this program was contracted to Hankins - a Boston outfit employing between 40 to 80 people, depending on who tells you. The compiler was to cost about $170,000 and was to be delivered January 15th with a $200 a day penalty clause in the contract for late delivery; Hankins refused an incentive reward for earlier delivery. I have no idea how the January 15 date was selected. But I am certain of one thing - it is about two months too late. The fact is the AS-206 program development by itself has now saturated the two 1800 digital computers and it's evident the situation is going to become much worse before the IBM 360 becomes operational. Debugging and integration of the AS-207 and AS-208 programs has just begun, and this activity will impose a very heavy load on the digital computer facilities very soon.

Hankins is not going to deliver on schedule. They estimate a slip of about approximately 6 weeks. Of course, delivery of the MAC compiler around the

1st of March does not by any means guarantee operational capability at that time - it will probably take at least another month to get the system working. Unquestionably the lack of adequate digital computer facilities at MIT during the first months of next year is going to impact delivery of the AS-207/208 programs badly, which is going to be extremely painful to bear.

What can be done about this? Well, MIT has obtained as much programming assistance for Hankins as is worthwhile in an attempt to prevent his delivery schedule from slipping even further, although I sure wouldn't count on it. We are attempting to identify all tasks that could be transferred from MIT to our CDC 3600 simulation facility at MSC. We have also offered to supply our 3600 software packages to MIT when completed about the first of the year for their use on whatever 3600 systems are available to them in the Boston area. These steps may help some, but do not really solve the basic problem - namely what has happened at Hankins. In spite of recent discussions with them emphasizing the importance of this pacing item, it becomes apparent that management of that organization is immature and unstable - completely unreliable. MIT and MSC have agreed that to maintain an approach depending solely upon Hankins is unacceptable. In our joint search for some way to work around this problem, it has been concluded that the best "backup" course of action is to replace the MIT developed MAC programming system with the IBM Fortran which, of course, exists right now and is said to be working well on the 360. This makes it necessary to completely recode the simulation programs, those defining the environment, spacecraft systems, world earth models, etc., into Fortran. However, since these two compiling systems are so similar, this conversion is not expected to be a very difficult or complex task although it will be time consuming. These programs are very large. Since the CDC 3600 facility here at MSC will also use these MIT simulation programs, we have been routinely obtaining and documenting them. It's our intention to supply this material to MIT for the use of their subcontractor, probably IBM, who will be given the task of this conversion. It is anticipated that parts of this simulation will be available for use during the latter part of January and the complete package should be finished in less than two months. Thus it is evident that this is a quicker approach for getting the IBM 360 on-line even if you believe the new Hankins delivery schedule. But I must say I have no faith whatsoever in that organization in spite of MIT's valiant efforts to support them.

I am very pleased to report that key personnel at MIT have given enthusiastic and wholehearted support to this plan. They have worked very hard to solve the problems and to get IBM on-board and working promptly and efficiently. I understand that if the Fortran approach succeeds as we anticipate it will, MIT will probably not maintain the simulation programs in MAC language for the 360 but will convert over completely to Fortran. Of course, they will have to carry along the MAC simulation system for the 1800 computers as long as we continue to use them at MIT. My personal opinion is that we will still be using them at the [illegible] of next year.

Aside from cutting back on the programs and thus reducing the work required, relieving the overloaded digital computer facilities at MIT seems to me to be the only course of action available to improve the delivery schedule for the AS-205 and AS-208 programs. Although it has taken some time to arrive at this solution, I believe it to be the best we can do unless you want to pray that the flight schedule will slip.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

Norm Sears

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
JAN 1
R. R. RAGAN

	Action	Info
R. RAGAN		
D. HOAG		
L. LARSON		
CENTRAL FILES		

DUE DATE

TO : FM2/Flight Software Branch

DATE: JAN 9 1967

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

67-FM-1

SUBJECT: Uplink will be on LM-4

A decision was made yesterday which I am sure will make a lot of people happy. ASPO has finally decided to equip the LM-4 with a digital up-link. Obviously, the associated computer programs must be added to the AS-504 LM program. I assume that these are the same as those developed for AS-208 and should present no significant problem.

Apparently it is too late to equip the AS-503 LM in this way, but since we are using the AS-208 program for that mission, that has no influence on our programming requirements. Please take whatever action is appropriate regarding technical direction to MIT.

Howard W. Tindall, Jr.

cc:
CF/C. C. Thomas
CF24/C. A. Jacobson
EG/R. C. Duncan
EG25/W. H. Hamby
EG43/R. E. Lewis
PD4/A. Cohen
FC4/M. F. Brooks
FL/J. B. Hammack
FM/J. P. Mayer
FM/C. R. Huss
FM/M. V. Jenkins
FM2/P. J. Stull

5010-103

John Sears

GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

R. R. RAGAN

	Action	Info
R. RAGAN		
D. HUSS		
L. LARSON		
DUE DATE		

TO : See list

DATE: FEB 8 1967

67-FM1-3

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: Rope manufacture for AS-502

This note is to inform everyone that the AS-502 spacecraft computer program ropes will be made precisely the same as those for AS-501. Specifically, it is MIT assembly Solarium 55. You recall Solarium 54 was our original AS-501 A-release, but it was necessary to make a modification in one of the rope modules to correct a scaling problem.

Cline Frasier was given the recommendation to direct Raytheon in accordance with this on January 6, and it is my understanding that he intended to have Raytheon begin rope manufacture for AS-502 immediately. He informed me that the manufacture of the AS-501 ropes will be completed by about January 12th.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

Lorin Sears

UNITED STATES GOVERNMENT

Memorandum

R. RAGAN	
D. HOAG	
L. LARSON	
CENTRAL FILES	

R. R. RAGAN

TO : See list

DATE: JAN 1 0 1967

67-FM1-4

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: No special spacecraft computer programs are to be developed for AS-208B and AS-503

DUE DATE

The decision has been made by the Apollo Program Manager that unique computer programs need not be developed for missions AS-208B (LM) and AS-503 (CM). This decision was brought about due to concern that effort on these programs would affect development of the main line programs. It is certainly consistent with numerous other actions taken recently in support of this activity such as augmenting the MIT staff and providing additional facilities for this work.

AS-208B LM:

As you recall, MIT had been directed to develop a LM program in support of the AS-258B alternate mission to be flown if some failure on AS-206 precluded flying the AS-258 mission as planned. It was to provide the capability for the crew to initialize the system such that it could carry out an unmanned maneuver sequence basically equivalent to that planned for AS-206. The only addition to the AS-206 program for AS-208B was the capability of performing an inflight alignment of the platform by the crew. Although MIT has been directed to cease work on a unique AS-208B program, they have been requested to investigate the use of the AS-206 program without change for the AS-258B mission. I feel there is a good chance that by a combination of special crew procedures and assistance from the ground, techniques could be developed for carrying out this backup mission with that program.

AS-503 CM:

It had been felt desirable to add three capabilities listed below to the AS-205 CM program specifically for the AS-503 mission. Since the schedule impact was unacceptable for the AS-258 mission, direction had been given to MIT to develop a unique AS-503 command module program consisting of the basic AS-205 program with the following added: (a) astronaut steering of the booster into earth orbit, (b) star/landmark and star/horizon navigation, and (c) TLI steering of the SIVB. Now, based on a review by the Apollo Program Manager, it has been concluded that the over-all Apollo project will benefit more by using the AS-205 program as is. MIT has been directed in accordance with this decision.

For the sake of completeness, I might point out the rationale behind the decisions for these deletions.

a) It has been concluded that astronaut steering of the booster is not required for main line Apollo. At some later time, when schedule and storage permit, it may be desirable to reconsider this addition. Agreement has been reached by all responsible management personnel, both here at MSC and at Headquarters, on this subject.

b) It is felt that adequate experience and confidence may be obtained in the spacecraft navigation mode utilizing star/landmark and star/horizon observations on AS-503 by merely making the observations as previously planned, but not processing them onboard except to include them on the downlink for post-flight analysis.

c) Although some elements of MSC have been proposing that command module guidance steering of the SIVB would be prime for the translunar injection (TLI) maneuver, the Program Manager emphasized that this is not MSC's position, and as a result the only purpose this program could provide on AS-503 is a backup in the event of a failure of the Saturn guidance prior to the maneuver. Adequate alternate procedures are available for post-flight analysis of the spacecraft guidance systems to determine if it could have handled this task properly in the absence of the actual TLI guidance program.

I should point out that it is currently planned to include the capabilities discussed in both (b) and (c) in the AS-504 command module program.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

J. Sears

UNITED STATES GOVERNMENT

Memorandum

	Action	Info
R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
CENTRAL FILES		✓
DATE: JAN 10 1967		
67-FM1-5		
DUE DATE		

TO : See list

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: Significant modifications currently planned in the Apollo Spacecraft Computer Programs

Quite a number of decisions have been obtained from the Apollo Program Manager affecting the development of the AS-258 and AS-504 spacecraft computer programs which I am recording here for my own later reference. As usual, I will send it along to you on the chance that you might be interested.

RCS translation maneuvers:

Although provision was being made in the AS-258 and AS-504 computer programs for G&N controlled RCS translation maneuvers, this capability is being deleted. As I understand it, the flight crew supported this decision which implies that all RCS translation maneuvers in both the command module and LM must be performed manually.

Auto proceed:

Auto proceed is the misleading term which has gained popular usage to define a capability requested by the crew for simplifying the procedure whereby the computer is commanded to progress on to it's next function with minimum input from the crew. At one time it was proposed that there be no input at all from the crew under certain circumstances. However, at this time the goal apparently is to provide the crew with the capability of making a "Proceed" command to the computer by a keyboard button assigned exclusively for that function in place of "Verb 33 Enter" - a 4-punch operation. No modification is currently planned associated with this in the AS-258 programs. However, Dr. Duncan has stated that it is his intention to provide this capability on the AS-504 and subsequent spacecraft through the redesignation of the "standby" button.

Direct intercept:

This program, which provides the capability for the crew to target a minimum ΔV, 2-impulse rendezvous sequence of maneuvers, was originally included to provide a flexibility it was felt might be required. Rendezvous mission planning, including aborts at the moon, has now progressed to the point where there is no recognized need for this processor, and as a result it is to be deleted from all Apollo spacecraft computer programs.

LM S-band antenna steering:

Although it had been tentatively decided to drop this capability, more definitive mission planning has revealed that there are critical periods in the mission, particularly during descent, wherein crew activity demands computer assistance in steering the LM S-band antenna to acquisition with the ground. Accordingly this capability is to be provided in the AS-504 LM program.

LM platform alignment while docked:

The Program Manager feels some provision should be made for alignment of the LM platform while docked without attitude maneuvering of the craft. The procedure he proposes is for all necessary computations unique to this process to be carried out in the LGC utilizing data already available from the CMC programs. It is probably too late to provide this capability in the AS-208 program, but it should be available for AS-504.

DPS backup of SPS:

At one time there was some consideration given to deleting the DPS backup of the SPS. Since procedures must be developed making large DPS maneuvers docked on the development flights, this proposal has been dropped.

Descent guidance:

Another major program change which has been under consideration is to substitute for the current landing site targeting a fuel saving approach referred to as "range free". In view of recent developments associated with the LM spacecraft hardware, this proposal is not considered a requirement at this time, and so the descent guidance will proceed as it has without change. However, analysis will be carried out on the G&C proposed modification to the descent program which would permit a range free option if that should become necessary at some future time. This option will not be included in the AS-504 LM program unless time and storage permit. A decision on this matter probably need not be made for another four or five months.

Our long awaited "Black Friday" review at MIT is now scheduled for Thursday, January 12, 1967. At that time other modifications will probably be made for storage reasons based on priority and size of the various processors and their options. It should be lots of fun. I'll let you know if anything interesting happens.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

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

UNITED STATES GOVERNMENT

Memorandum

TO : See list

DATE: JAN 23 1967

67-FM1-9

FROM : FM/Deputy Chief, Mission Planning and Analysis Division

SUBJECT: Latest on the AS-206 spacecraft computer

DUE DATE

During the January 11 program development plan meeting at MIT, a couple of things came up regarding the AS-206 program that are probably worth recording here.

The most significant one, affecting date of the program release, involves verification testing. MIT has laid out a complete test plan of about 46 runs. It was their strong recommendation that if time permits, i.e., if other factors are delaying the flight sufficiently, they should carry out the entire test plan. This would flight qualify the program not only for the nominal mission, contingency orbit insertion and launch aborts, but also would verify the system's capacity for tolerating spacecraft systems failures such as RCS jets or computer interrupts, etc. They felt they could do the whole business by February 15, going into configuration control about the 1st of February. Alternatively, MIT and MSC people have identified nine computer runs which the program must execute successfully before we would be willing to use it in flight. These mandatory tests could be carried out within the previously stated schedule with a release on about January 30. The Apollo Spacecraft Program Manager gave permission to slip release of the flight program to do the more complete job in accordance with our recommendation to do so on January 12.

You will recall our agreement with Grumman to release a program tape to them whenever they felt the program and their facility were ready. It is my understanding that we are making the first of these program releases on about January 18 along with sufficient typical test runs and verbal instructions to permit Grumman to make the most of it. Since early December, Grumman has assigned one of their better people, Clint Tillman, to duty at MIT for about two or three days each week. This arrangement seems to have worked out very well from everyone's viewpoint, I'm very pleased to report.

The AS-206 operational trajectory has just come out and apparently is based on four-second ullage. Since this indicated there is some confusion, Tommy Gibson and I thought it might be worthwhile to reiterate here that the spacecraft computer program is being designed with thirteen-second ullage as previously reported. This duration was selected, you recall, to provide adequate ullage in the event only two jets are active. It was our way of protecting against RCS jet failures without providing logic for changing ullage time in that event.

We have experienced considerable difficulty in obtaining from the Engineering and Development Directorate the necessary propulsion system data needed to complete the formulation of the spacecraft computer programs. Response by that organization has been completely unacceptable. I suspect this is partially due to the rather informal manner in which this data was requested. It is obvious that we cannot continue to operate this way, and so in the future requests for this information will be made on a much more formal basis - smothered in the usual stack of paperwork, signed by the necessary managers around here. It is evident that if we fail to deliver this data on schedule to MIT, slips in the delivery of the flight programs will be charged to us - and with some justification.

You remember the business we went through some months ago regarding the attitude hold mode to be programmed in the LGC for use during separation of the LM from the SIVB. Without going through all that history, it is probably sufficient to report that MIT has finally concluded they can develop a better program providing inertial attitude hold rather than the attitude rate hold I previously reported would be programmed.

For whatever it's worth, I might summarize my impression of AS-206 program quality. In spite of considerable difficulty in pulling this program together at MIT, Jim Miller and Dan Lickly have done a commendable professional job, and I really expect this program to perform very well for us. Considerable credit is also due Tom Gibson, Carl Huss and a number of others in providing the necessary coordination and input from MSC. I don't know why I'm sticking my neck out on a prediction like that. Just living dangerously, I guess.

Howard W. Tindall

Howard W. Tindall, Jr.

Addressees:
(See attached list)

Rory Sears

Fire about now!

GSA FPMR (41 CFR) 101-11.6

FEB 2 1967

UNITED STATES GOVERNMENT

Memorandum

R. RAGAN

R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
~~CENTRAL FILES~~		✓
[illegible]		✓
[illegible]		
[illegible]		✓
[illegible]		
[illegible]		✓
[illegible]		✓
DUE DATE		

TO : See list DATE: JAN 31 1967

FROM : FM/Deputy Chief, Mission Planning and Analysis Division 67-FM1-17

SUBJECT: AS-206 Spacecraft Computer Program Newsletter

We had another long AS-206 program development discussion at MIT on January 26th, and some things came up you might find interesting.

First of all, there is only one mission phase that has not been successfully run at this time - namely, the second APS maneuver. There is some feeling that this may be due to improper targeting as opposed to problems in the actual program. Completion of a satisfactory test of this mission phase will signal configuration control of the assembly to be maintained until the final release of the program. It is planned that verification testing to assure flight readiness will be complete on February 15th, and we've set February 17th as the date for the formal MSC review of the AS-206 program verification results. Final acceptance of the program, prior to rope manufacture, is based on this MIT presentation which will be here in Houston.

Although MIT insists that the Digital Auto Pilots are adequate for the mission, there are several program modifications under consideration in this area. In fact, MDRB's have been requested from MIT which must be acted upon very promptly if they are to be included. Briefly, they are the following:

a) As I understand it, an instability, due to fuel slosh, has been discovered making it desirable to modify the Kalman filter gains in the DPS DAP. As presently designed, when the RCS tanks get fairly empty, fuel slosh causes control to oscillate back and forth between the DPS and RCS Digital Auto Pilots. This results in inefficient use of RCS fuel, although it does provide adequate control of the vehicle. Since AS-206 does not have an RCS propellant shortage, it is not mandatory to make the change until a later mission. The primary advantage of doing it now is to get a test of the "ultimate" system.

b) At some time during the DPS maneuver, it was intended to freeze the DPS engine position, i.e., no further steering commands would be given to the DPS and all control would be carried out with the RCS. This had been proposed as an interim fix of the instability problem noted in (a), but subsequent testing at Grumman of the DAP on their digital simulation has shown that misalignment of the thrust vector from the spacecraft cg actually results in a greater use of RCS fuel than is spent in controlling the fuel slosh induced instability. We have requested an MDRB to fix the program so that it does not freeze the engine position. (Incidentally, there is concern that engine bell ablation or erosion may cause large thrust vector misalignment, and freezing the engine deflection during the maneuver could present a significant problem in that event).

c) MIT is very much concerned that insufficient data will be collected during the AS-206 flight for adequate analysis of the Digital Auto Pilots. It has been found that the PCM data will be saturated due to the unusual platform alignment which is required on this mission. Therefore, they are anxious to obtain another source of this data which they have identified as essential from the very beginning. One of their proposals is that the downlink be interrupted for four or five seconds during the DPS maneuver, substituting in it's place CDU data sampled every twenty milliseconds. Further, they feel it would be highly desirable to suppress the DAP during this period in order that the data be independent of control activity. Almost surely this type of program modification will cost a lot of time even if agreement could be reached by all parties that it was an acceptable change technically.

I predict we will not make change (a) but will make change (b) since it's so simple. I really am concerned about not getting the DAP data for postflight analysis since that is one of the primary reasons for flying the mission in the first place. Resolution of whether or not to make change (c) will probably bounce all of the way up to the Spacecraft Program Manager.

MIT reported that it looks like nothing can be done in either the hardware or software to fix the AS-206 downrupt problem. This, you recall, is the problem resulting from higher priority computer tasks preventing the computer from servicing the downlink needs ever so often during maneuvers. This causes that data frame to be garbled on the ground. As I understand it, it is possible to unscramble this data postflight, thus it is only a real time flight control problem which we have recognized and agreed to live with on this mission.

I hear that Grumman has not yet been able to use the tapes delivered to them due to problems with their own facility. I get the distinct impression that we have been "had" on this. Apparently Grumman knew their facility would not be ready on schedule, and in order to salvage their incentive points, got us (MSC) to give them a waiver based on our confession that the GFE computer program would not be available as promised. I guess we Texans are no match for those slick New York yankees.

That's about it. Obviously our toughest job is going to be wrenching this program out of MIT's grasp, since to them quality still comes before schedule. But that's just a little game we are playing, and I don't consider it unh y. I'm really not near as worried about the quality of the AS-206 pr as they are, but I am very anxious to get this bunch of experie AS-206 guys off onto the AS-278 programs as soon as possible.

Howard W. Tindall, Jr.

Addressees:
EG/D. C. Cheatham
EG23/K. J. Cox
EG25/T. V. Chambers
EG26/P. E. Ebersole
EG27/D. W. Gilbert
EG42/B. Reina
EG43/R. E. Lewis
EG43/M. Kayton
EG43/C. F. Wasson
KA/R. F. Thompson
KM/W. H. Hamby
PA/J. F. Shea
PA/W. A. Lee
PD/R. W. Williams
PD4/A. Cohen
PM/O. E. Maynard
PM2/C. H. Perrine
PM2/K. L. Turner
FA/C. C. Kraft, Jr.
FA/S. A. Sjoberg
FA/R. G. Rose
FC/J. D. Hodge
FC2/E. F. Kranz
FC3/A. D. Aldrich
FC4/M. F. Brooks
FC5/G. S. Lunney
FC5/H. D. Reed
FC5/J. E. I'Anson
FS/L. C. Dunseith
FS5/T. F. Gibson, Jr.
FS5/R. O. Nobles
FS5/P. J. Stull
FS5/L. A. Fry
FM/J. P. Mayer
FM/C. R. Huss
FM/M. V. Jenkins
FM12/J. F. Dalby
FM13/J. P. Bryant
FM14/R. P. Parten
FM/Branch Chiefs

FM:HWT:cm

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
MAY 29 1967

	Action	Info
R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
~~CENTRAL FILES~~ [illegible]		✓
J. Sears		✓
E. [illegible]		✓
J. [illegible]		✓
[illegible]		✓
[illegible] Hall		✓
John Miller		✓
DUE DATE		

[illegible] Division
J. Sears

TO : See list

DATE: MAY 23 1967

67-FM-T-41

FROM : FM/Deputy Chief R. B. RAGAN

SUBJECT: Spacecraft computer program names

I used to think MIT was a little odd when it came to selecting names for the spacecraft computer programs with all that weird preoccupation with the sun. But now I see they were right all the time and the rest of the world is nuts - let's name the missions sequentially as they lift off the launch pad. Good grief, Charlie Brown! Having seen my error I'd like to apologize to our Bostonian friends for the abuse - and worse - I used to heap upon them and publicly announce the end of my campaign to change the program names. I think the old ones are just great and recommend you learn to recognize them if you're interested in this business.

There are only five names you need to remember; they are:

a. SOLRUM 55

This contraction of the more familiar "Revision 55 of Solarium" was adopted for the AS-501/AS-502 program when it was released to Raytheon for rope manufacture. (The numerical part of the name is the number of the program assembly on which the final flight verification testing was carried out. This is a characteristic of all program names).

b. BURST 116

Contracted from "Revision 116 of Sunburst", this is the name of the program for the unmanned LM mission we used to call AS-206.

c. SUNDISK

Sundisk is the interim Command Module program now scheduled for release in July which could be used for any earth orbital development flight. It probably won't ever be flown but it's availability will ensure that flight software does not pace the first manned mission. Dave Hoag suggested I could remember this name if I associated it with the shape of the command module - sort of a disk - and, by golly, it's worked for me.

d. COLOSSUS

This is the name of the command module program designed to support the lunar landing mission as well as all development flights anyone has

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thought of, so far. According to Webster's New Collegiate Dictonary it also means (1) A statue of gigantic size; as, the Colossus of Rhodes, a statue of Apollo, about 120 feet high, made by Chares about 280 B.C. (2) Anything of gigantic size.

Pretty good except, I miss the Sun.

This program and Sundance (below) will undoubtedly be updated prior to rope manufacture for each mission, incorporating modifications and corrections as necessary. I expect these will be identified by different assembly numbers rather than completely new nemes.

e. SUNDANCE

You can remember the name of the LM program for all manned missions by associating dance with the LM's lovely legs - another of Dave's suggestions - and adding "Sun" as usual.

I'm serious, as usual.

Howard W. Tindall, Jr.

Addressees:
(see page attached)

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

UNITED STATES GOVERNMENT

Memorandum

NASA-Manned Spacecraft Center
Mission Planning & Analysis Division

	Action	Info
RAGAN		✓
J. HOAG		✓
L. LARSON		✓
CENTRAL FILES		✓
DUE DATE		

RECEIVED
AUG 21 1967

TO : See list below

DATE: AUG 14 1967
67-FM-T-60

FROM : FM/Deputy ~~Chief~~ R. R. RAGAN

SUBJECT: Crew monitoring of the LOI maneuver

1. On August 3 we had an informal meeting to talk about crew monitoring of the Lunar Orbit Insertion (LOI) maneuver. The subject came up in connection with Jim McDivitt's preparation for the STAC presentation. I'm writing this note because we tentatively agreed on some fairly basic points with regard to how we might use the various systems. These preliminary conclusions, if they hold up, could have application on some of the other maneuvers, not just LOI.

2. I am sure you are all aware of the slow response of the thrust vector control digital autopilot (DAP) in the Command Module when docked with the LM. In order to avoid exciting the low structural frequency of this configuration (about 1 cps), it has been necessary to reduce the response of the DAP to a very large degree. As a result, if there is an offset in the alignment of the initial thrust vector from the spacecraft c.g., turning moments will exist at the beginning of the maneuver causing large spacecraft attitude excursions which take a couple of long period oscellations to damp out. Our current estimate of the maximum excursion for LOI is about 8° based on the assumption of fully loaded propellant tanks and initial thrust misalignment of 1°. The period of oscillation, as I recall, is in the order of 20 seconds for the half cycle in which the greatest excursion occurs and, unless the crew were prepared for it, it could create considerable concern on whether or not the guidance system was working properly. In the case of the LOI maneuver, which has a nominal duration of about 370 seconds, it is probable that the transverse velocity increments accumulated during this period should not jeopardize the crew. If this is true, the consensus is that the crew would be willing to passively ride out this perturbation.

3. Crew monitoring of the rest of the maneuver must be provided for two characteristics: duration of the burn itself and attitude error. With regard to the former, it was readily apparent that the only danger to the crew occurs from an overburn, that is, failure of the engine to shut down in time. There are three devices which

can be used to monitor and cross check against overburn: the PNGS, the Δ V counter on the EMS based on acceleration measured along the longitude spacecraft axis, and the clock which can be used to compare against the anticipated duration of the nominal burn. An overburn of about 110 fps would result in lunar impact. This is equivalent to about 10 seconds of extra burn duration out of a total 370 second maneuver. (Acceleration level at burnout is approximately 1/3 g.) A 3 σ low performance engine would extend the burn time just about 10 seconds which makes monitoring with the clock somewhat marginal. The EMS longitude accelerometer is said to have an accuracy of approximately 1.3 percent which is equivalent to about 40 fps for the LOI maneuver. It should provide a suitable cross check. In addition, lunar impact resulting from overburn, of course, occurs as much as 180° from LOI, thus, MSFN should have a good capability of predicting this event as soon as the spacecraft appears from behind the moon with sufficient time for the crew to respond following advice from the ground.

4. Monitoring attitude error is somewhat more difficult. It appears that a constant pitchdown error of less than 5° throughout the maneuver would result in a radial, Δ V downward causing lunar impact approximately 90° orbital travel following LOI, that is, at approximately first appearance of the spacecraft from behind the moon. It was proposed that the FDAI's be set up with one driven by the PNGS and the other by the SCS for attitude comparison purposes once the initial attitude transients noted above have ceased. In addition, it is necessary that the attitude time history compare favorably with a nominal determined preflight. The comparison against the preflight nominal is to protect against a degraded Z-axis accelerometer which could cause the guidance to deviate dangerously but would not be apparent from a comparison of the two FDAI's with each other. Differences in the FDAI's, of course, would indicate that one of the two systems was in error. Since there is no capability for vote breaking with a third source, there would be little option but to shut down when either of the two systems indicate a dangerous condition is impending. It should be noted, though, that attitude dispersions in only one direction, namely in the direction causing a radial velocity increment downward, creates a crew safety problem. In all other cases, it would not be necessary to shut down the engine. Critical downward incremental velocity is approximately 440 fps.

5. I guess to sum it up, even without ground monitoring and without very much onboard redundancy, it looks like given some ingenuity ways can be found to assure crew safety. However, they may require a

willingness to have "blind" faith for a considerable time in a system that might be malfunctioning and may require an action that could prevent mission success, that is, premature manual shutdown of a perfectly performing system. Probably most of this is old stuff, but I thought it might be worthwhile to write it down.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
CA/D. K. Slayton
CB/A. B. Shepard
J. A. McDivitt
E. Aldrin, Jr.
CB1/T. P. Stafford
CF/W. J. North
C. H. Woodling
D. F. Grimm
P. Kramer (2)
CF22/C. C. Thomas
CF34/J. B. Jones
EG/R. A. Gardiner
D. C. Cheatham
EG23/K. J. Cox
T. P. Lins
EG25/T. V. Chambers
EG26/P. E. Ebersole
EG27/D. W. Gilbert
EG43/R. E. Lewis
C. F. Wasson
EG42/B. Reina
ET71/T. R. Kloves
EX/N. G. Foster
KA/R. F. Thompson
KM/W. H. Hamby
W. B. Evans
F. C. Littleton
B. D. Sturm
PA/G. M. Low
K. S. Kleinknecht
PA2/M. S. Henderson
PD4/A. Cohen
PM/O. E. Maynard
PM3/R. J. Ward
PE7/D. T. Lockard
FA/C. C. Kraft, Jr.
S. A. Sjoberg
R. G. Rose
C. Kovitz
FC/J. D. Hodge
E. G. Kranz
FC2/J. W. Roach
FC3/A. D. Aldrich
FC4/J. E. Hannigan
R. L. Carlton
FC5/C. B. Parker
J. S. Llewellyn
G. S. Lunney
C. E. Charlesworth
P. C. Shaffer
J. C. Bostick
H. D. Reed
FL/J. B. Hammack
FS/L. C. Dunseith
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L. A. Fry
FM/J. P. Mayer
C. R. Huss
M. V. Jenkins
FM13/J. P. Bryant
J. R. Gurley
G. L. Hunt
FM14/R. P. Parten
FM3/B. D. Weber
FM5/R. E. Ernull
FM7/S. P. Mann
FM/Branch Chiefs

FM:HWTindall, Jr.:pj

H. Leas

MIT 191 R. L. Ragan

GSA GEN. REG. NO. 27
UNITED STATES GOVERNMENT

Memorandum

NOV 24 1967

	Action	Info
R. RAGAN		
D. HOAG		
L. LARSON		
CENTRAL FILES		
DUE DATE		

NASA-Manned Spacecraft Center
Mission Planning & Analysis Division

TO : See list below
R. R. RAGAN

DATE: NOV 17 1967
67-FM-T-109

FROM : FM/Deputy Chief

SUBJECT: Spacecraft computer program orbital integration

1. This is just another little golden nugget for your files.

2. The spacecraft computer programs, of course, have orbital integration routines to support operations around the earth and moon, as well as in between. The gravitation of the earth, moon and sun are treated differently dependent on which of these regions you are operating in. On a number of occasions the question has arisen as to where the boundaries actually are governing this.

3. I have found out that MIT currently has written the command module program as follows. When operating within about 210 nautical miles of the moon's or earth's surface the orbital integration only takes into account the gravitational potential of that body including its oblateness effects. Beyond that altitude, and up to a radial distance of 42,500 nautical miles from the earth and 8,500 nautical miles from the moon, it adds to these the effect of the other two bodies (without their oblateness). Beyond that distance, the oblateness effects are dropped.

4. In order to save erasable memory in the LM computer, the LM program is somewhat different. No matter how high it is flying, it takes into account only that body around which it is operating including all its oblateness effects, but never takes into account perturbations caused by the gravitational potential of the other bodies.

Howard W. Tindall, Jr.

Addressees:
(See attached list)

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

RECEIVED
JAN 16
R. R. RAGAN

UNITED STATES GOVERNMENT

Memorandum

TO : See list below

DATE: JAN 11 1968
68-PA-T-2A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: First 2 hours on the moon is a countdown to launch - simulated or real thing.

1. Those who participated in the STAC presentation already know this, but perhaps some of you, like me, had not heard. It is currently proposed that on the lunar landing mission the first two hours on the lunar surface will be devoted to spacecraft systems checks and launch preparations which, for all practical purposes, simulates the final two hours before ascent and rendezvous. Going through an operation like this has a number of obvious benefits. It's a good pre-ascent "simulation" which lets you find out early if there are problems associated with that operation such as performing the necessary tasks within the time allotted. And, of course, it prepares the spacecraft for lift off at the end of the command module's first revolution if that action is required in response to some emergency situation. Also, it makes the countdown for that event the same as the countdown for the nominal ascent lunar stay---that is, standardizes procedures.

2. In preparing our mission techniques data flow we are assuming that the lunar operation will be conducted in this way. I assume those responsible for planning other facets of the lunar operation are doing the same.

Bill T

Howard W. Tindall, Jr.

Addressees:
(See attached list)

G. Sears

MAY 1962 EDITION
GSA GEN. REG. NO. 27
UNITED STATES GOVERNMENT

Memorandum

MIT/IL/R. R. Ragan

NASA-Manned Spacecraft Center
Mission Planning & Analysis Division

TO : See list below

DATE: JAN 16 1968
68-FM-T-8

RECEIVED
JAN 22 1968
R. R. RAGAN

FROM : FM/Deputy Chief

SUBJECT: AGS accelerometers may not work.

1. Apparently, there is a basic problem in the LM Abort Guidance System (AGS). Although it is not widely known, there is a rumor the accelerometers do not work and it is highly likely G&C Division will elect to procure the AGS accelerometers from another source. Since it is too late to obtain and incorporate them into the system immediately, LM-3 and LM-4 will use the original accelerometers in the AGS. I believe it is their intention to select the best ones available in hopes of avoiding an unoperable system.

2. I am writing this note since, if the AGS is considered undependable on LM-3 and LM-4, this fact should be taken into account in mission planning and data priority decisions for those missions. For example, it seems highly undesirable to plan on utilizing the AGS for executing maneuvers in a nominal mission as is currently planned on Mission "D".

Howard W. Tindall, Jr.

Addressees:
(See attached list)

	Action	Info
R. RAGAN		✓
D. HOAG		✓
L. LARSON		✓
~~CENTRAL FILES~~ R. Battin		✓
E. Copps		✓
G. Sears		✓
J. Miller		✓
G. Cherry		✓
C. R. Wieser		✓
Stan Miller		✓
Pete Hall		
DUE DATE		

John Dahlen ✓
Jim Nevins ✓

N. Sears

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED MIT/IL/R. Ragan
FEB 12 1968
R. R. RAGAN

TO : See list below

DATE: FEB 6 1968

68-PA-T-26A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Lunar Reentry Mission Techniques meeting

1. On February 1 we had another meeting on lunar reentry mission techniques. Almost all of our discussion dealt with the final midcourse maneuver prior to entry. As you know, midcourse maneuvers are currently planned to occur approximately 12 hours after TEI which is near the sphere of influence of the moon and about 15 hours prior to reaching the Entry Interface (400,000 feet altitude). Analyses have shown it is highly probable that these maneuvers will have to be made and propellant is budgeted for them. Planning has also included a third midcourse maneuver just prior to reentry, the need for which is nowhere near as certain. Of course, it must be included in the timeline regardless of that. It is this midcourse maneuver we discussed.

2. When should the maneuver be scheduled? Ron Berry stated that, according to their studies, the magnitude of dispersions at Entry Interface (EI) are relatively insensitive to the time at which the third midcourse maneuver is made as long as it is no earlier than about 5 hours before (EI). Therefore, this consideration puts an upper bound on the time at which this maneuver must be made. Paul Pixley states that for the cases they have examined it is always possible for the MSFN to obtain a good state vector for entry initialization provided the final midcourse maneuver occurs no later than 2 hours before EI. This MSFN tracking limitation establishes the lower bound. Selection of the actual time the maneuver should be made between these bounds is primarily based on operational considerations. That is, we would like to make sure the crew timeline following the maneuver is not unduly hurried and will be very much interested in the flight planning people's input on this (Tom Holloway please note). Until something comes along to change it, we propose for now to schedule the third midcourse maneuver 2 hours prior to 400,000 feet and all mission planning and analysis activity should be based on that.

3. We also established a criteria upon which it will be possible for the flight controllers to establish the need for this maneuver in real time. Based on the work of Claude Graves' group, it was stated that

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a flight path angle dispersion at EI of .38° is considered acceptable. According to Paul Pixley, the MSFN is capable of determining that parameter to within 0.02°, given 30 minutes of tracking within 2 hours of EI. By subtracting this we established a flight path angle dispersion limit of .36° as the GO/NO GO criteria for whether or not to make the midcourse maneuver. That is, if the predicted flight path angle at EI differs from the desired value by more than .36°, the third midcourse maneuver will be executed. According to Pete Frank, this value is sufficiently large that the likelihood of the third midcourse maneuver is very low.

4. It was decided that the midcourse maneuver, if necessary, will be entirely in plane. This ground rule was established based on an understanding that very little lateral landing point adjustment is available without very large out-of-plane maneuvers. Nor is it needed since the lifting reentry footprint should provide more than enough lateral landing point control.

5. Another ground rule we established was that there would be no comparison of onboard navigation to MSFN navigation associated with the third midcourse maneuver. This is a necessary constraint since onboard navigation changes the CMC spacecraft state vector, which is an unacceptable thing to do just prior to entry. Furthermore, it is unnecessary anyway, since by that time in the mission we should have sufficient faith in the one which has been uplink from the ground without that coarse comparison.

6. This ruling poses the question as to how long before entry the ground determined state vectors propogated to EI are of equal accuracy to that determined onboard since, given communication loss, at some point the crew should abandon the MSFN state vector and start navigation and maneuver targeting onboard. The Mathematical Physics Branch and Orbital Mission Analysis Branch people were given the action item of determining this crossover point which is anticipated to be well before the second midcourse maneuver. In other words, I expect that once we have committed the spacecraft to executing the ground computed second midcourse maneuver utilizing a MSFN state vector update, there should be no further star landmark/star horizon exercises carried out onboard the spacecraft.

7. As a side issue, it may be desirable to include in the lunar mission plan some sort of "onboard Navigation and Return-to-Earth targeting" exercise as a systems test either on the translunar phase of the mission, or more reasonably, early in the transearth phase to evaluate that capability. But it is to be emphasized that it is a systems test only and that navigation and targeting of all these maneuvers should be based on ground computations given adequate communications.

8. Another question which must be answered dealt with how soon before EI it is reasonable for the CMC Average g program to start running. Of particular concern is the effect of approximations on the accuracy of the average g integrator when computing the influence of just the gravitation the spacecraft is experiencing. Guidance and Performance Branch is to answer that.

9. In the current flight plan we propose that platform alignments be carried out based on a ground computed REFSMMAT at 3 hours and 1 hour prior to EI. (We still haven't pinned down its specific orientation.) In addition to the ground transmission of this REFSMMAT, it is necessary to send up the spacecraft state vectors and External Delta V targeting parameters for the third midcourse maneuver if it is needed. Also the state vector for entry initialization must be sent sometime during the last hour before entry with its time tag close to the predicted EI time.

10. There was considerable discussion regarding the spacecraft computer entry programs. Several modifications have been proposed, but it was evident from our discussion that we didn't know enough about the current definition of these programs to do anything. We also inconclusively discussed initialization of the EMS again. Accordingly, it was decided that our next meeting should include participation by MIT and North American personnel.

Howard W. Tindall, Jr.

Enclosure
List of Attendees

Addressees:
(See attached list)

TLI

Sears

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

MIT/IL/R.R. Ragan

UNITED STATES GOVERNMENT

Memorandum

TO : See list below

DATE: FEB 21 1968
68-PA-T-37A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: TLI platform alignment

Something came out of Ron Berry's Midcourse Mission Techniques meeting of February 7 that I think should be advertised widely. Apparently, we now have agreement among all parties, including FCOD and FOD, that the proper platform orientation for the TLI maneuver on a lunar mission is the one established prelaunch on the pad for use during the launch phase. Of course, this does not produce zeros on the 8-ball during TLI. The reason I am sending this note around is just to make sure that everyone knows and is working in accordance with that monumental decision.

Bill

Howard W. Tindall, Jr.

Addressees:
(See attached list)

Lunar Surface Phase Operations — Sears

UNITED STATES GOVERNMENT

Memorandum

MIT/IL/R. R. Ragan

RECEIVED
MAR 11 1968
R. R. RAGAN

TO : See list below

DATE: MAR 4 1968
68-PA-T-48A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Ascent Phase Mission Techniques meeting - February 27, 1968

1. In the absence of Charley Parker, our beloved leader, I inherited the job of chairing this meeting which probably accounts for why we didn't really get an awful lot done. However, there are a couple of things that are probably worth reporting.

2. We discussed the importance of the "stage verify" discrete to the spacecraft computer. Apparently, its sole purpose is to initialize the DAP such that it may perform properly. For example, it stops sending steering commands to the DPS trim gimbals. It also changes the spacecraft mass used in DAP operations from the ascent stage, plus whatever remains of the descent stage, to ascent mass only. Based on this information it computes jet firing duration for attitude control differently, of course. I had been concerned that failure to get this signal during Ascent would cause poor attitude control and we are initiating a program change request to back up "stage verify" with the "lunar surface flag" since whenever that event occurs use of the ascent stage only is a certainty. Jack Craven (FCD) pointed out that due to the design of the system the much more probable failure is to get a "stage verify" signal prematurely. If that happened, when we are still operating on the DPS, it would stop DPS steering and would make the RCS attitude control extremely sluggish. <u>That</u> would be bad news! All that is required to do this is for either of <u>two</u> relays to inadvertently open.

3. As you know, we are planning to devote a short period of time immediately after landing on the lunar surface to checkout of critical systems. This would be done both onboard and in the MCC leading to a GO/NO GO for one CSM revolution (about 2 hours). This is exactly the same sort of thing as the GO/NO GO for one revolution following earth launch. Jack Craven accepted the action item, which I had previously discussed with Gene Kranz, to establish how long it should take to do this systems check in order that we may make all other mission planning and crew procedures consistent. It is expected to be in the order of 3 minutes, unless it takes a long time to really detect an APS pressure leak. Until the GO/NO GO we intend to remain in a state from which we can instantly "abort stage" and go. After that it will take much longer.

4. Almost all the rest of our discussion dealt with what the command module should be doing during and immediately following LM ascent from the lunar surface. One unresolved question was whether or not the command module should attempt to observe the LM ascent with the sextant. It was not clear what purpose would be served other than more rapid acquisition for rendezvous navigation tracking after insertion. It seemed to us the most important thing, of course, was for the command module to take whatever steps are necessary to assure getting a good LM state vector in its computer for rendezvous maneuver targeting as soon as possible. It seems almost certain that we should load the nominal LM insertion state vector in the CMC from the ground prior to LM ascent to guard against subsequent communication breakdown. It was also agreed that we should probably prepare the MCC to automatically take the LM post-insertion state vector from the LM telemetry and transmit it back to the command module. Whether we would actually do this or not depends on whether we lose more by forcing the command module to stay in the Uplink Command program (P-27) thereby preventing rendezvous tracking and onboard navigation for a substantial period of time. That is, analysis may show that with good VHF ranging and/or sextant tracking the command module may be able to converge on an acceptable LM state vector better without this ground participation, if it gets going more quickly.

Templeman Problem?

5. I guess I am attacking the old "MIT me" in stating that we are seriously handicapped by having no reliable definition of the Luminary lunar surface and ascent programs (e.g., GSOP Chapters 4 and 5). I understand review copies of these should be available within 3 to 6 weeks and I am sure nothing can be done to speed them up. We'll eat'em raw when they get here!

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Enclosure
List of Attendees

Addressees:
(See attached list)

G I T/IL/R. R. Ragan

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
APR 15 1968
R. R. RAGAN

TO : See list below

DATE: APR 8 1968

68-PA-T-73A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some lunar mission earth orbit phase ground rules

1. I would like to make sure everyone is aware of some important decisions which were made at Ron Berry's Midcourse Phase Mission Techniques meeting on April 3. They have to do with operations during the earth parking orbit phase prior to TLI on a lunar mission.

2. Current planning involves performing the TLI maneuvers at the first opportunity. For Atlantic injection, this can occur approximately one and a half hours after launch. It is important that the efforts of all the organizations be in accordance with that. If it is determined that some activity precludes TLI this soon, the responsible organization should make this known immediately. As noted previously, it has been established that no spacecraft platform alignment is required prior to the first opportunity TLI, which helps the crew time line.

3. One component of the go/no go for the first TLI opportunity is validation of the S-IVB IU state vector. Since during the first revolution we are unable to generate an MSFN state vector superior to the anticipated IU's, the check can only be gross. The actual parameter to be tested will be magnitude of the anticipated midcourse correction. The criteria will be based on how well we will be able to determine right from wrong rather than on reasonable magnitude of the midcourse correction, we would be willing to accept operationally. It will be a function of MSFN tracking coverage available prior to the go/no go decision. ?

4. In order to avoid having to make unnecessary real-time decisions, in addition to all the associated pre-flight analysis and arguments to establish the decision logic, we have established the following ground rules:

a. We will never transmit a state vector update to the S-IVB IU for the first TLI opportunity.

b. We will always transmit a state vector update to the S-IVB IU for the second TLI opportunity.

c. We will always transmit a state vector update to the CSM G&N for the first TLI opportunity. The state vector to be sent to the CSM will be obtained via telemetry from the S-IVB IU.

The intention, of course, is to always use the best state vector. During the first revolution, the IU state vector should be superior to any other source and should be acceptable for use. Thus, there will be no reason to update the IU and no reason not to update the G&N. During the second revolution we can be certain the MSFN state vector will be adequate for guiding through the second TLI opportunity - at least as good as, or better than the S-IVB IU state vector - which means no harm is done by sending a state vector update, but it can improve the situation. There is reason to suspect that MSFC may not approve this ground rule (b) but it seems to me the burden of proving why we should do something else is on them.

5. All of this will be documented in detail in the minutes of the meeting. I hope the chairman will excuse my scooping him, but I felt it desirable to advertize and emphasize these things since they have a significant influence in the procedures we are implementing and you should all be aware of them.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
(See list attached)

MIT/IL/R.R. Ragan

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
APR 15 1968
R. R. RAGAN

NASA-Manned Spacecraft Center
Mission Planning & Analysis Divisi

TO : See list below

DATE: APR 8 1968

68-FM-T-74

FROM : FM/Deputy Chief

SUBJECT: Flyby solutions in the RTCC Midcourse program will not be absolutely optimum

This memo is to inform you of a simplification in RTCC program requirements I recently approved. As noted below, the capability we are providing appears to be adequate and the cost of the optimization is incompatible with the benefit to be gained. The rest of this memo is lifted almost verbatim from one Bob Ernull wrote to me.

Quite a few months ago, it was agreed by MPAD, FCD, and FSD that a circumlunar (flyby) mode would be included in the RTCC midcourse program for alternate missions and circumlunar aborts. One problem we were particularly concerned about was the case where we have to get back home with the RCS only; this implies both a SPS failure and DPS failure, or failure to extract the LM, after TLI. Because of the limited delta V available from the RCS, approximately 150 fps for translation, the guideline established was to develop a program logic which would provide the absolute minimum delta V solution to insure safe entry.

In trying to develop a program which would compute the "optimum" solution, we ran into many problems. We have reached a point now where even though program development is not complete, we probably know how to build the program required; however, the running time on the RTCC computers ranges from 20-40 minutes per solution. We have examined ways of reducing this time and do not see any possibilities which would effect any significant reduction. Although this might be acceptable during an operation, imagine the computer time and effort required to check it all out.

During the evaluation of computation techniques for the "optimum" solution it was found that a very near optimum solution could be found using a simple computation procedure based on a "return-to-nominal" concept. This concept simply takes advantage of the fact that the nominal pericynthion conditions which were optimized pre-flight, will still be very near optimum for any small midcourse maneuver. Since for the RCS problem we are by definition considering for the flyby solutions, get an answer which is near optimum and avoid the iterative search for optimized pericynthion conditions. This reduces the run time from 20-40 minutes for the "optimum" solution to 1-2 minutes for the "return-to-nominal" solution.

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The next question is how much delta V penalty is incurred if we decide to implement the simple and faster computation technique in the RTCC. It can be shown that the "optimum" solution will cover S-IVB injection errors 50-100% larger than the return-to-nominal. However, these dispersions must be compared with the expected S-IVB 3σ dispersions to get a true picture of the situation. This comparison shows that with the return-to-nominal we can cover S-IVB injection errors twice as large as the 3σ errors. This is based on the assumption that up to 100 fps is available for the first maneuver, the additional 50 fps is reserved for subsequent corrections.

Summarizing, in order for the return-to-nominal solution to be inadequate we have to have an SPS failure, a failure of the DPS (or no extraction) and a S-IVB dispersion twice as large as the predicted 3σ dispersions.

On this basis, and considering the major impact of developing, checking out and verifying a program where each run takes 20 minutes or more, the decision was made to delete the requirement for computing an optimum flyby solution and use the return to nominal technique. I hope you agree.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Attendees:
(See list attached)

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

MIT/IL/R. R. Ragan

UNITED STATES GOVERNMENT

Memorandum

RECEIVED

APR 3 0 1968

R. R. RAGAN

TO : See list below

DATE: APR 23 1968

68-PA-T-79A

FROM : PA/Chief, Apollo Data Priority Coordination

MAY 1 1968

SUBJECT: Rendezvous maneuver targeting for guidance system backup

1. During the "D/E" Rendezvous Mission Technique meeting of April 15, we spent a lot of time discussing the data transmitted from the ground to the spacecraft involving the CSI and CHD maneuvers. This discussion, of course, centered on how the data should be used and led to a tentative conclusion regarding the backup of these LM maneuvers, which is somewhat different than we had previously reached. The purpose of this memorandum is to point out this difference.

2. We had previously concluded that the command module should be prepared to make "mirror image" rendezvous maneuvers in the event of LM problems. We had planned to target the CSM with data obtained by the LM crew from the PGNCS. The failure we had in mind was primarily propulsive. However, when you consider that the problem in the LM could also be in the guidance system, it seemed logical to modify the procedures slightly, since it is no better for the command module to make a bum maneuver than for the LM. Also, it did not seem that we were taking optimum advantage of the LM systems, particularly the AGS. Accordingly, we now propose the following:

Both the AGS and the CSM G&N will be targeting with ground computed CSI/CDH maneuvers passed to the spacecraft in External Delta V coordinates. If for some reason the LM PGNCS computed maneuver is not acceptable, we would class this as a PGNCS failure. Rather than carry out some real time systems analysis at this time critical period, they would switch to the AGS and make the ground relayed maneuver. If some further problem is encountered prior to the maneuver, the LM would go passive and the command module would continue its countdown and make the ground computed CSI/CDH burn. Following the burn the crew and ground would attempt to ascertain what the problem is in an attempt to get the LM systems ready for the rest of the rendezvous.

This procedure gives two levels of backup (AGS and CSM) to a PGNCS problem and helps keep the LM active. However, operating in this way would likely preclude either input of rendezvous radar data into the AGS or running through its CSI/CDH targeting computations in order to keep it in the best state of readiness to backup the PGNCS. There is still a pocket of resistence (FCSD) to using the AGS in this way which makes some higher level direction necessary. I'll try to get a decision right away, one way or the other.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:
(See list attached)

PA:HWTindall, Jr.:js

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

MIT/IL/ R. R. Ragan

RECEIVED
MAY 1 1968
R. R. RAGAN

MAY 3 1968

UNITED STATES GOVERNMENT

Memorandum

TO : FA/Chairman, Apollo Software Configuration Control Board

DATE: APR 26 1968

68-PA-T-88A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Results of "C" Mission Rendezvous Review meeting - April 22, 1968

1. At your request, I set up a meeting on our current "C" mission rendezvous problems with participation by all organizations interested in this activity. The attached attendee list will show you they were well represented. Our basic purpose was to determine current status of the situation and to recommend where to go from here with regard to the problems which have recently been coming to light (both real and imaginative) primarily as a result of the crew training exercises at KSC.

2. In summary:

a. It is the consensus that the Sundisk program is acceptable for flight - that is, program changes and new ropes need not be made.

b. Post release Sundisk program testing is underway to further verify its flight readiness. Results to date have been highly satisfactory and no new program bugs have been found. This testing is continuing, but confidence is high that it will be completed successfully.

c. A number of open items in the crew procedures were discussed and decisions were made which will permit consistent, unified work in the future with regard to development of the crew timeline, simulation activity, program verification testing, etc.

d. A number of desirable program changes were discussed which should be incorporated in the follow-on spacecraft computer programs.

Each of these items will be amplified below.

3. Post release verification testing of programs associated with the rendezvous exercise, currently underway, falls into three categories. They are as follows:

a. Testing of the sextant rendezvous navigation. Two runs have been laid out in detail covering the period from the NSR maneuver to the terminal phase midcourse maneuver which are currently being run at MIT on their bit-by-bit simulator, their hybrid simulator, and their digital engineering simulation program. Math Physics Branch (MPAD) is designing an additional run utilizing the final crew procedures, parts of which are defined in this memorandum. MIT will also make this run. According to Flight Software Branch, these three runs are being made a part of the formal post release verification and will be well documented.

b. Twelve rendezvous targeting and burn runs covering the period between NSR and braking have been defined by MPAD and Flight Crew. Four of these tests will be run on the MIT bit-by-bit simulator and also on the North American ME-101. All twelve of these runs are being processed through the MIT engineering simulation program, the equivalent MPAD programs, and the bit-by-bit simulation here at MSC. Many of these runs have already been made and their results have been compared very favorably. In addition, the initial conditions and other data required to make these runs have been delivered to the AMS at KSC. The purpose of this is to provide test cases with which they may check out their simulator. It is not to test the Sundisk program, and as of this date, they don't intend to run these cases.

c. A completely independent test plan has been designed by TRW and reviewed by MSC defining a series of runs to be made on the local bit-by-bit simulator.

It was the consensus that successful completion of all this testing should provide adequate confidence in Sundisk for its use in the "C" mission.

4. Crew Procedures

In order that everyone may carry on using the same approach, we discussed and chose the following crew procedures which should be considered official. That is, they should not be changed without future discussion and widespread dissemination since so many organizations are concerned.

a. The first and most important involved the workaround procedure for the terminal phase midcourse maneuver targeting program (P-35). It has been decided to handle this program deficiency by designating that the CSM state vector rather than the S-IVB state vector be updated based on sextant observations after TPI. Tests have shown that this technique works very well. In fact, it provides a theorectically perfect solution.

b. It was also decided that the crew would make a so-called "phony mark" after the TPI maneuver and prior to beginning navigation. This decision was made in spite of the fact that MPAD representatives did not feel this operation was necessary.

c. The consensus is that the "phony mark" is not necessary following the midcourse correction maneuver and so it will not be made at that time.

d. It was decided to set the Delta R and Delta V test parameters to zero so that after each sextant observation the crew will be forced to observe the effect of that observation on the state vector. It will also cause a program alarm to occur. The primary benefit to be gained from this procedure is that it will provide the crew with information regarding the trend of state vector changes which will be helpful in their editing process. It should be noted that this is the procedure currently in use on all simulators at MIT, KSC, MAC, etc. It was observed that after more simulator experience, it may be desirable to load values somewhat larger than zero to simplify the crew operation a little. This would be a minor modification to the procedure.

e. Based on the strong recommendation of MIT, it was decided to reinitialize the W-matrix during the second navigation period between NSR and TPI. This procedure was also adopted over the objection of MPAD personnel who intend to carry out future analysis to provide their contention that it is not necessary and perhaps that it is even damaging. There was also discussion of the values to be used for reinitialization of the W-matrix at this time. MIT currently proposes 1,000 feet and 1 fps, although it seems that values as much as three times larger may be recommended before the flight.

f. The flight crew has concern over allowing the average "G" program (P-47) to run continuously after the second midcourse correction. They are afraid that the accelerometer bias may introduce unacceptable error in the state vector. MPAD was given the action item of determining the effect of various levels of accelerometer bias acting over different periods of time on the range and range rate displays. This information should give some insight into how the system should be operated when someone establishes what accelerometer bias we should expect. As of now, they will continue to run P-47.

5. At least two program modifications should be considered for future spacecraft programs:

a. It has come to light that the Sundisk short burn SPS logic will cause a premature engine shut down amounting to about four fps as a result of some inaccurate spacecraft characteristics frozen in fixed computer memory. It is recommended that these parameters be located in erasible so that they may be loaded after true values are known.

b. There is an infuriating "Delta V residual bounce" following spacecraft maneuvers which preclude accurate maneuver execution. MIT is in the process of tracking down the cause of this. Hopefully it may be fixed in the later programs or at least maybe we will find out what it really is!

6. Finally, KSC simulator people were asked if any possible assistance not already available could be provided to help solve their problems. It was their opinion that at this time they have a number of known things that must be done which will substantially improve their facility and until these are completed, they feel no organized help from MSC or MIT would be particularly helpful.

Howard W. Tindall, Jr.

Enclosure
List of attendees

cc:
(See attached list)

PA:HWTindall, Jr.:js

MIT/IL/R.R. Ragan

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
MAY 1968
R. R. RAGAN

TO : See list below

DATE: APR 30 1968
68-PA-T-89

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: CSM should have good rendezvous navigation in the lunar mission

1. As you know, I have been pushing to get the capability back into the command module computer program to compute CSI and CDH rendezvous maneuver targeting. The reason I consider this valuable is that with both VHF ranging and sextant data, the command module potentially has a better rendezvous guidance system than the LM. Thus, with that capability, it could provide the comparison "yard stick" for evaluating the LM PGNCS determined maneuvers during a nominal flight and could provide targeting for its own maneuvers if a command module rescue situation arises.

2. I submitted a PCR for Colossus and MIT responded with a six week program delivery schedule slip which, of course, is unacceptable. Therefore, this PCR has been added to the list of changes to be considered for later versions of Colossus. During our discussion of this PCR, someone remarked that the VHF ranging device is limited to use for ranges less than 200 nautical miles, whereas the nominal range at insertion is about 270 nautical miles, and that lighting conditions for sextant observation were poor prior to the CSI and CDH maneuvers. If this were true, it would substantially reduce the benefit of this capability, and in fact, might make it impossible to use the command module as noted above. I have checked into the actual situation for lunar rendezvous and have found quite the opposite. The tracking conditions are really very good. Attached to this memorandum are figures which show this. They were lifted from an excellent memorandum (68-FM64-17) written by a couple of Ed Lineberry's people - James D. Alexander and Francisco J. T. Leon-Guerrero. You will observe (Figure 1) that approximately five minutes after insertion into orbit both spacecraft are in darkness which should make sextant tracking ideal and in fact at no time after that and prior to TPI is the angle between the LM and the sun as observed from the command module less than 70°. Furthermore, you will note (Figure 2) that, even if 200 nautical miles is a hard constraint on VHF ranging, it should be possible to get between 5 and 10 minutes worth of tracking before CSI, which should do quite a bit of good. And, of course, as Ed Lineberry says, there is nothing sacred about doing CSI that soon. That is, by delaying it 5 or 10 minutes, we could obtain an equal amount of extra VHF tracking. Of course, hopefully, VHF will work at ranges greater than 200 miles, particularly, if we are willing to restrict voice communications. (Figures 3 and 4 are attached to show an equally good situation will exist on the "F" mission.)

3. My basic purpose in sending around this memorandum is to clarify the situation by distributing this data, which I found very interesting, and to reemphasize the desirability of equipping and utilizing the CSM in this way.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Enclosures 4

Addressees:
(See list attached)

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

MIT/IL/R.R. Ragan

TO : See list below

DATE: MAY 6 1968

68-PA-T-95A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: PIPA Surprise

1. Since I was surprised at what Gunter Sabionski told me and, in turn, almost everyone I have told has been surprised, perhaps you too will be surprised to learn that the least significant increment output by the CSM accelerometer is equivalent to 0.2 fps! (The LM is considerably better, the value being 0.03 fps per bit.) I suppose we have all heard these numbers before in units of centimeters per second which made them sound much smaller than they really are and I, for one, never bothered to make the conversion. Of course, what this means is that it will be impossible to trim delta V residuals in the command module dependably to less than 0.2 fps. Also, the actual triming operation will be a little more difficult since the readout will jump in such big steps.

2. No big deal, just thought you might be interested.

Howard W. Tindall, Jr.

Addressees:
(See list attached)

PA:HWTindall, Jr.:js

More interesting is that the display precision is 0.1 ft/sec !!

MIT /IL/ R. R. Ragan

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

UNITED STATES GOVERNMENT

Memorandum

RECEIVED

MAY 17 1968

R. R. RAGAN

TO : See list below

DATE: MAY 14 1968

68-PA-T-101A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Aborts from powered descent on the lunar landing mission

1. We spent the entire May 8 Ascent Data Priority meeting discussing mission techniques associated with aborts from powered descent on a lunar landing mission. This discussion led to some pretty simple procedures which are outlined in this memo. They are based on some assumptions which I've also listed below. If you feel that they are in error, please let us know.

2. The basic assumptions we made are:

a. From a DPS engine performance and dependability standpoint, it is preferable to operate the DPS at full thrust throughout the abort ascent trajectory rather than at some lower level. (Is this okay after operating for awhile at reduced thrust? Also, we must make sure there are no bad guidance system transient problems at staging.)

b. The low level sensor light comes on when there is 1200 pounds of propellent remaining, which is equivalent to about 120 seconds burn time at 25% thrust, and 30 seconds burn time at maximum thrust.

c. It is operationally acceptable to run the DPS to fuel depletion. That is, there is no reason for the crew to prematurely shut down the DPS engine if there is an advantage to be gained by running it to fuel depletion. (I'll bet I hear something about this!)

d. Use of the "Abort Stage" automatic sequence is as safe or safer than manually proceeding through it one step at a time. (Someone's not going to like this either.)

e. The crew can make a go/no go decision one minute after the DPS low level sensor light comes on, at which time they should be prepared to either commit to landing or to abort immediately. (At least we are recommending this if it is at all possible. Of course, they may abort after that, but it's getting hairy.)

f. There is a very great advantage to be gained by keeping the variety of abort modes to a minimum - that is, always do the same thing as often as possible. The point is, there may be some special cases in which some benefit could be gained by doing things a little differently. But, we always felt the advantage of standarized procedures outweighted them in those cases we recognized and discussed.

3. The abort procedure is really very simple, at least if the above assumptions holdup. So simple, in fact, that I'm sure you'll wonder how we spent the day! Basically, whenever an abort situation arises at any time during descent, the crew will hit the "Abort" button which will automatically put the PGNCS (or AGS) into the DPS abort program (P70) and the DPS should be run to fuel depletion or to a guided cutoff at orbital conditions, whichever occurs first. If fuel depletion occurs, the crew should then "Abort Stage," which will automatically cause separation of the DPS and will put the PGNCS (or AGS) in the APS abort program (P71), leading to a guided insertion into orbit. We propose never initiating an abort with "Abort Stage" as long as the DPS is still operating okay.

4. There is one special case requiring attention which occurs with an abort approximately five minutes into power descent. It is at about that time when the DPS is able to return the spacecraft all the way to nominal orbit. If the DPS does make it all the way to orbit, all is well and good. If, however, fuel depletion results in DPS shut down just shy of that, something must be done of course. The procedure we propose if the velocity required to get into orbit is less than 10 fps, is for the crew to remain in P70, <u>not</u> to stage the DPS, and to use four jet RCS to achieve orbit. This requires approximately a 15 second burn. (This value was selected in deference to the problems brought about by a spacecraft whose thrusters shoot at itself.) If the velocity required to achieve orbit is in excess of 10 fps, which would require an APS burn of one second duration or greater, the procedure is as before - "Abort Stage" and use the APS.

5. One item requiring some research is to make sure that the spacecraft computer program (P71) will provide proper guidance to the APS for a "small" maneuver following DPS shut down. Another is to confirm that 10 fps is within the APS minimum impulse mode capability.

6. Consideration was given to establishing a special procedure in this region where the RCS would be used to insert the <u>staged</u> spacecraft. However, there was no advantage apparent to avoiding use of the APS unless there is some sort of freezing problem for short burns. In addition to keeping the procedure simple and standard, this technique should reduce the demand on RCS propellent and thruster lifetime. As a matter of interest, the magnitude of the remaining APS and/or RCS maneuvers in the coelliptic rendezvous sequence for an abort at that time are approximately as follows: CSI 35 fps, CDH 100 fps, and TPI 30 fps.

7. The only other situation I'd like to discuss deals with aborts late in the descent phase after the DPS low level sensor light has come on. There is a real advantage to be gained if the crew spends no more than about 60 seconds in that state before aborting since after that time the DPS will have less than 15 seconds of burn time remaining at full thrust. This duration would assure getting through "vertical rise" and pitchover before DPS fuel depletion. After that, it's cutting things pretty close. However, even then, it stills seems best to always attempt "Abort" on the DPS in order to get as much out of that engine as possible - if it's only a cough. The full thrust DPS acceleration is over twice that of the APS and if it's ever needed it's there! The only disadvantage occurs with a more-or-less simultaneous "Abort" and DPS fuel depletion causing a delay in "Abort Stage" with no engine on. If the crew has been watching the fuel gauge, etc., he should never let this situation arise and special procedures should not be required to handle it.

8. Finally, I'd like to outline the alternate techniques we established if fuel depletion DPS is not acceptable. As before, we always recommend "Abort" rather than "Abort Stage." The modified procedures are based on providing the equivalent of at least five seconds of DPS burn time at maximum thrust as a pad against fuel depletion. This is equivalent to shutting down the engine with about 120 fps DPS remaining. There are two classes of abort which must be considered:

a. The first is if the abort situation is detected <u>before</u> the low level sensor light has come on. In this case after "Aborting" into P70, it is necessary to monitor the inertial velocity in the DSKY (or the DEDA) at the time the light comes on. If the inertial velocity is less than 5,000 fps, the astronaut should "Abort Stage" 25 seconds after the light comes on and proceed into orbit on the APS. If the inertial velocity is greater than 5,000 fps, it is possible to proceed into orbit on the DPS without fuel depletion occurring. (Note: it is only necessary to monitor the "thousands" digit to make this decision.)

b. If the abort situation arises <u>after</u> the low level sensor light has came on, the crew should "Abort Stage" immediately after the pitch-over maneuver following vertical rise. This would occur about 10 seconds after the "Abort," if the abort is from hover.

9. In summary, if the DPS is still working, always use the DPS to initiate the abort and after getting as much as possible from the DPS, "Abort Stage" if necessary to achieve orbit. This provides the following advantages:

a. Avoids shutting down and changing engines at a time critical point and insures a positive altitude rate before staging.

b. Obtains the maximum delta V available from the DPS.

c. Produces the greatest possible acceleration at the abort time to get the heck out of there.

d. Makes the procedure standard for all cases - and simple!

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Enclosure
List of Attendees

Addressees:
(See list attached)

PA:HWTindall, Jr.:js

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

Memorandum

MIT/IL/R. R. Ragan

RECEIVED
MAY 29 1968
R. R. RAGAN

TO : See list below

DATE: MAY 24 1968

68-PA-T-106A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Spacecraft computer program newsletter

1. I learned some things at MIT last week that seemed interesting enough to justify this note. Of course, it deals primarily with the spacecraft computer programs and their influence on the mission techniques we are developing.

2. Pete Conrad reported that during their KSC LMS simulation, they have experienced an apparent deficiency in Sundance when making a docked DPS burn. He says that the DPS engine gimbal angles do not get changed at all during that low thrust period at the beginning of the burn which was provided specifically for trimming them. MIT looked into this problem and agreed that for some reason the program does appear to work - or not work - like Pete says. Their preliminary guess as to the course of this is that with low thrust and high inertial the gimbal trim estimator may be experiencing underflow. That is, the computer is simply not able to determine that a movement of the trim gimbal is necessary as it is currently coded. Of course, the RCS jets are very active both before and after throttle up.

white → 3. Our requirements for getting rendezvous radar (RR) data on the downlink while the LM is on the lunar surface was discussed again, and I am afraid I really blew it. MIT has resisted the program change we requested and I am beginning to think they may very well be right. That is, I am not so darn sure any more that the program as currently designed and coded is not good enough. In any case, George Cherry now proposes to look into a very simple change which can be made in the lunar surface navigation program (P22), which would substantially increase the frequency of RR data on the downlink. All that it amounts to is to remove the delay after the previous computations before the computer collects another batch of RR data. Right now this delay is 15 seconds. If we eliminate this delay and operate P22 in the "no state vector update" mode, the computer should cycle very fast. George Cherry is going to make an estimate of what this RR downlink frequency would be as well as evaluating the schedule impact for this change. I would be surprised if it is not acceptable to MSC even if it is not perfect - whatever perfect is.

4. As Colossus is currently designed, the crew is required to press the "Proceed" button during the period of maximum reentry G's to obtain a DSKY display change. A PCR had been submitted to make this procedure

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automatic. However, on future consideration, we are not so sure that it is a good thing to do. The initial display parameter in P65 are used in the primary go/no go logic employed by the crew in evaluating the G&N performance to decide whether to stay on it or to go with the EMS backup. It is essential that they see these parameters and an automatic "Proceed" could wipe them out before they have seen and digested them under certain circumstances. Accordingly, I suspect we should delete our request. The discussions have revealed, however, that some modification in the coding will probably be needed to make sure the system will work throughout the rest of the entry even if the crew does not provide the "Proceed" signal.

5. Here is one more note in the continuing "Stage Verify" story. According to John Norton the lunar ascent program (P12) no longer checks stage verify. That strikes me as a real improvement in the program but it mystifies me as how it go changed without a PCR or PCN, or even letting anyone know. Norton, of course, uncovered it by going meticulously through the program listing.

Howard W. Tindall, Jr.

Addressees:
(See list attached)

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

RECEIVED
JUL 0 1968
R. R. RAGAN

~~Muller~~
~~White~~
~~Tempelman~~

TO : See list below

DATE: JUN 25 1968

68-PA-T-137A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: "D" Rendezvous Mission Techniques Ground Rules, Working Agreements, and other things

On June 14 we cranked up the "D" Rendezvous Mission Techniques activities again. It was a grueling profitable day. In fact, we had such a good time we've scheduled another one for July 12.

Prior to the meeting I distributed a list of working agreements I thought we had reached previously. The crew presented another list dealing primarily with the docked LM activation/mini-football period based on a lot of planning and simulations they have been doing lately. The major part of the meeting was spent going through these lists. I have since compiled a new set derived from those - including the changes, agreements, and comments the discussion brought about. This list is attached and we can review it July 12. The last section lists some major discussion items still open. A list of action items is also attached since they help to paint the picture of our current status, which I would describe as being typically frantic.

Howard W. Tindall, Jr.
Howard W. Tindall, Jr.

Enclosures 3

Addressees:
(See list attached)

PA:HWTindall, Jr.:js

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

JUN 28 1968

IN REPLY REFER TO: 68-PA-T-136A

RECEIVED
JUL 2 1968
APOLLO DIRECTOR

THROUGH: NASA Resident Apollo Spacecraft Program Office
Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge, Massachusetts 02139

TO : Massachusetts Institute of Technology
Instrumentation Laboratory
Cambridge, Massachusetts 02139
Attn: D. G. Hoag, Director
Apollo Guidance & Navigation Program

FROM : Chief, Apollo Data Priority Coordination

At the June 14 "D" Rendezvous Mission Techniques meeting, I unofficially (I guess) assigned an action item to your people who were there. Specifically, we asked for MIT's recommended procedure for adjusting the W-matrix during rendezvous navigation in both the LGC and CMC. As a matter of fact, I understand that your people intend to discuss this with the "D" flight crew while they are there the week of June 17. However, I would appreciate it if you could write down the procedure you recommend in one of your informal MIT memos for discussion and incorporation into the mission techniques at our next meeting.

Incidentally, I think there was substantial benefit from having your people at our last meeting and hope they can come down for the next one, which is currently scheduled for July 12.

Bill T

Howard W. Tindall, Jr.

Enclosure

	Action	Info
R. RAGAN		
D. HOAG		✓
L. LARSON		✓
CENTRAL FILES		
N. Sears	✓	

DUE DATE 12 July

C

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

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: JUL 16 1968

68-PA-T-151A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Lunar Ascent preparation

1. At the July 3 Lunar Ascent Mission Techniques meeting we cleaned up the last of the main open items for the phase of the lunar landing mission from LM touchdown to liftoff. We are now ready to go to press for that part of the mission and will hold a world-wide review of it before the end of the month.

2. Most of the discussion was devoted to establishing the CSM timeline prior to LM Ascent. Much to my surprise, the CSM requires about eight hours (four orbits) to prepare for LM Ascent. Involved is all of the work associated with determining the position of LM with respect to the CSM orbit and with making a plane change if it is necessary. Time required for the LM to get ready is less than two and one-half hours unless rendezvous radar tracking is required. In that case, the LM crew would have to start powering up the PGNCS about three hours before liftoff, in order to track the command module during its last pass overhead. It is necessary for either the command module to track the LM on the lunar surface using the sextant or, if that is not possible, for the LM to track the command module using the rendezvous radar. The data thus obtained is required to target the CSM plane change or the LM Ascent. In the timeline that we settled on, the sextant tracking of the LM would be done three revolutions (approximately six hours) before Ascent and the CSM plane change, if it is required, would be performed one and one-fourth revolutions (approximately two and one-half hours) before liftoff. If the command module pilot is unable to track the LM with the sextant it will be necessary for us to target the command module plane change based on MSFN tracking and navigation, realizing that that the resultant CSM orbit may be as much as 0.3° away from the LM position as a result of MSFN inaccuracies. It is only in this event that we would require the LM to track the CSM with the rendezvous radar to obtain the data the ground would use to determine the out-of-plane steering the LM should execute during Ascent. It is only in the event that the command module is unable to track the LM that both the command module plane change and LM Ascent out-of-plane steering would be performed.

3. The other thing we firmed up was the logic defining when to use the command module SPS to make a pre-Ascent plane change vs. yaw steering

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the LM into the command module orbit during Ascent. The rule we established was that if the LM is less than half a degree out of the CSM orbital plane, the LM would take care of it during Ascent at an APS propellant cost of approximately 19 fps. If the plane change required is greater than half a degree, the command module would be used. Thus, the minimum SPS burn would be 50 fps. The maximum should be no more than 200 fps, depending on the location of the landing site and the inclination of the plane. These limits represent burn times between three and thirteen seconds.

Howard W. Tindall

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

MIT/IL/N. Sears

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

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: JUL 10 1968

68-PA-T-154A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: "C" Mission Clean Up

We'll try to clean up the rest of the "C" mission open items at a meeting on Friday, July 19, in Room 2032B of Building 30. Retrofire and Reentry will be discussed in the morning, starting at 9 a.m., and Rendezvous in the afternoon - or as soon as we finish the Retrofire session. Attached are open item lists for each session, kindly prepared by Stu Davis, FCD.

Howard W. Tindall, Jr.
Howard W. Tindall, Jr.

Enclosures 2

PA:HWTindall, Jr.:js

DEORBIT AND ENTRY DATA PRIORITY MEETING ITEMS

1. Is the entry following an RCS deorbit to be ballistic or guided?
2. Will the EMS be used for G&N failure occurring at any time?
3. Is closed loop G&N entry to be the nominal?
4. What are the thrust vector magnitudes and directions for SM - CM RCS deorbit ΔV's?
5. Is a fine align or coarse align sufficient for deorbit?
6. Are crew using ADPC procedures?
7. What are DSKY VG and gimbal angle limits in comparison with ground maneuver pad?
8. What are 3σ BMAG drifts?
9. What are PIPA bias and gyro drift limits and the compensation procedure?
10. Are the pads current?
11. What is the new REFSMMAT flag setting procedure?
12. Is the G&N needed for hybrid deorbit?

RENDEZVOUS DATA PRIORITY MEETING ITEMS

Open Items:

1.	Trim NCC1 to keep from doing NCC2.	Ken Young
2.	Rendezvous with SCS if G&N fails anywhere prior to to NSR.	Phil Shaffer
3.	Δ h limits for terminal phase.	Ed Lineberry
4.	Lighting constraints for TPI hard or is elevation angle hard?	Flight Crew
5.	Is 27.45° the elevation angle for TPI?	Paul Kramer
6.	Are P-52 alignment completion necessary prior to NCC1?	FDB and FCSB
7.	Are the maneuver pads current?	Will Presley
8.	Limits on onboard TPI solution comparisons with ground TPI.	Ed Lineberry
9.	Discussion of backup TPI ΔT burn solutions (duty cycle problems).	Dick Moore
10.	Are crew using ADPC procedures?	Flight Crew
11.	Limit on DSKY VG's agreement with target load, and limit on gimbal angles comparision with maneuver pad.	MIT
12.	Residual reasonableness limit	G&PB
13.	What are allowable BMAG drift and gyro torquing angles.	Gary Coen
14.	What are crew time requirements for sextant star check, P-52, P-40?	Mosel
15.	What are PIPA bias and gyro drift limits and compensation procedures?	Gary Coen
16.	Should NC1 and NC2 be external ΔV or SCS targeted?	Stewart Davis
17.	What are 3σ BMAG DRIFTS?	NR
18.	What short burn logic will be programmed for RTCC?	Phil Shaffer
19.	Any corrections to Techniques Description document.	

Enclosure 2

MIT/IL/M. Johnson

G

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

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: JUL 16 1968

68-PA-T-155A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: LM Descent abortability computation is proposed

Ed Copps of MIT attended one of our mission techniques meeting recently during which we discussed the use of the LM Descent Propulsion System low level sensor light. This is the light, you recall, which comes on when approximately 30 seconds worth of propellant is still available at full thrust or two minutes at 25% thrust. Recognizing that the astronaut has a complicated job to perform during the terminal part of descent, Ed Copps is proposing a rather simple new program to be added to the LM computer to relieve the situation. Rather than the astronaut trying to keep track of his status based on altitude, altitude rate, time since the low level sensor light came on, and the throttle profile he has executed since that time, this new program would predict for him the time at which he would no longer be able to abort. This would be in the form of a five second warning, during which he must either commit to landing or must get out of there. The PGNCS would be telling him that if he fails to abort before that time, it is probable that an abort would not be successful.

This sounds like a good thing to me - perhaps allowing us to get more out of the systems more than we would otherwise be able to do. If enough interest can be generated in it, it will probably be added to the Luminary Hopper.

Bill T

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: JUL 17 1968

68-PA-T-156A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Powered descent throttle logic correction

On July 2 I sent you a note regarding the way the DPS is throttled up after the gimbal trim phase during the powered descent maneuver. There were a couple of errors in that memo which are too significant to be left uncorrected.

I pointed out that MIT has programmed the LM computer so that the throttle up time was a fixed number of seconds after the targeted time of ignition (TIG). To illustrate how important it is that the engine be throttled up to the FTP at that time, I pointed out that for each second delay in throttling we lose 12 seconds of "hover time." This was my first error since it is not hover time that is lost but rather "throttle recovery time." Throttle recovery time is that period which has been allotted in the powered descent maneuver for the guidance system to regulate the thrust such that it can achieve the hi-gate targeting conditions. Failure to provide a sufficient period of throttling will jeopardize meeting those conditions and can result in a fouled up descent.

I went on to say that if the engine failed to start when it was supposed to, the crew could recycle to TIG minus five seconds and the PGNCS would countdown to ignition again with a delay of about 13 seconds from TIG (all true) and that the trim time would be reduced by that amount since the throttle up time was maintained as originally set. George Cherry informs me that this is not true since in the event of a recycle to TIG minus five seconds the throttle up time is redesignated. Accordingly, the recycle capability is really not an acceptable thing to use on the powered descent maneuver. I do not believe that the program has been designed improperly. It is just that the capability, as I described it, does not really exist.

MIT is submitting a PCN describing how the program has actually been coded since it is different than documented in the GSOP.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: JUL 18 1968

68-PA-T-159A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: No 15 minute constraint for Lunar Ascent Guidance

The Luminary GSOP indicates that it is necessary for the astronaut to call up the Ascent Guidance Program (P12) at least 15 minutes prior to lift off. This, of course, is not consistant with our desire to be able to use P12 if we get a No Go for lunar stay approximately 10 minutes after landing. In that case, we intend to call up P12 with less than seven minutes to go before lift off. By checking with MIT, we have verified that the 15 minute limit is not a real constraint and that the only limit is the time required for the crew to go through the operations associated with P12, which is currently estimated to be less than five minutes. (Simulations will eventually refine this, probably to a smaller value.)

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+7
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I have asked MIT to modify their GSOP (by PCN) to reflect this.

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: JUL 1 8 1968

68-PA-T-160A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: The LM can handle big Descent plane changes but requires protection against APS abort fuel depletion

We have recently verified that the LM has a substantial capability to translate out of its initial orbital plane during powered Descent at very little cost. That is, whereas previously a limit of 0.3° had been quoted, it now appears that 1° or more is probably possible without effecting the performance of the guidance equations, the landing radar, the visibility of the crew during landing, nor are the ΔV costs excessive. This capability gives us more than adequate assurance that it will not be necessary to perform a plane change trim burn on DOI day. And that's darn important!

In order to take advantage of this capability, however, it appears that something may have to be done to limit the yaw steering the LM would do in the event of an APS abort during powered Descent. As currently programmed, the PGNCS would attempt to guide the LM all the way back into the CSM plane. If the abort were to occur at "hover" or after touchdown, the APS ΔV cost could be excessive (i.e., 1° costs approximately 80 fps and could result in fuel depletion prior to obtaining a safe orbit). Obviously the thing we must do is to achieve the targeted in-plane conditions in the case of an abort. We can take care of the plane change after the LM is in orbit, perhaps using the CSM. Therefore, it seems necessary to make a (hopefully) rather small change to the APS abort program (P71) which would limit the extent of the out-of-plane steering. MPAD and MIT people are both in the process of studying this and we plan to recommend specific action very soon. Something similar will be needed in the AGS too, I suppose.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: JUL 1 8 1968

68-PA-T-161A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: LM Ascent lift-off time can be determined by the crew

Some months ago we submitted a PCR to remove the pre-Ascent targeting program (P10) from Luminary and this was done. This action was based on an assumption that a simple crew procedure could be developed for doing the same job, in the event of loss of communications, making the rather complicated computer program unnecessary. The Lunar Mission Analysis Branch of MPAD has concluded their development and analysis of this technique and is in the process of documenting it. It is only necessary for the ground to supply two parameters by voice to the crew prior to DOI which will allow them to independently determine lift-off time to within about six seconds. This dispersion takes into account current estimates of MSFN accuracies, etc. The effect on the rendezvous differential altitude due to this error is less than one mile, which is certainly far smaller than other dispersions which would occur in a non-communication situation. In other words, it is more than adequate.

Quite simply the procedure requires that the crew determine the time of closest approach of the CSM one pass before lift off by noting the time rendezvous radar range rate passes through zero on the tape meter. To that time, he must add the CSM orbital period and another ΔT to obtain lift-off time. These are the two parameters included in the pre-DOI pad message noted above which will be determined by MCC-H based on the actual CSM orbit.

Howard W. Tindall Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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G

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

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: JUL 26 1968

68-PA-T-169A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: July 9 and July 24 "G" Rendezvous Mission Techniques meetings

1. During the July 9 and July 24 "G" Rendezvous Mission Techniques meetings we have developed preliminary intra-vehicular rendezvous navigation sighting schedules. Crew work load estimates currently in use for the "D" mission rendezvous are included. These tracking schedules are very important since they have a predominating influence on almost everything else. For example, from these it has been possible to develop a preliminary spacecraft attitude time history which shows some fairly large gaps are going to be present in the CSM MSFN telemetry coverage. This, of course, is due to the fact that the S-band antenna is on the same side of the spacecraft as the sextant, which must be pointed down in order to observe the LM. Of course, during maneuvers occuring within sight of the earth, the CSM can be yawed to a heads down attitude enabling S-band telemetry coverage. The rendezvous activities do not ordinarily interfere with LM telemetry coverage.

2. The Orbital Mission Analysis Branch (OMAB) of MPAD has distributed a memo (68-FM62-217, dated July 15, 1968) which presents the revised rendezvous profile including the relative motion plots and visibility and slant range time histories. Some of the most interesting features are:

a. Insertion occurs at approximately 340 n.m. slant range. By CSI this range will have decreased to approximately 170 n.m.

b. The LM will appear to the CSM to be less than 8^{o} above the lunar horizon for the entire first two hours after insertion into orbit. After that, it will move below the lunar horizon.

c. There will be two points of sun interference for the sextant tracking of the LM, one immediately after insertion and another approximately two hours later, about 20 minutes before TPI.

3. OMAB presented the results of a study which shows that it is not possible to use the same maneuver solutions for LM maneuver targeting and CSM mirror image targeting on a lunar mission as is done on the "D" mission. Accordingly, if the CSM does not have CSI targeting capability in its computer, the LM crew will have to sequence through P72 to provide mirror image

maneuver targeting to the CSM and then P32 to target its own guidance systems. If the CSM does have the CSI targeting programs, the LM crew will be relieved of this job and will use P32 only. The CSM pilot will pick it up since the nominal procedure would call for his determination of the LM maneuver targets using P72, which he would relay to the LM for PGNCS solution comparison and AGS targeting. He would then use P32 to compute his own mirror image maneuver. It appears that the TPI time used in the P32 and P72 computations may have to be different regardless of which spacecraft does it. Since the mirror image maneuver is to be executed with a one minute time delay after planned LM ignition time, it may also be necessary to change CSI time. OMAB is looking already into this.

4. There was considerable discussion regarding initialization of the LM PGNCS and CSM G&N for rendezvous navigation. As reported previously, platform alignments by both vehicles right after insertion are now included in the timeline. Upon completion of the CSM platform alignments, the MCC-H will relay a new LM state vector into the CMC based on LGC telemetry after insertion. Even with this update, it is anticipated that the uncertainties in these state vectors will be quite large, making it necessary to use initial values in the W-matrix which will not be suitable for W-matrix reinitialization during the rendezvous sequence. The Math Physics Branch is looking into that. We ended the meeting by starting the development of some "G" mission rendezvous ground rules and working agreements similar to those developed for "D". Those we agreed to so far are attached.

5. The next meeting will be in September since many key people will be on leave during August.

Howard W. Tindall

Howard W. Tindall, Jr.

Enclosure

PA:HWTindall, Jr.:js

July 25, 1968

"G" MISSION RENDEZVOUS GROUND RULES WORKING AGREEMENTS

AND THINGS LIKE THAT

1. General

a. The reference trajectory is that provided by MPAD, dated August 15, 1968.

b. Nomenclature for the burn sequence following insertion is:

(1) CSI
(2) CDH
(3) PCI
(4) TPI
(5) TPF

c. The rendezvous will be run throughout with the vehicle roll angles $\cong 0^\circ$. The only exception to this is when during maneuvers within sight of the earth the CSM roll is 180°. TPI from above will be initiated "heads down" and TPI from below will be initiated "heads up" for either vehicle.

d. A LM state vector time tagged 12 minutes after insertion will be uplinked to the CMC within five minutes after insertion. State vectors are not sent to either vehicle again during the rendezvous phase.

e. IMU alignments will be made starting five minutes after insertion by both spacecraft and take precedence over the state vector update if timeline and/or attitude conflicts develop.

f. On both spacecraft all rendezvous navigation will be carried out to update the LM state vector. That is, the LM radar data will be used to update the LM state vector in the LGC and the CSM sextant and VHF data will be used to update the LM state vector in the CMC.

g. The CMC's LM state vector will be updated after each LM maneuver with the P76 Target ΔV Program using the pre-burn values as determined in the LM's pre-thrust program.

h. The state vectors in the AGS will be updated each time PGNCS is confirmed to be acceptable. This will likely be at each time it is committed to make the next maneuver using the PGNCS except perhaps TPI.

i. AGC alignments will be made each time the PGNCS is realigned and each time the state vector in the AGS is updated from the PGNCS.

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Enclosure 1

MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

6.

TO : See list attached

DATE: JUL 30 196[illegible]

68-PA-T-173A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Pulse Torquing to Achieve IMU Realignments

This memo is to describe the gyro pulse torque realign capability being added to the IMU Realign Program in Luminary and Colossus, Jr. Most of it is quoted word for word from a memo Steve Copps (MIT) wrote last February proposing it.

"The purpose of the program is to provide the capability of moving the stable member from one orientation to another without losing inertial reference. The actual program change is an addition to the IMU Realign Program (P52). Presently a display comes on showing V06N22 and the gimbal angles which will be achieved by coarse aligning the gimbals. This display is being changed to provide the navigator the option of achieving the new orientation by coarse aligning <u>or</u> by pulse torquing ('enter' achieves one and 'proceed' the other).

"Obviously the most accurate method of realigning the IMU is to use star sightings, and if star sightings will be taken there is probably not much advantage to pulse torquing. However, if there is some doubt as to one's ability to acquire and mark on stars, or the inertial reference accuracy required in the next orientation is less than the error induced by pulse torquing, then this option has great value.

"The time to pulse torque to a new orientation is a consideration. The maximum time to coarse align is 15 seconds. The time to pulse torque is much longer. Since only one gyro is torqued at a time, the total changes in angle for each axis is summed together and that total angle is multiplied by 2 (torquing rate is approximately 1/2 degree per second) to obtain an estimate of realignment time.

"The induced error is directly proportional to the sum of the angles tha each gyro is pulse torqued through. An estimate of the error induced is obtained by multiplying the sum total of change in angle by .002.

"So a single 90° yaw reorientation would take three minutes and would induce an error of .180 degrees. The time to pulse torque is alleviated by the fact that no star sightings are required following the alignment.

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"It should be noted that during pulse torquing there is no need to ho: the spacecraft in a fixed orientation since the IMU is always ine .: However, there is a possibility of pulse torquing the middle gimb. ir gimbal lock. It was decided to do nothing about this problem and lea\ it to the astronaut to monitor the FDAI or N20 and maneuver if require

The significant point to be made is that the change is being mechanize as an option in P52 - the IMU Realignment Program - and so the control for achieving the new alignment are the same as exist for that program That is, there is no direct way for the crew to tell the system to mov 90°. Of course, he can probably fake it out by targeting an External maneuver he has no intention of making - say out-of-plane to get a pre REFSMMAT and then go into P52 to realign the IMU to an out-of-plane orientation. This last paragraph is my comment. Don't call Steve if its nutty - or me either for that matter.

Bill

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

ATES GOVERNMENT

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tached

DATE: SEP 1 2 196

68-PA-T-195A

ɔllo Data Priority Coordination

SUBJECT: G Rendezvous

In spite of the feverish activity we have on three swinging missions C, C', and D, a few of us found a couple of minutes to spend on the G Rendezvous. Some things came out of it that are probably worth reporting:

1. As you know, on the D mission during a LM active rendezvous the command module will be targeted with mirror image maneuvers to backup the LM for CSI and CDH. These mirror image maneuvers are identical in magnitude but opposite in direction, since it has been found that the small errors resulting are a reasonable price for the simplicity we obtain in the operation. Unfortunately, when operating around the moon it's apparently not possible to use identical ΔV components for CSM mirror image targeting. This means that it will probably be necessary for the crew to first cycle through the CSI/CDH targeting program for the other spacecraft (P70 series programs) and then run through the targeting for their own spacecraft (P30 series programs).

2. For the D mission it was decided that a single TPI elevation angle could be adopted (27.5°) for all rendezvous situations. That i either spacecraft coming in from either above or below. Unfortunatel the lunar rendezvous geometry prevents us from adopting this operatio simplification and we must use different values of elevation angle de ing on whether the approach is from above or below. The values we ha selected (based on Jerry Bell's work) are 26.6° for the approach from below and 28.3° for the approach from above. The basic difference be these values is the phase angle between the two vehicles at TPI, whic lunar orbit is much greater than around the earth for the same separa distance. The primary reason for having to use different values is t keep the TPI maneuver along the line-of-sight. Another reason is to] component maneuver execution time for the two vehicles the same excep for differences in their navigation.

If you have any comments or questions about any of this, our next get together on the lunar rendezvous is currently scheduled for 9 a.m. on September 18, 1968.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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MIT/IL/ Johnston

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.5
UNITED STATES GOVERNMENT

Memorandum

TO : See list below

DATE: September 23, 1968

68-FM-T-201

FROM : FM/Deputy Chief

SUBJECT: Results of September 17 Apollo Spacecraft Software Configuration Control Board (ASSCCB) meeting

The first three hours of this marathon meeting were devoted to implementation of the descent program in LUMINARY. The currently approved plan is to implement the one-phase descent scheme proposed by Floyd Bennett and his merry crew. However, MIT has been directed to implement it in such a way that it would be possible to fly the old two-phase technique - if desired. Almost all effort is to be devoted to the one-phase technique with only one day's worth of testing included for the two-phase - and no design improvements are to be developed or included in the two-phase. What this really means is that at the cost of one day's worth of testing we have provided some cheap insurance for being able to change back later if we have to. If the decision were made to use the two-phase, a considerable amount of additional testing would be required and at that time, program deficiencies might be uncovered revealing that that capability does not really exist.

Several things that interested me about the new one-phase are:

1. The decision of which way to go - one or two-phase is made pre-flight and an option flag is set in erasible memory before launch.

2. The much smoother attitude time history of the one-phase scheme may very well permit the DPS trim gimbal to do all the steering, substantially reducing RCS usage.

3. MIT is providing a crew option via the DSKY for manually changing from P63 to P64 in the event they want to do that earlier than the automatic switch.

4. High-gate is now being defined as the time at which the landing radar position is changed.

MPAD has submitted a Program Change Request (PCR 249) to eliminate a lock-out of the landing radar data above 35,000 feet (estimated altitude). This was a two part change since it is necessary to fix a program to allow the data to be read and also necessary to change the weighting function such that data above 35,000 feet is not given a zero influence

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on the state vector. Since the proposed change was estimated to cost three days schedule impact, Floyd Bennett was requested to rewrite his PCR to simplify the requirement while achieving the same end results. Essentially, it amounted to replacing the 35,000 foot boundary with a 50,000 foot boundary. In addition, it is necessary that I verify that the rendezvous radar powered flight designate routine (R29) can be eliminated as a requirement and thus be made uncallable from the descent programs. Subsequent to the meeting I did that and have informed FSD.

Guidance and Control Division brought in two PCR's (Nos. 224 and 248) which influence the processing of the landing radar data. One changed the reasonability tests and the other provided a delay in utilizing landing radar data for four seconds after the LGC receives a "data good" discrete because it takes that long for the landing radar output to converge on the true value after lock-on. Both were approved at a cost of one day each.

MIT was requested to determine the impact of changing the descent program such that it would be possible for the crew to command all four RCS jets in the minus X direction immediately upon touchdown in order to smoosh the LM into the lunar surface and keep it from turning over while the DPS belches to a stop. Ain't that the damnest thing you ever heard?

Flight Crew Support Division presented a proposal to modify COLOSSUS II to permit the crew to manually steer the TLI burn in the event of a SIVB IU failure. No action will be taken on this until the technique is approved by Mr. Low's CCB.

A really ancient PCR, No. 132, submitted by the crew to provide a VHF ranging data good discrete light, was finally disapproved since the spacecraft will not be modified to provide the additional DSKY lights which would have been used for this.

Tom Gibson presented their proposal, which was approved, for the follow-on spacecraft programs. A so-called COLOSSUS I Mod A will be prepared, which is basically the COLOSSUS I program with all known anomalies corrected plus the following three simple program improvements:

1. IMU pulse torquing

2. Backup integration

3. An improvement on the mark incorporation.

It is planned that a tape release of this program will occur on December 1, at which time mission operations testing (Level 6) can be started along with rope manufacture. This program will be used for the D mission.

A COLOSSUS II program is also now being developed which starts from the COLOSSUS I Mod A baseline to which CSI/CDH will be added. I suppose it will also include anomalies uncovered too late for the Mod A version. MIT's estimate of tape release for this program is February 1, 1969. It is felt that this program can probably be made ready for Spacecraft 106 - that is, the flight after D, whatever that is. VHF ranging, incidentally, should also be available on spacecraft 106.

Howard W. Tindall, Jr.

Addressees:
FM/J. P. Mayer
C. R. Huss
D. H. Owen
FM13/R. P. Parten
J. R. Gurley
E. D. Murrah
M. Collins
FM4/P. T. Pixley
R. T. Savely
FM5/R. E. Ernull
FM5/H. D. Beck
FM6/R. R. Regelbrugge
K. A. Young
FM7/S. P. Mann
R. O. Nobles
FM/Branch Chiefs
TRW/Houston/R. J. Boudreau
MIT/IL/M. W. Johnston

FM: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: September 23, 1968

68-PA-T-202A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: G Rendezvous Mission Techniques

If you can stand it, I would like to announce another change in the G mission lunar rendezvous timeline. In order to provide more tracking which will hopefully improve CSI targeting and to avoid bothersome real time variations of time between CSI and CDH which foul up the plane change scheduling, we propose:

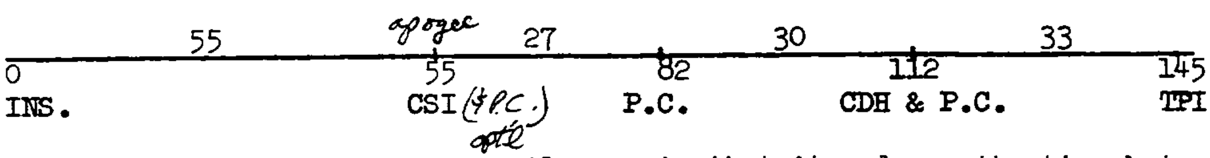
a. Move CSI five minutes later - to 55 minutes after insertion which is nominal apogee. This is primarily to avoid a rather large radial ΔV at CDH.

b. Always schedule CDH one half a revolution (180°) after CSI.

c. Schedule plane changes 30 minutes prior to CDH and at CDH, as before. The LM should use the Z-axis RCS LM thrusts for the CDH maneuver (by yawing if necessary) to avoid losing RR acquisition.

d. The LM may include a plane change at CSI if the CSM has adequate sextant tracking for targeting it. Rendezvous radar only is not considered adequate.

The new timeline looks like this:



The only disadvantage we currently see is that it reduces the time between CDH and TPI to about 33 minutes. However, 33 minutes should be adequate even with dispersions and the advantages of a relatively fixed maneuver schedule and better navigation before CSI seem well worth it. It should be noted that a (hopefully small) change in the CSI targeting programs (P32 and P72) would be required to force the computer to use the 180° spacing between CSI and CDH. This can be done in either of two ways. Our preference would be to provide the crew control probably by modifying the second P32 DSKY display format to utilize the third register which is currently blank as option code. [The other two displays in this format are apsidal crossing (N) and TPI elevation angle (E).] The simplier but less flexible way of doing this job is to increase the magnitude of the parameter currently stored in fixed memory which is used in the CSI $\dot{R}$ test, which forces the logic to use a 180° transfer when the pre-CSI orbit is found to be essentially circular and apsidal crossings become ill-defined. Ed Lineberry will submit a PCR for this.

Several action items came out of our meeting as follows:

a. MPAD - It is necessary to develop a rule governing the use of the VHF data in the event no sextant data is being obtained. It is our understanding that VHF data by itself is not only inadequate, but could actually degrade the processing. If this is so, we need to establish procedures whereby the crew inhibits VHF into the CMC when sextant data is not available.

b. MPAD - It is our proposal that the CSM be the prime source of targeting the plane change maneuver regardless of which spacecraft executes it. This is because the sextant is potentially more accurate than the rendezvous radar for this particular purpose. Here again a rule is needed to define how much sextant data is needed to target the plane change maneuver as opposed to using the rendezvous radar solution.

c. MPAD - We came to the conclusion at the last meeting that it was not possible to use the same maneuver solution for CSM mirror image targeting as the LM uses for burn execution. This meant the crew would have to cycle through two programs rather than just one. On further thought, it seems as though we can avoid this extra complexity, which is really rather serious. I am sure we can for the CDH burn and it seems probable that something can be done for the CSI burn too, particularly since it's constrained to be horizontal. Accordingly, we have requested OMAB to re-examine this procedure to see if we can't clean it up. We must also determine whether one minute delay in the mirror image targeting is really a requirement since these are RCS burns and problems at TIG don't appear to be too likely.

d. ASPO - Milt Contella repeated a rumor that the rendezvous radar may have random error in the shaft angle measurement when the line-of-sight from LM to CSM is close to the lunar surface. We must find out what the true situation is as quickly as possible and start figuring out some workaround procedure to be added to all the other ones.

Odds and Ends

We are assuming that the CSM will backup the LM CSI and CDH maneuvers using the SPS; it is probable, however, as on the D mission, that it will backup TPI with RCS. We have also concluded that the CSM should not backup the plane change since that requires yawing out-of-plane and disrupts tracking between CSI and CDH. Of course, if it is known that the LM will not be able to perform the plane change maneuver, the CSM will do it at that time. If the LM and CSM both fail to perform the plane change 30 minutes before CDH, the CDH plane change will force the node near TPI and so in that event the plane change will be taken out during the TPI burn targeted with R-36 to force a new node 90° after TPI time. This, of course, is a departure from the nominal TPI plan which calls for forcing the node at intercept (TPF).

That's it!

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: September 26, 19(

68-PA-T-208A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Unusual procedure required for LM Ascent from the moon

Jack Craven surprised us with a little jewel the other day during the Lunar Surface Mission Techniques meeting. He says that in order to enable the APS engine-on and staging commands from the LGC, it is necessary for the crew to depress (now get this) the Abort-Stage button! That is, depressing this button must be part of the standard countdown procedure to LM liftoff.

Alternately the crew can manually arm the engine which permits them to send the engine-on command manually, but it does not enable the LGC signal. Furthermore, if they do this, it is necessary for the crew to also send the engine-cutoff signal manually since the signal from the LGC is inhibited.

Bill

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: October 2, 1968

68-PA-T-213A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Lunar orbit revolution counter for C'

This may seem like a trivial matter - however, before any confusion arises let's firmly establish the means of identifying revolutions in lunar orbit by number. Specifically, unless there's some good reason for choosing another way:

1. Revolutions will be started and ended at 180° lunar longitude, i.e., on the back of the moon near the point of lunar orbit insertion (LOI). As I understand it, the RTCC is programmed this way.

2. The first revolution in lunar orbit shall be, appropriately, called number one (1). It starts at LOI (1) and ends approximately two hours later as the CSM passes over 180° longitude.

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: October 7, 1968

68-PA-T-215A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Cis-lunar spacecraft navigation for C'

We are still thrashing around trying to figure out what to do with regard to cis-lunar spacecraft navigation for the C' mission. It is not clear whether a couple of things are really necessary or not. If we could get rid of them, it would simplify things. Unfortunately, we aren't confident it is safe to delete them at this time, so they are still included. Specifically, I am speaking of:

a. Conditioning and preserving the W-matrix

b. Making star/landmark (both earth and lunar) observations as opposed to relying completely upon star/horizon measurements.

I think we have chosen the technique requiring the least diddling around by the crew which preserves the W-matrix. It is based on the following decisions:

a. The MSFN state vector will always be used for maneuver execution.

b. The MSFN state vector will always be used to reinitialize the onboard navigation state vector. That is, we don't intend to preserve the onboard computed value when new data comes from the ground.

c. The ground will only update the CMC CSM state vectors by uplinks then into the LM state vector memory locations. (This applies for all MCC's - translunar and transearth - except for the final one at EI minus two hours. In that case, the ground will send the ground state vector to the command module slots.)

It will be the standard procedure to send state vectors for whatever the spacecraft needs them (primarily MCC maneuver execution) into the LM state vector CMC memory locations since this does not effect the W-matrix. When preparing for a maneuver, the crew will transfer these MSFN state vectors into the command module state vector slots by use of programs provided specifically for that purpose. This, of course, will wipe out any state vectors that have been computed using the onboard navigation and subsequent navigation will use these state vectors transmitted from the ground as a new starting point. As the crew executes the maneuver, the guidance system will, of course, measure the maneuver and add it to the state vectors providing the best source following the maneuver. The crew should then transfer these new updated CSM state vectors back into the LM slots prior to any additional onboard navigation in order to preserve them in case of communication failure, whatever that is. Note that a small change is being made in the MCC-H/RTCC to permit automatically generating a command message to uplink the CSM state vectors into the CMC memory locations used for the LM state vectors.

Someone came up with a clever idea for comparing state vectors onboard the spacecraft. By calling up a rendezvous display of range and range rate between the LM and the command module, they are about to see the displacement and velocity of the state vectors - that is, the MSFN versus the onboard values. How the capability should be used is not at all clear.

Something else came up at the meeting that was rather startling and may have major impact. Namely, it may be impossible to do effective transearth navigation on a number of days in the current C' launch window. Apparently on the later days of the launch window, the sun, when viewed from the spacecraft may be too close to the earth horizon and star/horizon observations by the sextant may be impossible to obtain for a substantial part of the transearth coast. MIT, MPAD, and GCD are in the process of establishing what days in the launch window are effected, based on the various systems constraints. Once this situation has been clarified, it may be necessary to make a decision as to whether it is acceptable to launch the C' mission on a day when transearth navigation capability onboard the spacecraft does not really exist. How does that grab you, "Communication Loss" fans?

Howard W. Tindall

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: October 15, 1968

68-PA-T-219A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Lunar Rendezvous Mission Techniques

A number of people who know about the rendezvous radar (Myron Kayton, Richard Broderick, etc.) came to our little Lunar Rendezvous Mission Techniques meeting October 2 and assuaged our anxieties regarding the possibility of poor shaft angle measurements when the line-of-sight to the command module passes close to the lunar horizon. According to the data they presented, the error introduced by multi-path in the rendezvous radar data is essentially lost in the noise for elevation angles above 10° from the horizon. (During the nominal lunar rendezvous tracking begins at approximately 10° elevation and approaches 20° at CSI.)

Ed Lineberry's people have made sufficient runs to show that it is possible to use the same CSI targeting data computed in the CMC for P72 LM maneuver solution comparison (properly biased) and for CSM mirror P32 image maneuver targeting. We are currently recommending that the CMP use P32 rather than P72 since this would avoid the necessity of going through two pre-thrust programs.

One of the most significant things coming from the meeting, I think, was a report by the Math Physics Branch people to the effect that the rendezvous radar data is not expected to be of sufficient accuracy to target plane change maneuvers prior to terminal phase. The estimated errors are simply too great (e.g., 11 fps, one sigma). Accordingly, all plane change targeting prior to terminal phase must come from the CSM which can do an excellent job given as little as 10 minutes worth of sextant tracking (0.5 fps, one sigma). This does introduce sort of a problem since the technique for determining the magnitude of the plane change maneuver is to input the time of interest into the R36 routine. Unfortunately, if we put in the time of the LM maneuver, the solution would apply to the out-of-plane the command module should make at a substantially different place in orbit. For example, at CSI the command module is leading the LM by as much as 12°. Of course, the CMP could go through some "mickey mouse" to bias this time as a function of this phase angle based on some charts or something. However, he is already pretty well bogged down with other work and so we are going to put in a program change request for COLOSSUS II giving us a solution based on the LM state vectors rather than the CSM state vectors somewhat as the 70 series programs compliment the 30 series.

Jack Wright, TRW, had an interesting idea regarding the technique for checking the validity of the VHF range data. It is his impression that the rendezvous radar range and range rate measurements are essentially independent of one another, in effect providing two data sources for comparison with the VHF. Agreement of either of these with the VHF would provide confidence in its use. The crew display of raw VHF data is not really accessible to the CMP in the lower equipment bay and, of course, does not provide range rate at all. Therefore, the comparison must be against the DSKY display of range and range rate based on the navigated state vectors which include the sextant observations. It seems to us, in lieu of real data that this is probably a valid test of the VHF since it probably overwhelms the sextant data in the determination of navigated range and range rate. I would like to emphasize that this is a proposal requiring verification and may prove to be not useable. However, I thought it interesting enough to pass on to you.

Howard W. Tindall, Jr.
Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

O : See list attached

DATE: October 17, 1968

68-PA-T-220A

ROM : PA/Chief, Apollo Data Priority Coordination

JBJECT: Transearth Spacecraft Navigation

During Jim McPherson's Transearth Spacecraft Navigation Mission Techniques meeting of October 8 and 15, a potpourri of ground rules, working agreements and constraints was established. I may be duplicating other reports with this memo but figure better too many reports than not enough. All of the following apply specifically to the first batch of sextant sightings - star/lunar horizon - after TEI on the way back to earth. Many may also apply to later navigation observations, but I won't attempt to identify them here.

a. Prior to initiation of transearth onboard spacecraft navigation, the pre-TEI MSFN state vector navigated through TEI will be stored in the CMC LM slots and will be used to initialize the navigation. That is, no new state vector will be uplinked.

b. Navigation using star/lunar horizon observations give approximately the same accuracy as star/lunar landmarks - at least as far as hitting the entry corridor is concerned. Accordingly for purposes of mission simplifications - both pre-flight preparation and real time operation - all star/lunar landmark observational exercises will be deleted from lunar missions starting with C'. !

c. This exercise is to start at TEI + 1½ hours.

d. Altitude, which is not a constraint, should initially be about 6,000 nautical miles.

e. Stars of 2.3 magnitude or brighter are required for lunar observations.

f. Due to the required spacecraft attitude, the hi-gain antenna will probably be out-of-lock. Therefore, low bit rate telemetry will probably be used to transmit the data in real time. If so, marks must be made no more frequently than one for each 10 seconds - procedures are required to assure proper downlink antenna is selected.

g. After completion of this exercise, the crew will obtain sextant photographs of the lunar horizon - to see what the horizon looks like at altitudes of 10,000 to 20,000 nautical miles - not to determine its location. ?

C' data load: 10,000 m., 10 m/s.

h. The W-matrix will be initialized to 3,300 feet and 3.3 fps. If possible, they will be initialized at TEI and propogated from there. These are the same values to be used after TLI and included in the E memory load.

i. MPAD and MIT will establish the ΔR, ΔV threshold the crew should use for data selections - hopefully, it will be simple but perhaps must be a function of geometry and time in the mission. (The data is on the downlink regardless of whether the crew accepts the update or not.) It should be noted that no good simulation facility will ever be available to provide the crew any pre-flight judgment. Although the V83 rendezvous RR display gives relation of pre-navigation versus navigated state vectors, this kind of activity shall not be a part of the decision logic. If someone comes in with a good, useful proposal, this will be reconsidered.

j. A P52 align shall be performed immediately prior to this exercise.

k. The sextant calibration shall be repeated until agreement of at least two checks (not necessarily sequential ones) are within .006° before "preceeding."

l. Sextant calibrations will be performed every one-half hour.

m. The CMC clock shall be updated by the MCC-H whenever in "error" by more than .040 seconds.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: October 16, 1968

68-PA-T-222A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: C' maneuvers - SPS versus RCS crossover

Neil Townsend (EP2) informed me by phone - and will supply written confirmation - that the minimum duration SPS burn for C' should be no less than 0.5 seconds. We had been assuming something smaller. According to MPAD (Otis Graf, FM7) this makes the crossover point between use of the RCS versus the SPS engine:

Translunar midcourse correction - 5 fps

Transearth midcourse correction - 12 fps

These values will be explained completely in an FM7 memo soon to be distributed. I just want everybody to be aware of the new values and to start using them in his planning.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: October 16, 1968

68-PA-T-224A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: C' Earth Orbit and TLI Mission Techniques Open Items

It appears we have the Earth Orbit and TLI Mission Techniques for the C' pretty well under control. The only two significant open items that I know of deal with the optics check and the crew procedures for protecting against an SIVB engine cutoff failure during TLI.

The problem with the optics check is that no one has really established what they are trying to accomplish by doing it. My own personal opinion, of course, is that it is not really necessary. That is, we will be willing to do TLI with the optics busted, whatever that means, since we should be able to align the platform using the COAS good enough to perform the return to earth maneuver. Although, I guess, we really haven't proven that to everyone's satisfaction yet.

How the crew should backup the SIVB IU engine cutoff signal has been a sticky wicket (I believe that is the expression). I think we have now gotten through the emotional phase of this one and have zeroed in on two possible techniques, both of which seem pretty good. The one I personally favor was proposed by Charley Parker. Its merits are simplicity and the fact that it gives the IU the greatest chance to perform its job, if it is going to. Basically, no crew action would be taken until after an elapsed burn time is equal to that expected from a 3 sigma low performing engine. This would be like 10 seconds past the nominal burn duration. At that time, the crew would manually shut the engine down as soon as the GNCS indicated the targeted inertial velocity has been achieved as readout from their DSKY display. Of course, if we really have had an IU failure, the GNCS would indicate that we have already exceeded that velocity at that time and so the crew would take immediate action by turning the abort handle to shut down the engine and return it to its neutral position to avoid automatic separation of the spacecraft from the SIVB. (Note that the EMS ΔV counter plays no role in this procedure.) In the event the IU has truly failed to send the cutoff command when everything else is perfectly normal, this procedure would result in an overspeed of about 500 or 600 fps which would require a 2,000 to 3,000 fps return-to-nominal midcourse maneuver three hours after TLI. This does not preclude going into lunar orbit.

The alternate proposal is precisely the same as that, except than an additional period permitting manual crew engine cutoff is included - namely, that period containing all burn durations possible with a 3 sigma performing engine. This would be a 20 second period centered about the nominal cutoff time. During this period, the crew would send a manual engine off command if both the GNCS and the EMS ΔV counter indicated the desired cutoff velocity had been achieved.

Studies are continuing on both these techniques and a crew preference will also be obtained hopefully leading to resolution within the next couple of weeks. Since there is no crew simulation facility capable of faithfully simulating the TLI maneuver, it will not be possible to base the decision on experience gained in that way.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

Mal Johnston

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: October 16, 1968

68-FM-T-225

FROM : FM/Deputy Chief

SUBJECT: Results of the October 8 Apollo Spacecraft Software Configuration Control Board (ASSCCB) meeting

In this memo I will briefly describe some of the highlights of the subject meeting:

1. There was a long discussion regarding the effects of CDU transients on AGS alignments while on the lunar surface. It appears there are some fairly simple procedures for making sure unacceptable errors are not introduced into the system. A matter that was not discussed was what sort of problems we can have in the AGS alignment while on coasting flight where spacecraft attitude changes make checking very difficult. We will have to pursue these matters in the mission techniques development.

2. There were four PCR's approved that I would like to call your attention to. They are:

a. PCR 546 (LUMINARY): Delete V50N25 display in P68. Crew must insure a stable LM before "proceed" response to V06N43. The V50N25 display is not necessary. Attitude storage can be done after crew response to previous V06N43.

b. PCR 547 (LUMINARY): Delete V37N57 display at end of P68 and add "Do final automatic request terminate routine (R00)." Chapter 4 incorrectly shows P68 terminating with V37N57.

c. PCR 551 (LUMINARY): Reduce normal maximum commanded rate from 20°/sec. to 14°/sec. since maximum commanded rate of ACA normal scaling is too high for manual lunar landing. Reduce normal and fine scaling by a factor of 7 for the CSM-docked case since normal and fine scaling of ACA are too high for manual lunar landing.

d. PCR 552 (COLOSSUS): Add P22 assumption to read as follows: The first mark obtained by this program cannot be the landing site. Coding in P22 cannot accept landing site as first mark.

3. Since all of DPS guided burns on the currently planned missions terminate at 40% thrust or less, it was decided to place the DPS tailoff for 40% in memory rather than full thrust.

4. MIT requested that we approve a change (PCR 494), which would put the LGC value of landing site location (RLS) on the ascent and descent downlink format. I am not sure why they want this unless it is for systems testing purposes. Note: We have no capability of reading it out in the control center in real time right now. You should! RLS update

5. PCR 250 to put SPS mass flow rate (M DOT) into erasible memory of COLOSSUS 1A was approved.

6. PCR 245 to permit use of planets in P23 and R53 was approved for COLOSSUS II but will not be in COLOSSUS 1A.

7. Just so there is no misunderstanding on this, MIT has been directed to delete the rendezvous radar acquisition routine (R29) from the LGC descent program (P63) completely.

Howard W. Tindall, Jr.

FM:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: October 21, 1968

68-PA-T-226A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Descent Aborts

We have finally started mission techniques meetings on lunar landing descent aborts. At the risk of losing whatever confidence you might have in my judgment, I would like to describe a technique we are probably going to propose for aborts early in the descent phase. That is, within about 25 seconds of commanding the DPS to full thrust. It is a technique that Joe D. Payne and Floyd Bennett have been suggesting for quite a while, but which most of the rest of us had been unwilling to accept.

First of all, I don't think anyone will argue about what should be done between initialization of powered descent and DPS throttle up after the trim gimbal period (currently set for 26 seconds). The ΔV acquired during that period only drops the apogee down to about 40 miles so the best thing to do is probably just shut off the engine and sit tight. That is, no immediate abort maneuvers are required unless it is necessary to get away from a hazardous DPS stage.

After going to full throttle, though, there is a short period (roughly 25 seconds) during which aborts become a little difficult to handle. In this region the trajectory rapidly becomes suborbital, making an immediate abort maneuver necessary to achieve a safe orbit. The problem is that the spacecraft is oriented retrograde to perform the descent maneuver, which is exactly opposite to the direction required to get back into orbit. This causes the problem. Namely, if we want to abort on the DPS, you have a choice of:

a. Either turning off the engine, reorienting the spacecraft about 180°, and reigniting the DPS to make a posigrade burn into orbit - and no one wants to turn off the engine! or

b. Leave the DPS engine on as the spacecraft is being reoriented. Unfortunately, in order to avoid gimbal lock this attitude maneuver must be made in the pitch direction and leaving the engine on causes us to acquire a large radial velocity during the attitude maneuver which must be removed. To do this the spacecraft would go through a pretty wild pitch profile rotating almost a complete revolution from the time of abort to the time of engine shutdown. The reason for this is that attitude change is made at a rate of only 10 degrees a second, which means the engine would thrust with a component in the radial direction for a long time. As you can imagine, there are also considerable problems in the guidance equations, which would cause the engine to be shutdown prematurely under certain circumstances.

Abort Staging with the APS is not much better since it was felt necessary to provide an immediate separation maneuver (currently coded to be three seconds or 30 fps) to get away from the DPS before reorienting to posigrade attitude. And, you can't leave it running for the same reasons as the DPS. So you see, even for an APS abort, we end up turning the engine on, then off, and then back on, which we don't want to do.

Let me point out that after about 25 seconds at full throttle, the horizontal velocity required to get back into orbit when combined with the radial velocity picked up during the attitude change results in a guidance and attitude control situation considered acceptable. That is, it is not necessary to turn off the engine during the pitch over to posigrade attitude. So our only concern is with aborts during the first 25 seconds after throttle up, when it is neither acceptable to leave the engine on nor to turn it off for fear that it won't start again.

Standby for Payne's solution!

It is proposed that in the event of an abort recognized in that troublesome period to continue operating the DPS in the retrograde direction until we have reached the time it is possible to make the attitude change to the posigrade direction without turning off the engine! If the DPS is the system that isn't working and it is necessary to "Abort Stage" and use the APS, it is proposed to burn the APS in the retrograde direction as long as necessary to reach the point when we can pitch to the posigrade direction without turning off the APS.

This solution, you see, avoids the need for turning off an operating engine and makes the procedures for both DPS and APS about the same in this time period as they are after this period. The thing that takes awhile to get used to is burning in a retrograde direction lowering the orbit still farther after a need for an abort has been recognized. How do we rationalize doing a thing like that? We currently feel that the advantages of the simplified, standardized procedures and particularly of not shutting down a running engine sufficiently justify thrusting to a situation a little worse than that which existed at the time of abort recognition. And, of course, we do have a tremendous propellant surplus if we abort at this time. Furthermore, aside from some problem associated with throttle up, the probability of an abort being required in this 25 second period seems awfully remote making it very difficult to justify development of a unique set of abort procedures and training to use them. In effect, this proposal creates two rather than three abort zones. No abort maneuvers are required prior to DPS throttle up since the LM is still orbital. Procedures after throttle up are all the same. There is no discret point in the descent required special techniques.

Formulation of the LUMINARY DPS abort program (P70) is completely compatible with this procedure. That is, for a DPS abort the crew would always delay taking abort action until 25 seconds after throttle up. A program change will be necessary to support this procedure in the APS abort program (P71) so that if the crew hits "Abort Stage," the APS will light off and separate, maintaining a retrograde attitude until 25 seconds after DPS throttle up time. Then it could go into the abort guidance as currently programmed. Specifically, the change is to have the spacecraft perform a continuous retrograde APS burn as opposed to a three second burn followed by an attitude change and reignition.

Mal Johnston of MIT was at our meeting and will discuss this with our friends in Boston. We'll talk about it some more next time after thinking it over a couple of weeks. I'd be interested in your comments.

Howard W. Tindall

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

C'

TO : See list attached

DATE: October 25, 1968
68-PA-T-234A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: C' Contingency Review

We went through the draft of the C' Contingency Mission Techniques document on October 22, and I must say I was impressed with its quality. It seemed to me the Flight Analysis Branch, the Apollo Abort Working Group, and TRW had done a good job of putting this together. The final version will be distributed within the next week or so.

One item that came up needed resolution deals with the block data maneuvers - that is, those abort maneuvers which the MCC-H periodically sends to the spacecraft to be used in the event of a subsequent complete communication failure. It is necessary to agree on the targeting objectives of these maneuvers. First of all, let me emphasize that the free return trajectory that we adhere to on the way to the moon does not necessarily provide a water landing and almost assuredly does not provide a landing near the primary recovery forces. All it does it to make sure that the spacecraft can get back to earth with minimum ΔV in the event of an SPS failure. The question to be answered is: Should the block data maneuvers merely be designed to provide a water landing or should they also meet the additional constraint of landing in the planned recovery area - that is, targeted to the CLA? We had been assuming that they would aim for the CLA, although, this may require maneuvers of as much as 1200 fps. Some people were questioning whether it would be better to avoid making a maneuver any larger than is necessary to insure a water landing regardless of where it might occur. Basically, it is a tradeoff between a maneuver (of up to 1200 fps) to get where we really want to go versus a smaller maneuver (up to 250 fps) to provide a safe landing somewhere. Of course, there is also the question during the translunar coast of when to target the maneuver for a direct return which costs a lot of ΔV (up to 7,000 fps) as opposed to going around the moon, which is much cheaper. These things are really mission rules which must be established before the flight. They apparently aren't agreed to yet. At least I don't know the rule.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

5010-108

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C'

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: October 25, 1968
68-PA-T-235A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some more C' Lunar Orbit Mission Techniques

At our October 14 C' Lunar Orbit Mission Techniques meeting we settled on a few things I would like to tell you about. Along with the TEI block data to be sent up each revolution in lunar orbit, we are also going to update the spacecraft state vector in the CMC every revolution. This will be done after tracking the pseudo-landing site and before the P52 fine alignment. Some consideration was also given to including a TEI external ΔV targeting load on the uplink each revolution but this will not be done since the block data should be adequate. Incidentally, the block data will be for a TEI maneuver for the revolution following the present one - that is, about three hours after its transmission.

We discussed the use of the tape recorder if the high-gain antenna does not work. In this event, you recall, it is not possible to dump the tape at lunar distances. The question to be answered is: What data should be recorded on the tape to be brought back by the spacecraft out of lunar orbit? Surely high-bit recording of the SPS burns - LOI and TEI - must be included and will use about half of the tape (15 minutes at high-bit rate). Recording of landmark tracking on the back side of the moon should have a high priority to be included and will take very little tape. The technique will be for the crew to obtain all of the sightings on a given landmark, which the CMC will temporarily store in memory. After completion of taking that set of observations the recorder is turned on for approximately 20 seconds at low-bit rate to collect and save that data. Since we are making eight sets of observations on the back of the moon, we are only using 160 seconds worth of tape, that is, about $2\frac{1}{2}$ minutes out of the remaining one-half hour at low-bit rate.

What else should be recorded is an open question and people with requirements should come forward soon and identify themselves so the procedures can be worked out for the "no high-gain antenna" situation. Of course, if the high gain is working, continuous recording on the back side of the moon should be standard practice.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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MDT/TL/M. Johnston

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: October 25, 1968
68-PA-T-236A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: CSI and CDH back into the AGS - maybe

Apparently the TRW AGS people have done a good job of putting the new rendezvous radar navigation filter into that dinky computer. In fact, they now estimate a surplus of some 80 words.

One of our brilliant ~~young~~ engineers here in MPAD - Ed Lineberry - has developed a simple technique for computing the CDI and CDH rendezvous maneuvers provided the CSM orbit is near circular as it should be on the G mission (reference MPAD memo, 68-FM61-318, dated October 15, 1968, subject: Linearized solution for CSI and CDH for a multiple-half-orbital-period transfer between maneuvers!). In fact, he expects that it could be fit into the aforementioned 80 words. He and Milt Contella have already discussed this with the TRW people who are looking it all over. If things go well, he expects they will come to the Software Configuration Control Board with the proposal to include it in some future AGS program and we can decided at that time if that is the best way to use our little 80 word Christmas present.

I wrote this because that idiot Ed Lineberry is too darn modest to tell anybody and I thought you might find it interesting.

Bill T

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

D Rend.

TO : See list attached

DATE: October 25, 1968

68-PA-T-237A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: X-axis or z-axis for LM TPI?

This memo is in response to a question that came up at the October 21 D Rendezvous Mission Techniques meeting. The question was: What is the additional LM RCS propellant cost if we use the z-axis RCS translation rather than the x-axis for TPI? Chuck Pace checked with the MPAD Consumable people who figured the x-axis would cost about 15 lbs. (taking into account the required attitude changes and use of the APS interconnect) and the z-axis will use at least 31 lbs. of RCS propellant (assuming the best CG location). These numbers are based on current spacecraft data book information. They intend to verify them through use of a 6D simulation program in the near future and will document the results.

In the meantime, we can probably use these estimates to decide which to use - x-axis which costs less RCS or z-axis which avoids breaking radar lock on.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: October 25, 1968
68-PA-T-238A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Descent Aborts - Part II

This memo is to carry on from that three page snowflake I sent you the other day on the same subject. It turns out we have encountered one of those rare situations when in doing something to fix an undesireable situation we actually improve something else at the same time. Specifically, the rendezvous people want to target the LM to a substantially higher orbit following an early descent abort than they had previously proposed. This makes the horizontal posigrade burn following the descent abort larger, of course, and alleviates that crazy pitch profile problem which used to exist during an abort in the first 50 seconds of powered descent. The point is that by some fairly minor changes in the spacecraft computer program (LUMINARY), we can probably eliminate the special abort procedure we used to think was necessary early in descent. Changes to the DPS abort program (P70) are essentially just changes in some erasible constants. This does not impact coding but has a significant impact on testing. By that, I mean the program will work now. The APS program change noted in last week's memo is still required but is essentially achieved by a erasible constant change too. This will all be firmed up and brought to the Software Configuration Control Board in the near future for their approval or something.

Having the early abort situation under control, we pressed on to another phase of descent aborts requiring some attention - specifically, how to handle the situation when the DPS is not quite capable of getting the LM all the way back into the desired insertion orbit. In order to establish procedures, it was necessary to make some assumptions. They are:

1. We never want to "Abort Stage" and use the APS, if the DPS is still operational.

2. It is acceptable to operate the DPS to propellant depletion.*

3. We have no desire to use the APS engine again after achieving orbit (that is, during rendezvous). Of course, we intend to use the APS propellant through the RCS interconnect.

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* This assumption must be verified by ASPO and then included in their data books.

4. The "Abort Monitor" in LUMINARY remains active following a DPS propellant depletion cutoff, which may result in a ΔV monitor alarm, even though the crew calls up the ΔV residuals.*

If we can make the above assumptions, the procedures become quite simple and standard. Namely, whenever aborting on DPS, the crew will permit that engine to operate at full thrust until either a guided cutoff is acheived or propellant depletion occurs. At that time, the crew will "proceed" to the DSKY display of ΔV residuals. If the ΔV remaining to be gained is less than 30 fps, the DPS will be manually staged and the crew will utilize the RCS to achieve the desired insertion condition by nulling the ΔV residuals. (It is probable that only the horizontal component need be trimmed if a convenient attitude reference is available. The FDAI eight ball should be good for this.) If the ΔV to be gained is in excess of 30 fps, the crew will hit "Abort Stage," automatically jettisoning the DPS and lighting off the APS to make up the ΔV deficiency. Again, only the horizontal ΔV residual need be trimmed.

Reset DAP – 2 APS config [illegible]

It is to be noted that with the new, high apogee we will be targeting for, the RCS/APS switchover point is orbital by a substantial margin (apogee in excess of 75 miles) and so there is no problem in the use of an RCS burn whose duration is less than 30 seconds. It is also to be noted that if the ΔV required of the APS is less than 100 fps, the burn duration will be less than 10 seconds, which probably makes it unsafe to reignite the APS. There is so much mystery with what is and what is not acceptable with the APS we cannot really be sure about that. However, it does not matter since there is no problem anticipated in performing the rest of the maneuvers with RCS.

[illegible]

One final comment - it has been proposed that the DPS be operated at half thrust during aborts to prevent lofting when the APS is required to achieve orbit. Two miles perigee and four miles apogee are the maximum effects. Those do not significantly perturb the abort rendezvous and therefore the decision was to maintain full thrust.

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* This assumption must be verified by me with MIT. Ok!

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

abort discretes monitor is turned off after the ΔV residuals display comes up. i.e. we can still abort stage after we've seen the ΔV residuals - we can "always" call P70 or 71 via V37 also.

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

UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: November 4, 1968

68-PA-T-241A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: When is the rendezvous radar designate routine (R29) needed?

George Cherry (MIT) asked if it is possible to drop the rendezvous radar designate routine (R29) out of the descent abort programs (P70 and P71). He gave me the impression that to do so now would significantly reduce their work and permit concentration in testing in more profitable areas. I don't know when the next Software Board meeting is - soon I hope. Perhaps this would be a suitable subject to bring up at that time.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

OPTIONAL FORM NO. 10
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UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: November 5, 1968
68-PA-T-242A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: C' earth parking orbit duration is a variable

This note is just to make sure everyone is aware of the rather siginificant variation in the time between earth orbit insertion (EOI) and translunar injection (TLI) on the C' mission, depending on day and azimuth of launch. This came as a surprise to me and may have some impact on what you are doing. According to Ron Berry, the time from EOI to TLI ignition is 2 hours and 42 minutes at the start of the December 20 launch window and decreases to 2 hours and 28 minutes at the end. On the last day of the launch window, December 27, this time period starts at 2 hours and 22 minutes and shortens at the end of the window to 2 hours and 7 minutes. All these numbers, of course, are for the first TLI opportunity. It may be desirable to perform a simulation with the shorter duration earth parking orbit just to make sure everything goes together properly. The poorer ground coverage and shortened crew timeline may give some trouble if it hasn't been thought out in advance.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

TO : See list attached

DATE: November 25, 1968

68-PA-T-258A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Descent Aborts - Part III

We have had a couple more Descent Aborts Mission Techniques meetings resulting in substantial progress which I would like to tell you about in this memo, if you haven't already heard.

A basic ground rule we have established is that these abort procedures go into effect at the time powered descent initiation (PDI) is attempted (i.e., starting at the time of PDI TIG). The point is, if the descent burn is not attempted at all another procedure is used (TBD). But once descent is started and an abort is required, the crew will always go to P70 or P71, the DPS or APS abort programs.

As noted previously we have eliminated the special abort zone during the first 50 seconds of powered descent which used to require special procedures. A simple program change was made to LUMINARY to do this. In order to cause the system to work in an acceptable way, it is also necessary to increase the insertion apogee altitude in the PGNCS targeting. This is done by changing the value of an erasible memory constant in the LGC. (Insertion apogee altitude is now 100 n.m.; it was 60.) A preferable solution was considered for LUMINARY but must be delayed to LUMINARY II due to schedule impact. It is to have the PGNCS compute the optimum apogee insertion altitude in real time based on the phase angle between the LM and the CSM at the time of the abort. It is possible to do this such that the subsequent rendezvous sequence is almost identical to the nominal lunar landing mission rendezvous sequence - always providing a one rev rendezvous with a differential altitude of 15 n.m. This program change will likely be made in the AGS, too - perhaps even in time for the F mission since it is relatively simple. Assuming we are able to fix the PGNCS program for the lunar landing mission, it looks like we have a very good, straight forward, simple and standarized abort/rendezvous procedure.

One caution must be observed since the DPS abort program (P70) commands full throttle immediately. Therefore, if the crew decides to abort on the DPS immediately after PDI they must at least await engine stability before hitting the Abort button. I should also point out that aborts during the first 40 seconds of powered descent will currently result in a spacecraft pitch maneuver which will cause the MCC-H to lose all telemetry until the crew can realign the hi-gain antenna or switch to the omnis. A program change request for LUMINARY II has been submitted to fix this.

Another area in which we have been working is the procedure following a descent abort using the DPS engine immediately after the engine cutoff. Like any other maneuver, the standard procedure is for the crew to call up the ΔV residuals on the DSKY and check the horizontal ΔV still required. Then:

a. If the horizontal ΔV to be gained is less than 5 fps, which should be the usual case for aborts prior to about 300 seconds into powered descent, the crew will trim it with RCS without staging the DPS. Out-of-plane and radial ΔV components will be left untrimmed and their effects will be eliminated by the subsequent rendezvous maneuvers.

b. If the ΔV in the horizontal direction at the end of DPS burn is more than 5 fps but less than 30 fps, we want to stage the DPS off prior to burning into orbit with RCS since RCS plume impingement precludes dragging the DPS along. However, staging presents a problem since the PGNCS digital auto pilot (DAP) will not be aware it has happened. Since it would continue to assume the high inertia, unstaged spacecraft, it would command excessive RCS firing for altitude control. Like LM_1, it would really hose out the RCS fuel. The easiest way around this is to switch guidance control to "AGS" and attitude control to "AGS attitude hold" and then manually translate into orbit with RCS based on the PGNCS DSKY ΔV display. The procedure would be to manually stage immediately after initiation of the RCS trim burn. Again, there is no reason for trimming the out-of-plane and radial ΔV residuals.

c. If at DPS engine cutoff the ΔV residual in the horizontal direction exceeds 30 fps, the procedure is to simply hit "Abort Stage." This will automatically separate the DPS and utilize the APS to complete the maneuver required to achieve the desired orbit. The ΔV required depends on the abort time and can range from as little as 30 fps all the way to a full Ascent duration burn. The 30 fps boundary was chosen because attempts to use P71/APS for smaller maneuvers can result in very large ΔV errors, in fact as much as 60 fps. Again, only the horizontal in-plane component of ΔV need be trimmed after the main engine cutoff.

Of course, in case "a" noted above it will be necessary to separate from the DPS sometime. There was considerable discussion as to whether a special post-insertion maneuver should be made for this or if it was preferable to await the first of the scheduled rendezvous burns - CSI. We finally concluded that the most straight forward procedure was to separate the DPS at CSI in order to avoid the need for more complicated special procedures for this special situation. Separation at CSI rather than immediately at insertion also provides the peripheral advantage of an extra hour use of DPS consumables. But that is not our reason for recommending this procedure. Of course, it will be necessary for the crew to carry out certain DPS safing procedures. Specifically, they must vent the tanks just as they do after a nominal lunar landing. One open item in regard to this is the determination of how propulsive this venting is. If it turns out to be unacceptable we may be forced to provide some special procedure to stage the DPS at insertion. FCD has the action item of determining the magnitude of venting ΔV.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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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, the consensus is that it would be a serious mistake at this time for the flight plan not to include optical observations of the landing site as part of the descent targeting operation. But, based on the ease with which the C' crew located and tracked the landmark on their first opportunity there seems to be no reason not to eliminate the first series of landmark tracking, which we had previously included primarily for on-the-job training. Accordingly, we intend to utilize the tracking plan and ground targeting operations previously developed in our Descent Mission Techniques meetings except that the first of the two tracking periods will be deleted or moved to LOI day if it can be conveniently included in the timeline. Since the landing site will be in darkness at that time, this particular session would have to be on some other landmark located 5 or 10 degrees to the east of the landing site.

I would like to discuss briefly the reasons for retaining the optical observations. Basically, they reduce to two things neither of which could be described as mandatory - but they are certainly not just "nice to have" things either. The first, of course, is to significantly improve the accuracy of the descent targeting which will make the descent trajectory more nearly nominal. In line with this, it also makes it more likely the landing radar can return the trajectory to within acceptable limits. The second benefit is that they provide a complete, independent check on the overall targeting system in the same sense that the star check confirms burn attitude or the horizon check confirms retro attitude on other mission phases.

Our discussions included numerically defined MSFN and spacecraft systems performance (expected and/or experienced) compared to descent targeting requirements which, you see, I have not included at all on this memo. However, they support the above conclusions substantially and could be made available to you if you want to see them. I left them out here simply because it is too complex a matter to discuss clearly in a memo such as this. What I am trying to say is that I feel these are well-founded conclusions which may be applied to both the F and G missions and we are going to press on based on them.

Howard W. Tindall, Jr.

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_2	For TEI after sleep
Pre LM Jettison	TEI 2 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 abort 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.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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 short 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 consideration 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.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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OPTIONAL FORM NO. 10
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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

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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.

Howard W. Tindall, Jr.

Enclosure
List of Attendees

PA:HWTindall, Jr.:js

OPTIONAL FORM NO. 10
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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 <u>no</u> 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.

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 <u>any</u> CLA following a 60 n.m. flyby.

2. DPS burn at pericynthion + 2 hours to <u>any</u> 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 <u>prime</u> 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 <u>prime</u> 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.

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

Memorandum

TO : See list attached

DATE: February 5, 1969
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 170 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 pericynthion 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
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: 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 45 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 (6.5 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 .5 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.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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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 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 meetings 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. <u>REFSMMATS</u>

a. The launch REFSMMATS 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 <u>lunar orbit REFSMMAT</u> to be used for the period between the PTC times defined in "b" shall be such that the <u>LM in landing attitude, over the landing site</u> <u>after DOI</u> would <u>have 0, 0, 0 on the FDAI</u>. 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.

8. 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 (P51). 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 $1\frac{1}{2}$ 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. gimbal will be live, but need intermediate thrust level for Luminary (Bellcomm KC 5 trim loop) Luminary 7A does not/ MIT

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

+ ?

9. The crew was somewhat concerned with the technique MPAD has developed for the LOI-15 minute abort. This abort 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 abort 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. MI

That's all I can rememeber. 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

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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 LOI maneuver. Wait until they discover it just takes an extra 12 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

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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. R77!

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. IT will be!

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 "b" 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). MIT

non zero Centang! Zero Centang will result in a CDH @ N(next apsidal crossing)

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.

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: February 11, 1969
69-PA-T-22A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: G Lunar Surface Phase Mission Techniques

During the first half of 1968 we held a sequence of meetings which culminated in a proposed set of mission techniques concerning use of the guidance and propulsion systems while the LM is in the lunar surface. This was documented in a Lunar Surface Phase Mission Techniques book, dated October 6, 1968. On February 5 we reviewed these techniques with the newly selected G crews, MIT, and other organizations concerned with this business. Some changes were made, which I would like to tell you about.

Probably the most significant change deals with CSM activity during this period of time, something which most people almost completely ignore. The most important thing the command module does is to execute a plane change such that the LM ascent can be carried out essentially in-plane. The second thing the CMP does is to attempt sextant tracking of the LM on the lunar surface in order to refine targeting for the LM ascent maneuver. Our proposed plan had both of these things scheduled in the period immediately prior to LM ascent, taking almost eight hours of fairly continuous activity. The plane change was $1\frac{1}{4}$ revs before lift-off. As a result of somebody's suggestion - I think it was Buzz Aldrin - we looked into performing the plane change about $2\frac{1}{4}$ revs after the LM lands. We found that this resulted in considerable improvement in the overall operation, provided it is unnecessary for the LM to lift-off prematurely. This single disadvantage is brought about by the fact that the plane change targeting is based on an assumed LM lift-off time. The advantages are:

a. It provides a long period of stable trajectory conditions prior to the LM lift-off.

b. It makes the mission plan tolerant of slippage in plane change execution or any other CSM activity, for that matter.

c. It shortens, simplifies, and balances the periods of CSM activity better and makes them more consistant with LM periods of activity.

By moving the plane change into the landing period of activity, it is only necessary for the CMP to start LM ascent preparation about 3/4 rev before

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LM lift-off. It is at that time while in darkness that he aligns his platform such that during the last pass over of the LM he may hopefully make sextant observations for MCC-H's use in targeting the ascent.

Incidentally, you will probably be interested to know that the nominal plane change for a mission carried out in July will be about 60 fps and in August about 170 fps. Although the state vectors for MSFN tracking should provide ample stability for carrying out the CSM plane change maneuver this long before ascent, it is probable that some LM yaw steering will be necessary to compensate for whatever errors propagate to lift-off time. These errors, we feel, should be well within the LM yaw steering capability. (Note: The yaw steering propellant requirement is proportional to the square of the yaw steering required; one-fourth degree costs about 5 fps, one-half degree yaw steering costs about 20 fps of APS propellant.)

Considerable time was spent discussing the insertion orbit for which we should target aborts immediately after LM landing. As you know, during powered descent, aborts are targeted for a variable insertion velocity to achieve the desired rendezvous light and ΔH characteristics. At the start of powered descent abort targeting aims for a high apogee. This is continuously decreased for aborts later in power descent until it reaches 30 n.m. apogee below which we do not care to aim. Therefore, for aborts from powered descent later than that and when first on the lunar surface we continue to aim for a 10 x 30 orbit. After passing the first go/no go approximately three minutes after touchdown the crew exits the descent programs which deactivates the "instantaneous" abort capability. Thereafter, if it is necessary to abort they must use the standard ascent program (P12). The question was - what should we aim for then? After lengthy discussion we arrived at the non-unanimous decision to target an abort at that time to the 10 x 30 orbit also. The most favorable alternate was to aim for the standard 10 x 45 which is used in the nominal mission, although in this case, you recall, it is necessary for the LM to remain in the insertion orbit for two revolutions in order to catch up to the command module before going into the standard rendezvous sequence. The primary advantage of the lower orbit is that its higher catch up rate permits spending about three more minutes on the lunar surface evaluating the LM systems and preparing for the LM lift-off if it's necessary. It also reduces probability of APS propellant depletion which is somewhat more likely in an abort since the crew has not yet gotten rid of some of the equipment which they plan to jettison on the lunar surface. We may hear some more about this decision.

The third topic consuming most of our time dealt with lunar surface PGNCS alignment. I think everyone is now pretty well satisfied that the operational alignment procedure should use the gravity vector as opposed to the

AOT since it is not only easier for the crew to perform but is more likely to provide the smaller dispersion in flight path angle - that is, it is the safer. On the other hand, it was finally agreed that AOT/star alignments should also be attempted - not only as a test of the system but also for the data they will provide for determining the location of the LM on the lunar surface. For those familiar with the various alignment options, we all finally agreed on the following sequence for both the simulated count-down to lift-off at the end of the first CSM revolution (abort) and for the lift-off at the end of the nominal lunar surface operation; the option order is 1, 2, 1, 3. (One thing someone ought to look into is whether the LM legs deflect as a result of crew movement within the spacecraft because if it does significantly change the spacecraft attitude they must be careful not to move around during these alignments. This sounds like a good action item for the FOP.)

George Cherry suggested an alternate way of stopping RCS jet firing immediately after touchdown. He pointed out that just jogging the hand controller will not necessarily immediately stop the firing and suggests instead cycling the PGNCS mode control switch to Off and then back to either Attitude Hold or preferably Auto to reset the DAP.

In summary, I would say this whole business was substantially simplified at our clam bake and is in pretty good shape right now. We have a solid plan for the crew and ground activity which everyone is satisified with. I think the only soft spot is in regard to the targeting for aborts from the second go/no go point and that should be easy to settle soon.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

MAY 1962 EDITION
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UNITED STATES GOVERNMENT

Memorandum

Mal Johnson

Copies to: 1) Dave Owen
2) Bob Ernull
3) Ron Berry
4) Carl Huss
5) Return to me

TO : See list below

DATE: FEB 20 1969

FROM : FA/Director of Flight Operations

SUBJECT: Spacecraft guidance for TLI

After yesterday's meeting (2-18-69) on the F mission, I have had some second thoughts and prompting by others about using the spacecraft guidance and platform for S-IVB TLI. The following summarizes my position and is to be used as policy in FOD.

The primary (and originally my only) reason for using the spacecraft guidance as a backup to the launch vehicle platform is to assure crew safety during first stage flight where a platform failure could cause a nasty abort situation at or near max q. Following this decision, it was fairly reasonable and relatively easy to provide the crew with the capability of guiding the launch vehicle into orbit, and I therefore subscribed to this position. The switchover to spacecraft guidance was to be utilized when and only when the platform fail lights were given to the crew and for no other reasons. My concern here was that we would get ourselves back in the same box as Gemini where an inordinate amount of work was required to provide switchover criteria throughout the powered flight phase. The probabilities associated with Apollo 10 platform failures just plainly don't warrant that kind of effort when faced with the work load we have in the Apollo program.

After listening to yesterday's discussion on the work we're about to set out on in order to be able to perform TLI with the spacecraft guidance, it began to be painfully obvious to me that we were putting ourselves back in the same box mentioned above. Further, as Sig Sjoberg pointed out to me, Sam Phillips gave very specific instructions to both MSFC and MSC that we were to limit our studies to backup guidance during the launch phase and, in fact, gave explicit instructions not to consider any other backup modes other than the polynomial in the first stage and manual guidance during the second and third stage for orbital insertion.

Based on the above, it is my direction that we cease work on any switchover or backup guidance schemes that would be used beyond normal orbital insertion. I realize that this will make some people in FCOD unhappy, but I don't feel that the work necessary to accomplish TLI guidance with the spacecraft is worth the effort at this time.

Christopher C. Kraft, Jr.
Christopher C. Kraft, Jr.

Addressees:
(see list attached)

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.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

MIT/IL/M.W. Johnston

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center
Mission Planning & Analysis Divisio[n]

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 erasible 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

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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.

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FM13/R. P. Parten
FM2/C. A. Graves
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FM:HWTindall, Jr.:js

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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

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: February 24, 1969

69-PA-T-32A

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 19.

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.

Bill

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list below

DATE: February 25, 1969
69-PA-T-34A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: D Mission LM PGNCS IMU drift checks

This memo is to backup a telephone conversation with Will Fenner. I hope it doesn't just add confusion but I thought it might be worthwhile to put into writing my latest with regard to the D Mission LM PGNCS IMU alignments and gyro drift checks. I am pretty sure if limits are approached or slightly exceeded, the guidance officer is going to be forced to exercise some real time judgment and I don't envy him in this particular case. I would recommend he reference this memo if it supports his judgment but if he doesn't use these numbers, I certainly will not call anyone's attention to it.

Marty James, TRW, has spent a considerable amount of effort in determining the magnitude of the various error sources contributing to our uncertainty in the relative orientation of the two nav bases. I spent a good bit of time talking to him and my feeling is that he has done a good job and these numbers are probably okay. The following table shows the contribution of each of the error sources:

Values listed are the 1 sigma misalignment uncertainty estimates between the listed spacecraft components

	Around x-axis	Around y and z-axes
CSM IMU		
	½ min	½ min
CSM NAV BASE		
	10	10
CSM SPACECRAFT AXES		
	20	8
CSM DOCKING RING (OR INDEX)		
	15	4
LM DOCKING RING (OR INDEX)		
	5	4
LM NAV BASE		
	½	½
LM IMU		
RSS	14 min	28 min

If you RSS these values, we find the 1 sigma uncertainty around the y and z-axes is about ¼ degree and around the x-axis is about ½ degree. That is, The PGNCS alignment against the CSM IMU should be within better than 3/4 degree around the y and z-axes and $1\frac{1}{2}$ 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 then that 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.

Howard W. Tindall, Jr.

Addressees:
FC/E. F. Kranz
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FC5/W. E. Fenner

cc:
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CF24/M. C. Contella
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PA:HWTindall, Jr.:js

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Memorandum

NASA - Manned Spacecraft Center
Mission Planning & Analysis Division

TO : Informal Distribution

DATE: FEB 25 1969

69-FM61-47

FROM : FM6/Chief, Orbital Mission Analysis Branch

SUBJECT: Comparison limits for rendezvous radar test on Apollo 9

Reference: Shannahan, Philip: Rendezvous radar checkout for Apollo 9, OMAB Memorandum 69-FM62-38, Feb. 20, 1969.

The comparison limits for the rendezvous radar test on Apollo 9 were determined by OMAB and documented in the above reference. Recent studies conducted by MIT/IL have pointed out an additional error source not considered in the OMAB analyses. This error source results from the computational inaccuracies in the Rendezvous Parameter Display Routine (R31) for range and range rate based upon the vehicle state vectors. At the very close range at which the radar test is being conducted (~ 0.6 n. mi.) the computed range can be in error by 600 feet and the range rate by 2 fps. This information was relayed by Mr. Malcolm Johnston of MIT/IL via a telephone conversation on Feb. 24. Inclusion of this error source results in limits as follows:

Range comparison	1600 feet
Range rate comparison	7 fps

The revised limits have been relayed to Mr. R. Carlton of FCD and Mr. M. Contella of FCSD.

Edgar C. Lineberry

Edgar C. Lineberry

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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

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 ~~5~~ 14, 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.

FM3:EMHenderson:js

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

M. W. Johnston

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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
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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?

HWT

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: 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 of 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

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MAY 1962 EDITION
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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

OPTIONAL FORM NO. 10
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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 passing 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

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OPTIONAL FORM NO. 10
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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 those 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.

Howard W. Tindall, Jr.

Enclosure

PA:HWTindall, Jr.:js

LM IMU ALIGNMENT SEQUENCE

1. Pre-undock - align to Mission Control Center REFSMMAT

2. Pre-DOI - P52 AOT align to REFSMMAT (stored)

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-DOI 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 $1\frac{1}{4}$ 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 - $2\frac{1}{2}$ 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) If 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 ~~23~~

MIT/Mal Johnson

OPTIONAL FORM NO. 10
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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/descent 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. Orbital Mission Analysis Branch

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 on ΔV trimming at insertion, too.

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

2. Math Physics Branch

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 PGNCS.

3. Landing Analysis Branch

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

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c. Is there some way to monitor the PGNCS to determine failure of the P63/P64 program change to occur when it should have by using the V, H, H DSKY displays? 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. Guidance and Performance Branch

Establish strip chart limit lines defining AGS performance in terms of acceptable, marginal, and failed. Similar limits are also required for the telemetry comparison display.

5. Landing Analysis Branch and Math Physics Branch

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

6. Guidance and Performance Branch and MIT

Establish abort limits for the strip charts beyond which impending failure of the PGNCS should be considered imminent.

7. Landing Analysis Branch, G&CD, and MIT

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 adequate landing radar data. Specifically, what should be used as a measure of this:

(1) The amount obtained and when it was obtained.

(2) ΔH from the strip chart at the time of landing radar loss.

(3) Others?

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Addressees:

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FC/C. E. Charlesworth
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FM/Branch Chiefs

PA:HWTindall, Jr:js

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 <u>change</u> 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 noodled 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.

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 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 $1\frac{1}{2}$ 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 $11\frac{1}{2}$ 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.

Howard W. Tindall, Jr.

Enclosure

PA:HWTindall, Jr.:js

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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 <u>prime</u> 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 <u>AND</u> 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 it 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.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

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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.

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 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 10, 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 15 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.

Bill

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?

Bill T

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 16, 1969
69-PA-T-64A

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 type-writer 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

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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 techniques 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 : 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 15 seconds duration at 10 percent thrust and about 15 seconds at 40 percent. The Phasing burn is about 195 fps achieved by 26 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 $1\frac{1}{2}^{\circ}$ 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

Howard W. Tindall, Jr.

cc:
(See list attached)

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

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 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.

I don't agree.

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 better? The only disadvantage seems to be the hazard involved in the act of switchover itself; all the switches, relays, and so forth have to 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.

Not switched to AGS (or ...) ??

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWTindall, Jr.:js

MIT/M. W. Johnston

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list below

DATE: May 6, 1969
69-PA-T-72A

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 gyro 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 .003 ft/sec^2. (See F Rules 15-11 and 25-10, G Rules 15-11 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.)

Bill

Howard W. Tindall, Jr.

Enclosure

Addressees:
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PA:HWTindall, Jr.:js

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 (R04) 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 R04 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.

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 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 C' 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

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 12, 1969
69-PA-T-76A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: G mission lunar descent is uphill - all the way

Just in case you didn't know, I thought I would send you this note about some nominal G mission landing site characteristics which I thought were kind of interesting. First of all, apparently this landing site (2-P-6) is about 9,000 feet lower than the mean lunar radius. The significance of this, of course, is that all ascent and descent targeting - in fact, all lunar altitudes - are referenced with respect to the landing site radius. That is, the 60 mile circular, LOI orbit is targeted with respect to the landing site and thus is lower by 9,000 feet than you might have assumed. But more important, the insertion altitude after ascent which is nominally 60,000 feet above the landing site is really only 51,000 feet above the mean lunar surface and, of course, less than that over the bumps.

Another interesting characteristic is that the approach to this landing site is even lower. Specifically, the estimated slope of the lunar surface as the spacecraft approaches the landing site is about 1° uphill. This in itself appears to be tolerable, although it does perturb the descent trajectory a little causing the approach angle to be low - that is, toward the visibility washout direction. Something we do want to look into about this was brought out by Bernie Kriegsman (MIT) the other day. One of his computer runs showed that during the final portion of the descent trajectory under automatic control, the spacecraft would actually stop descending and would achieve a positive altitude rate prior to landing. The dispersion that caused this was a 1° slope uncertainty in the lunar datum, which when added to the aforementioned estimated slope resulted in a 2° uphill grade. We are going to have to cross-check this to see if this is really what happens. If it is, we are going to have to look in to the effect of this on how the crew would respond and how the landing radar works under this condition.

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 status 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 <u>no</u> 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 come 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 - $2\frac{1}{2}^{\circ}$.

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

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 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 undectected. (Specifically, the accuracy of this drift estimate is $\pm$ .25°/hr.) PDI occurs about $1\frac{1}{2}$ hours after the AOT alignment, which means it is possible for pitch misalignments like $3/4^{\circ}$ 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 ephermis 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^{o}, 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 LOS.

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 <u>highly</u> 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.

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 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 switch-over 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 over-pass 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.

Howard W. Tindall, Jr.

PA:HWT:js

OPTIONAL FORM NO. 10
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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.

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

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: June 5, 1969

69-PA-T-87A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: PRN ranging in lunar orbit is 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. The only time ranging could become a requirement is if the entire trajectory determination system blows up and it is necessary to reinitialize from scratch when knowledge of the current state vector is essentially nil.

Since the specific questions arising recently deal with PRN requirements during powered flight - that is, ascent and descent, I would like to further state that during those 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 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 rendezvous and the effect of various separation ranges on the rendezvous tracking schedule. The point to be made is that even though it is possible to list a 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 is 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 initiation (i.e., LM insertion +12 minutes), the ΔV_x, and the pitch gimbal angle.

b. For the CSM to backup the phasing burn, we concluded that no special voice transmission to the CSM is required. Immediately after LM insertion the ground will voice to the LM (and the CSM will copy) the ΔV_x and CSI time as soon as possible. If time permits, this will be followed by a complete P30 Pad to the LM but nothing more will be sent to the CSM.

c. Before DOI the CSM will be sent a "CSM rescue Pad" consisting of a Phasing TIG, TPI time for abort before PDI + 10, and TPI time for abort after PDI + 10. These quantities are included in some more extensive LM Pad messages but some effort should be taken to assist the CMP in stripping out these specific parameters of interest to him or to send them up as a separate Pad. Upcoming simulations will show which course of action is preferable.

d. If it is decided to delay PDI one rev, MCC will relay to the CMP Phasing TIG, TPI time for all descent aborts and TPI time for the "T_2" abort time shortly after LM touchdown.

Bill T

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: 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.

Howard W. Tindall, Jr.

PA:HWT:js

MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6
UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: June 19, 1969
69-PA-T-94A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Ascent with busted guidance and control systems

On June 11 we had a Mission Techniques meeting to discuss manual ascent from the lunar surface. The term manual ascent, though, is somewhat misleading since most of our discussion had to do with how the guidance systems should be operated if certain of its components failed prior to ascent. In summary, I think everyone generally agrees that:

a. Given a rate command attitude control system, the crew should be able to guide the spacecraft into orbit quite satisfactorily using the horizon viewed through the overhead window as his attitude reference. The resultant orbit will be far from nominal which could present rendezvous problems, but at least we feel fairly confident he can get into orbit. Manual steering in the "Direct" attitude control mode is considered pretty hopeless in the sense that it is probably impossible to control the spacecraft at all - not in the sense that the insertion conditions are not acceptable.

b. Both the AGS/CES and the PGNCS have a substantial capability, even if the accelerometers are broken. However, special procedures are required to utilize this capability.

c. Gyro failures virtually wipe out the system with the possible exception of the rate gyros in the AGS/CES package.

The rest of this memo just adds a little detail to the above summary if you are interested.

Pure Manual Ascent using rate command and the horizon

Since our last meeting, Paul Kramer and Chuck Lewis have set up and run a series of simulations using CES rate command and the overhead window, which I understand were generally quite successful. They are in the process of documenting their results, so I suggest you contact them if you are interested. Briefly, they found that using the four step pitch profile MPAD/TRW has recommended works very well. They also found that it is possible to use the pitch angles in the current checklist that the crew uses to monitor a nominal guided ascent. These angles are tabulated for each 30 second time-hack. They found that letting the APS run to propellant depletion always resulted in an excessive overspeed - that is, yielding apogees up around 400 miles or so which suggests that it may be desirable to use the interconnect during manual ascent just as during nominal, thereby using APS propellant rather than RCS for attitude control. I expect we will all agree this is the right thing to do. Due to simulator limitations, they used the initial FDAI as an azimuth reference. It was the consensus of those at the meeting that if the inertial reference is not available, as could easily be the case, an acceptable alternate is for the crew to yaw the spacecraft during vertical rise to place the LPD line on the LM shadow. Given this initial launch azimuth as a reference, they should be able to choose prominent features downrange to head for in real time. In addition to the horizon angles, as viewed through the overhead window, corresponding angles as displayed on the FDAI are also available for the crew's use if an inertial reference is available. The reason we place greatest emphasis on the horizon is that it will always be there and a good FDAI may not be.

PGNCS with accelerometer failed still provides attitude hold rate command and FDAI

As well as anyone can determine, there is no reason why the PGNCS IMU cannot be aligned even with accelerometers broken. Of course, the gravity align is out, but it still should be possible to use the LM body attitude option and the AOT two star sightings option (alignment techniques 0 and 2). The accelerometers will cause program alarms but the alignment programs should still work. In either case, we would recommend aligning the IMU to the standard nominal REFSMMAT. No special procedures are required for this and the crew would be provided a perfectly nominal FDAI display.

Of course, no navigation or automatic guidance can be carried out without the accelerometer, but it still should be possible to get a rate command attitude, hold control capability provided we are able to manage the digital autopilot (DAP) in the LGC properly. Of specific concern is what special inputs, if any, are required to take care of vehicle mass as the ascent progresses. You recall, the LGC decrements mass as part of its DAP function but without PIPA's it won't. This also had some impact on which program the LGC should be operated in during ascent. It was our impression that the standard Ascent program (P12) is preferable. Alternates suggested were the Average G program (P47) or the Idling program (P00). MIT was assigned the action item of advising us precisely how we should handle the mass in the DAP and which program was best from their viewpoint. One thing, reasons for preferring P12 is that the PGNCS might offer a redundant Engine-On capability as well as a more favorable attitude deadband. If the PGNCS is used with a broken accelerometer, the crew should follow the standard four step pitch profile and fly to propellant depletion as noted above.

PGNCS-LGC failed leaves only an attitude reference - maybe

If the LGC has failed, it is impossible to realign the IMU. This presents two choices, if the alignment is known and favorable at the time of LGC failure, it may be desirable to leave it alone. If that is not the situation, it is possible to cage the IMU thereby aligning it to the LM body axis, which may provide a useful reference if the LM has landed in a fairly level attitude with the z-axis close to in-plane. Obviously if the LGC has failed, the only capability the PGNCS can possibly offer is an inertial attitude reference since attitude control and navigation demand a functional LGC.

AGS y or z accelerometer failed - AGS can still go "Auto"

If either the y or z-axis accelerometer is broken, it is impossible to do a lunar surface gravity alignment. However, it is possible to align the AGS given two AOT star sightings and ground assistance to compute the LM body attitude. Given the star data, the MCC will compute and relay to the crew both the LM and CSM state vectors in the AGS coordinate system assuming a body axis alignment (DEDA entry 400 + 50,000). It will be based on the assumption the crew will select initial guidance (DEDA entry 400 + 10,000) at precisely two minutes before lift-off. By zeroing the bias and scale factor coefficients in the AGS computer for the failed accelerometer, it is possible to use automatic AGS steering into orbit with a guided cutoff. Of course, no out-of-plane steering will result since the spacecraft will always be oriented such that the broken accelerometer is oriented out-of-plane.

If it is the z-axis accelerometer which is broken, it would be necessary for the LM to fly into orbit on its side. It is instructed to do this by loading the so-called W_B (Addresses 514, 515, 516) as relayed from ground to arm the W_B (DEDA entry 623 + 10,000). It may be possible to load a pseudo bias to compensate for the $1\frac{1}{2}°$ APS engine cant angle. There is a real trade-off to be made here between using the manual guidance noted above with a resultant overspeed or to fly the automatic AGS guidance with the LM on its side. The crew would be unable to monitor its performance but, if it works as advertized it would produce good insertion conditions for the subsequent rendezvous.

If AGS x accelerometer is broken a good inertial reference is all that's left

If the AGS x accelerometer is broken, it is possible to perform a lunar gravity alignment using the standard procedures associated with broken PGNCS/good AGS. In this case, we are assured of a good initial attitude reference for use in flying the pitch profile, but the automatic guidance and navigation is completely lost by the AGS.

AGS/CES with a rate gryo broken

No one is able, at this time, to say whether or not the AGS can fly completely automatically with a rate gyro disabled. It is suspected that rate feedback is required to provide a stable system but we are not sure. Accordingly, some runs are planned on the GAEC facilities with the RGA disabled to see what happens. If it can't handle it, the crew will have to fly Direct in the channel with the broken rate gyro using the error as a reference. This will also be simulated.

One major open item coming from all this is how we should play the rendezvous game given any of the situations here. Specifically, should we bias the lift-off time either late or early to give more time to do the rendezvous or to put the command module behind the LM at insertion? Should some CSM maneuver be made prior to or immediately after launch? A number of people will think about this and we'll probably get together in the next couple of weeks to lay out some plans since this is just as important as knowing how to get in orbit in the first place.

In all of the above cases a number of action items were identified, primarily dealing with establishment of precise procedures for initialization of the systems. It is expected that the necessary information should be available within a few weeks so that we can document all this before the G flight.

Howard W. Tindall, Jr.

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: June 24, 1969

69-PA-T-95A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Post Insertion CSM P52 is optional

Dick Gordon and Pete Conrad called the other day to ask how important we feel the CSM platform alignment is just after LM insertion into orbit. As I recall, this alignment is a carry-over from the time we planned to do the CSM plane change just prior to lift-off rather than just after landing as we currently plan to do. We didn't have pulse torquing then either. Given these changes I don't really see why it is needed anymore, particularly if we have been monitoring the IMU for several days inflight and if necessary, have compensated it. As a matter of fact, if it is not too late it might be reasonable to consider dropping this CSM platform alignment from the G Flight Plan too. The main advantage is that it would permit CSM to remain in an attitude compatible with rendezvous radar tracking by the LM as soon as they finish with their P52. Any comments anyone?

Howard W. Tindall, Jr.

PA:HWT:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: July 1, 1969
69-PA-T-101A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Post-insertion alignment is lower priority than rendezvous navigation

It has been agreed that it is more important for the LM to obtain rendezvous navigation tracking data than to complete the platform realignment after insertion into orbit if problems occur which prolong it. The point is, an accurate CSI maneuver is vital but it is recognized that bad angle data does not substantially degrade that solution. Thus, even though the lunar surface platform alignment may not be red hot it should be adequate to support the rendezvous navigation; if the crew experiences difficulty in realigning, they should terminate that effort to insure they get an adequate amount of rendezvous radar data. Specifically, they should complete or terminate the P52 by 30 minutes before CSI. If they do fail to complete the alignment, they should add one into their timeline immediately after CSI and depend on the CSM for their plane change targeting.

I would like to emphasize that this is a contingency procedure since everyone anticipates that adequate time has been provided to do this alignment.

Howard W. Tindall, Jr.

PA:HWT:js

OPTIONAL FORM NO. 10
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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: July 1, 1969
69-PA-T-102A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: New DPS GDA Descent mission rule is imminent if not now

A lot of activity has been going on lately regarding the manner in which the DPS gimbal drive actuator (GDA) is managed during descent. This memo is to make sure everyone knows this business is going on - and producing dramatic changes - and it is not finished yet.

The basic question, of course, is, What should be done if the GDA caution and warning alarm goes off during descent? Until a few weeks ago it was planned to ignore it until some secondary cue appeared to backup the alarm since it was felt a properly operating GDA was mandatory for descent. A number of new factors have appeared on the scene recently, which almost certainly changes this procedure. The first and most significant was the addition of the RCS plume deflectors which apparently have all but eliminated RCS impingement as an operational constraint. GAEC's analysis is continuing and unless we have some sort of duty cycle limitation, it appears we can tolerate as much activity as is required for total attitude control by the RCS during a complete lunar descent. Incidentally, RCS propellant quantities also appear adequate for this purpose.

Some secondary factors which support this technique are the uncertainty of whether or not the crew can sense a build-up in RCS activity when wearing helmets and gloves. Another interesting factor is that during normal descent, apparently the GDA doesn't move the DPS engine more than about 0.1° to account for c.g. shift during the entire descent. Apparently, the main excuse for even activating the GDA is to guard against unsymmetrical DPS throat erosion and engine compliance changes when throttling. It appears a final mission rule will be to turn off the GDA as quickly as possible if a GDA caution and warning alarm occurs and complete the descent using RCS attitude control unless something unexpected appears in the analysis going on now and between the flight.

Howard W. Tindall, Jr.

PA:HWT:js

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MAY 1962 EDITION
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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: July 3, 1969
69-PA-T-103A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Some new ideas on how to use the AGS during Descent

This memo is to fill you in on a couple of late crew procedure changes proposed for the G mission regarding AGS operation during descent. The first is a technique to prepare the AGS for immediate ascent which can be used to quickly reinitialize the AGS LM state vector immediately after touchdown if there is any concern that the navigation during descent has fouled them up somehow. This is possible since the LM state vector on the lunar surface can be easily predicted before descent. Specifically, it involves loading some storage location through the DEDA just after the final state vector update from the PGNCS at about seven minutes before PDI. The numbers loaded would be the lunar radius (240 + 56923) and the lunar rotation (262 - 00150), which essentially constitute the entire state vector on a lunar surface. The rest of the state vector elements (241, 242, 260, 261) are all loaded zeros. None of these addresses are used during descent or descent aborts so this procedure does not conflict with anything planned. The idea is that immediately after touchdown, when the lunar surface flag is set, the crew would key in 414 + 20,000 instead of updating altitude as currently planned. This would initialize the AGS state vector with these quantities quite accurately to support an immediate ascent. This procedure is supposed to be brought to the Crew Procedures Change Control Board very soon, but I noticed that Buzz Aldrin was already doing it during the Descent simulations last week.

Everyone I have talked to feels it is a good thing to do provided it does not overload the crew.

The second possible addition to the crew timeline involves making use of the AGS DEDA display just after touchdown to provide the crew a little more information regarding his touchdown attitude condition. Bob Battey called me with a Braslau suggestion (AGS/TRW) that, since the DEDA is not used during the terminal descent, immediately after touchdown it is possible to call up address 130, a component of the transformation matrix, which is essentially the cosine of the tilt angle displayed in octal. It was noted that this parameter has an interesting characteristic. If the spacecraft is perfectly vertical, the DEDA will read 40,000. If the spacecraft is tilted 42°, which is the critical tilt angle, the DEDA will read just under 30,000 regardless of the direction of tilt. Display above

30,000 is okay - the bigger, the better - and below 30,000 is bad news. This convenient crossover value seems to make this a possible extra cue for the crew to quickly assess whether the spacecraft has tilted more or less than the critical tilt-over angle. So far, none of the experts I have spoken to have seen anything wrong with this idea and generally consider it a desirable thing to do. That is, the procedure should work and should provide some useful intelligence for the crew, if they get into a suspected tilt-over situation. It could certainly not be considered mandatory and so the decision as to whether to do it or not to do it rests entirely on the crew's task loading during the last several hundred feet of descent. Simply, should the crew be fooling with the DEDA at this time? Ordinarily I would say no, but Buzz seems to be able to get music from that little mommy with his head turned off and both hands tied behind him.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: July 7, 1969

69-PA-T-104A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Manual Ascent revisited

On July 2 we had another meeting regarding Manual Ascent. As I have pointed out previously, the consensus is that the crew should have an excellent chance of achieving a safe orbit by manually steering the LM from the lunar surface if they have a rate command attitude control system by using the horizon view in the overhead window as an attitude reference. The two primary facets we discussed this time were:

a. What sort of ground support could be provided to the crew during powered flight and

b. What sort of rendezvous sequence would be pursued following the LM insertion.

This memo is to summarize the results of this session. Briefly though - the ground assistance can be substantial and the rendezvous can be a fairly standard CSM rescue requiring one or two extra revs.

As you recall, the flight controllers on the ground have a substantial capability for monitoring the LM's trajectory during powered ascent, even with the guidance systems broken, providing the RTCC powered flight processor (the "Lear") is working. This program provides a complete up-to-date state vector to drive the analog and digital displays in the control center. As a result it is possible for the Flight Dynamics Officer (FDO) to monitor the ascent trajectory continuously and to discern deviation from the nominal. For example, by monitoring the altitude vs. downrange distance plot and the velocity vs. flight-path-angle plot, he will be able to advise the crew if the radial velocity (altitude rate) becomes unacceptably dispersed. Specifically, starting about three and a half or four minutes into ascent, after the trends are well established, he should be able to advise the crew to bias the remainder of their pitch profile up or down probably using 2^{o} increments. Given this assistance, it is anticipated that the crew should insert with a nearly nominal flight-path-angle.

It is also possible for the FDO to assist the crew in maintaining a near nominal out-of-plane velocity. That is, once the crew has keyed their initial launch azimuth on their shadow and then aimed for a prominent landmark (such as the south rim of Crater Schmit for landing site 2), the

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FDO will call out 2° north/south (or left/right) attitude changes whenever his digital display of out-of-plane velocity exceeds 50 fps. This vectoring of the crew can start very soon after lift-off if necessary.

A major problem we feel we have now resolved has to do with when the crew should shutdown the APS. Analysis has shown that a continuous pitch angle bias of 2° can result in an unsafe perigee unless the APS is run to propellant depletion. Therefore without ground vectoring, as noted above, we feel it is advisable to permit the APS to operate until propellant depletion; a 2° bias does not appear to be out of reason for manual steering using that weird lunar horizon as a reference. However, given ground assistance in attitude control a propellant depletion cutoff will certainly result in an excessively high apogee, which makes the rendezvous situation more difficult and costly. Accordingly, we propose that as long as the ground monitoring of the trajectory indicates that it is reasonably close to nominal, the FDO will voice command engine "Off" when his display of safe velocity (V_s) equals zero. (Briefly, V_s is the ΔV required to assure a 35,000 feet perigee at the current altitude and flight-path-angle.) A call at this time, assuming a 15 second delay, will produce an overspeed of about 300 fps yielding about 200 miles of excess apogee which should be adequately safe. The important thing is that it protects against apogees in excess of 250 n. mi. (which have been regularly occurring in simulations). Although these high orbits can be handled, there seems to be no reason to accept them. In this same vein, analysis has shown that we have been unduly conservative in proposing use of the RCS propellant for attitude control during ascent. We now feel confident that it is safe to stick with the nominal procedure of using APS propellant for attitude control during manual ascent and saving the RCS for whatever comes next.

Just about any failure combination which makes it necessary to perform a manual ascent will also demand a CSM rescue sequence. The sequence which seems to suit the situation best is as follows:

a. CSM performs a phasing burn (NC1) on the LM's major axis "maneuver line" approximately one rev after LM insertion.

b. CSM will perform CSI $\frac{1}{2}$ to $1\frac{1}{2}$ revs after NC1 depending on how high the LM apogee turns out to be.

c. CSM performs CDH $\frac{1}{2}$ rev after CSI.

d. CSM performs TPI at nominal elevation angle which should occur about midpoint of darkness.

e. Braking can be done by the LM and/or CSM at the crew's discretion, based on the real-time situation.

f. Plane changes should be handled in the standard way - that is, combined with the other CSM maneuvers and with the extra plane change burn between CSI and CDH performed by the CSM if it is necessary. (It is to be noted that any large out-of-plane situation must almost certainly be due to a velocity error at insertion and not an out-of-plane position error.) This would cause the node of the orbital planes to fall near the major CSM burns such that most of the plane change required would be efficiently combined with them. Given control center assistance in ascent steering though, a large out-of-plane situation seems unlikely.

To insure that even a very low insertion orbit can be handled, it was decided to bias the LM lift-off late, approximately three and one-half minutes. Specifically, the FDO will compute a LM lift-off time consistent with a 10 mile circular insertion orbit and a nominal rendezvous sequence. However, since it is most desirable to utilize the sequence noted above rather than having to make rendezvous maneuvers soon after insertion if a low orbit is achieved, we feel the best course of action is for the LM crew to be advised to make whatever ground computed maneuver is required at insertion to achieve an orbit equivalent to at least 10 x 30 n mi. orbit. That is, if they truly burn out very low, they should boost their orbit with RCS to permit use of the CSM rendezvous sequences noted above. Incidentally, they will also be advised to make an apogee maneuver to pull up perigee to about 16 n. mi. as a safety measure in any case.

If for some reason the LM does not achieve a safe orbit with or without the control center assistance noted above, we still have a straw to fall back upon. The flight controllers have the capability immediately after insertion of computing a maneuver to insure at least a 35,000 feet perigee based on the Lear Processor. This maneuver will be scheduled at three minutes after APS shutdown or at apogee, whichever is required. It is to be noted that ample RCS should be available to execute this maneuver.

Although we have nowhere nearly the same confidence of success, procedures have been established for the crew to execute manual Descent Aborts. The problem here, of course, is that a single pitch attitude time history cannot be established for aborts occurring at any time in powered descent. However, the necessary work has been done by MPAD and TRW to provide the flight controllers with an acceptable pitch profile as a function of abort time in powered descent using the horizon attitude reference which would provide a safe orbit if the crew were to follow it. Accordingly, if communications are retained or regained after a descent abort, the crew can be informed of a pitch profile to follow to achieve orbit.

One other item we discussed was the relative merits of flying a completely manual ascent vs. a completely automatic ascent using the AGS with a broken z-axis accelerometer. You recall in this event it would be necessary to fly the LM into orbit on its side in order to place the broken accelerometer in the out-of-plane direction and bring the good y-axis accelerometer into plane to provide the automatic AGS capability. If the AGS works, everything should be just fine, but the crew will be unable to monitor its performance which leads to consideration of a completely manual ascent with its horrible overspeed problem. However, given ground monitoring we feel confident that a malfunctioning AGS can be detected and it is our strong recommendation that it be used. If the control center detects an unacceptable failure, the crew would be advised to yaw in-plane and proceed into orbit using the standard manual ascent technique.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: July 10, 1969

69-PA-T-105A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Tweak burns

If you can stand it I would like for you to hear the latest on tweak burns - the trim maneuvers made after LM insertion from a descent abort. I thought we had this settled and on ice a couple of months ago but some things have happened which probably make it logical to revise the tweak rules. The things that have happened are:

a. The LM RCS plume impingement constraints have been substantially reduced.

b. Simulations have shown that the Flight Dynamics Officer (FDO)/RTCC capability of computing the tweak maneuvers on a timely basis is much better than anticipated.

Some FCSD, FCD, and MPAD guys got together July 8 and came up with the following:

a. Our previous rule was quite simple; if the LM inserted into orbit with the DPS attached, the command module would make the burn; if the LM had staged, the LM would make the maneuver. Now that the LM has been modified with plume deflectors and additional thermal protection, it has the capability of performing any tweak maneuver we foresee. Accordingly, the rule is being modified to say that for all descent aborts prior to PDI + 10 minutes the LM will perform the tweak provided it is within the RCS plume impingement constraint, regardless of whether the LM has staged or not. If for some abnormal reason the LM capability is exceeded, the CSM will perform it; the LM should not stage the DPS just to provide a greater RCS capability. Also, the LM should not trim insertion conditions.

b. As you recall, aborts after PDI + 10 minutes require an extra rev in addition to a phasing maneuver, which makes the tweak burn unnecessary. We have also stated that trimming the insertion conditions is ~~necessary~~. However, if the crew wishes to trim +x there is no objection to that and obviously if the +x required is large, there is no choice. It must be trimmed.

c. I would like to emphasize another rule which has been on the books for a long time but which may not have been clear to the crew. Namely, if the DPS shuts down with a ΔV required to reach the insertion conditions greater than 30 fps, the crew should utilize the APS and P71 to achieve orbit. We have recommended that automatic Abort Stage sequence to achieve 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: July 11, 1969
69-PA-T-106A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Descent Data Select procedures are finalized

On July 7 and 8 we held a final review of the Data Select procedures and Flight Controller interface during the Descent phase of the lunar landing mission. This lengthy memo is to describe briefly some of the items discussed, all of which are being thoroughly documented before the flight.

On F, as you know, John Young did not track the center of the Landing Site 2 landmark - a crater designated "130" - but rather used a much smaller crater on the rim of 130. He did this primarily because it was much easier to do and, he thought, would improve the accuracy. It is planned to use this smaller crater, which has been called "130 Prime," on the G mission also, and the RTCC is set up to do so. However, it was emphasized that we must also be prepared to use the old "130" if for some reason lighting makes it impossible for Mike Collins to acquire "130 Prime."

It was strongly emphasized by the Data Select people that they should be in the high-speed mode for Lear filter initialization and conditioning at least four minutes before PDI. If for some reason they are delayed past this point, their confidence in the system will be degraded. In fact if initialization is delayed until 20 seconds before PDI - the drop-dead point - they feel they will have no confidence in the system throughout descent at all.

Analysis of the F flight data has revealed that the Lear processor for some reason gives best results when using three tracking stations rather than four, which it was originally set up to use. Accordingly, it will be operated in the mode where the fourth station's data are available but are excluded from the solution. If one of the three active sites fails during descent, the Data Select people will immediately replace it with the previously excluded site. If it is concluded that the failed site will not be restored quickly, another site will be called up immediately to provide backup for a second failure. It is to be emphasized that bringing up this new station is to provide a backup and an opportunity to observe its data. It will not be actively used unless another site breaks down or the performance of the Lear processor unexpectedly becomes degraded in a manner consistent with poor station location geometry which the new station could help correct.

The Data Select people reviewed their real-time procedures for declaring the "Lear filter is go" as follows:

a. During the free-flight processing after going into the high-speed mode at PDI minus four minutes, they plot and compare Lear results with their best estimate of radius and altitude rate based on previous MSFN tracking and a confirmed DOI maneuver. If these parameters differ by more than 3,000 feet and 13 fps, respectively, the Lear is considered uncertain.

b. During powered descent they have doppler comparison plots for each of the individual MSFN sites vs. the PGNCS. These are used to sort out a bad station.

c. They monitor Lear output plots of altitude, altitude rate, pitch, and LM mass rate of change looking for discontinuities, internal incompatibilities, smoothness, etc.

d. The Lear filter displays an estimate of its own performance - residuals, rate biases, and so forth. A particularly strong indicator of performance is the residuals of the fourth (excluded) site, which is not included in the solution.

During the Descent briefing to the management people, a week or so ago, Chris Kraft proposed that some sort of inflight lunar orbit checkout be made of the Lear Processor prior to Descent. After lengthy and sometimes emotional discussion, we have concluded that it is most advantageous to use the same tracking stations and communication lines as during descent. To do this we must perform the test on either the first or second lunar orbits before the Madrid station is lost due to earth's rotation. It was also concluded that to perform this test in the on-line RTCC computers with the active third floor MOCR was too risky. Accordingly, the proposal is as follows. Configure the network stations to transmit high-speed data for a period of 15 minutes during the first lunar rev when the spacecraft is more-or-less over the landing site. Log the data in the control center and then play it through a third, off-line computer utilizing the second floor MOCR display system. Since no compatible G&N telemetry will be available at this time, it will be impossible to operate some of the displays such as the guidance officer strip charts. It will be possible however to make a realistic, useful comparison of the Lear output with the other MSFN processing to see that this system is working properly end-to-end - from spacecraft to display system in the MCC. Mike Conway (FSD) is responsible for assigning personnel to do this and for getting the control center configured for the test. He also intends, if possible, to get some simulated data and practice this test before the flight. I think the consensus is that this test is like airline flight insurance - a small waste of resources with very little chance of gain; however, it can pay off real big, if we're lucky!

Another question answered was, What spacecraft position should be used for initialization of the Lear Processor in preparation of the T_2 lift-off? ("T_2," you recall, is the delayed abort time shortly after landing associated with the second stay/no-stay decision.) The problem here is that very little time is available to assess the descent tracking and telemetry data in order to select the best estimate of the actual landing site location. We finally concluded that the best solution was to use the preflight nominal value - the one computed from the F mission tracking.

One very significant item resulting from our meeting dealt with reconfiguring the MSFN tracking network after a T_2 stay decision. It had been planned to keep all stations in the same configuration as during descent in order to support a lift-off one rev later (T_3) if that turned out to be necessary. Unfortunately this leaves only two tracking stations with very little geometry on the command module which produces two substantial disadvantages. First, the command module state vector hasn't been updated since before DOI and it's getting kinda worn out and yet it is the one which would have to be used in support of a T_3 launch and rendezvous. Probably more significant is the effect on the nominal mission, namely it is intended for the CSM to track the LM with the sextant at the end of that first rev. It is anticipated that this data will provide the best estimate of LM position on the lunar surface in support of nominal ascent targeting as well as post-flight analysis. In fact, we intend to use this RLS determination in preference to any of the other RLS sources unless there is some reason to suspect it is screwed up. However, for the sextant data to be useful we must have an accurate CSM state vector to reference the sextant data too. This requires better MSFN tracking than had been planned. Accordingly, it was decided that immediately after a T_2 stay decision, the Ascension station would be reconfigured for CSM tracking on the remainder of the descent rev and for the next rev too. It will only be switched back to the LM in the event of a T_3 no-stay decision.

The problem of determining LM position (RLS) to support a T_3 launch is a tough nut to crack. Our choices are based on powered flight navigation by the PGNCS, AGS, and Lear adjusted after touchdown with an improved estimate of LM position at PDI. It is anticipated that the LM's AOT/gravity alignment data will not be available in time to support the Ascent targeting although if everything goes just right it might be. The point is that none of these data sources have ever been used before and each has its own potential problems that could foul it up badly. This makes its unreasonable to assign hard and fast priorities to these sources today, although everyone agrees that the Lear should probably be the best. The point is, determination of RLS for T_3 is being left open to real-time judgment of the experts who will include whatever bits of intelligence are available during the flight to select the best value. As noted before, the CSM state vector and sextant tracking will normally be used for the nominal ascent, but it obviously won't be available for a T_3 launch.

We discussed the PGNCS reinitialization required if PDI is delayed one rev. It was finally decided that virtually under no circumstance would the state vectors in the PGNCS be updated even though later tracking data is available. The values of RLS will be updated by applying additional propagation biases to account for the extra rev. The exact procedure for doing this is too complicated to put in this memo but I believe it is understood by everybody involved.

And that's that!

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

NASA - Manned Spacecraft Center
Mission Planning & Analysis Division

Memorandum

TO : FC/Chief, Flight Control Division

DATE: JUL 1 4 1969

69-FM21-191

FROM : FM/Chief, Mission Planning and Analysis Division

SUBJECT: Descent monitoring after landing radar velocity updating

There has been considerable discussion concerning the capability to monitor powered descent with velocity residuals after landing radar (LR) velocity updating begins. This memorandum presents the recommendations of the Mission Planning and Analysis Division (MPAD) for powered descent monitoring during this period of powered descent.

After LR velocity updating begins, the AGS/PGNCS velocity comparisons are no longer valid. However, the powered flight processor (PFP)/PGNCS velocity residuals and the MSFN/PGNCS range rate residuals ($\Delta\dot{\rho}$) can be used for powered descent monitoring provided this data is valid. Therefore, if the PFP is operating satisfactorily until the time of LR velocity updating and no anomalies in the PFP are detected after velocity updating, the PFP/PGNCS and MSFN/PGNCS $\Delta\dot{\rho}$ should be used to monitor the descent trajectory.

The objective of this monitoring is to prevent erroneous LR velocity data from destroying the PGNCS state vector to the extent that a PGNCS abort cannot be achieved. The monitoring should basically ensure that the PFP/PGNCS velocity residuals converge to a near zero value after LR velocity updating. The limits for PFP/PGNCS velocity residual monitoring after velocity updating should be the same as the values used prior to velocity updating, unless the PFP/PGNCS residuals are near the limits when velocity updating begins. In this case the PFP/PGNCS residuals limits should be increased by 10 ft/sec to ensure that the LR has sufficient opportunity to cause the PGNCS velocity to converge to the correct value.

for Howard W Tindall
John P. Mayer

cc:
(See list attached)

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: July 14, 1969

69-PA-T-109A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: How we will handle the effect of mascons on the LM lunar surface gravity alignments

What do we do if one of those big damn lumps of gold is buried so near the LM that it screws up our gravity alignment on the lunar surface? Without exception, the calculations of all the various far-flung experts predict that mascons should have no significant effect on our lunar surface gravity alignments. In fact, based on this we have chosen to use gravity alignments nominally as opposed to star alignments. They are easier to do and probably more accurate. A few of us got together the other day, though, to figure out what to do if, contrary to expectation, some sort of weird gravity effect is noted, which appears to be acting on the LM on the lunar surface. This memo is to tell you about that.

As you know we have several sources of data for determining the LM's position on the lunar surface (RLS). One of these is through the use of data obtained from LM platform measurements of the direction of the lunar gravity and from AOT observations of the stars. If this determination, using the LM data, disagrees substantially with the other data sources, we must consider the possibility that it's due to gravity anomalies. The sort of difference we are willing to tolerate is 0.3° in longitude, which is more or less equivalent to 0.3° pitch misalignment in the platform. True alignment errors in excess of that could present ascent guidance problems. Since 0.3° is equivalent to about five miles, you'd expect the crew's estimate of position could probably be useful in determining the true situation. All they'd have to do is tell us they are short or over-shot the target point a great deal.

If uncertainty still persists, it seems we must believe the gravity and use it for our alignments - both PGNCS and AGS. That is, we have more faith in it than in our other sources of RLS determination. However, if examination of all these sources convince us that the gravity does have some funnies greater than 0.3° associated with it, we would have to modify the crew procedures in real time such that the ascent platform alignment is done using the stars (Alignment Technique 2) rather than gravity.

Consideration was given to hedging our bet by aligning the PGNCS to the stars and using the lunar gravity alignment in the AGS. Further consideration, however, revealed an interesting and somewhat sad thing. What we actually discovered was that the ground trajectory processing during ascent is also affected by downrange position error - that old demon that seems to be plaguing us in so many ways recently. The fact is that throughout ascent we would never know which system was right and so we would never have the intelligence to switch over from one system to the other. In other words, there is no point in using different Alignment Techniques for the two guidance systems.

The problem noted above is primarily in support of Ascent 1 rev after landing. After that, additional very accurate sources of RLS determination become available. Specifically CSM sextant tracking of the LM is always the prime source and if Mike has trouble on one try, he should try again on later revs - there are plenty of opportunities and little else to do. If he still fails and the uncertainty noted above exists, we have the situation in which LM rendezvous radar tracking of the CSM becomes mandatory. You recall we deleted this from the timeline with the understanding it would be reinserted if we could determine RLS in no other way and this is that case. We sure don't expect this to happen, but if it does RR will be needed.

In summary then:

a. We should always align both AGS and PGNCS to the same data source, gravity or stars.

b. We use gravity unless we have some concrete reason to question it - such as all data sources including the crew estimate of RLS are in disagreement with it by more than 0.3^{o} in longitude (pitch). In that case, use the stars (both AGS and PGNCS).

c. Naturally longitude initialization error louses up the ground ascent trajectory monitoring just like it does descent.

d. If RLS uncertainty persists, either CSM sextant or LM RR tracking of the other vehicle becomes mandatory.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: July 16, 1969

69-PA-T-111A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Change in delayed PDI Descent targeting procedures

This probably doesn't amount to a gnat's elbow to you, but I would like to change something in a memo that I just sent out the other day dealing with spacecraft state vector updating if we delay PDI one rev. Previously we planned to leave the state vector in the LM computer alone but to change the landing site position (RLS) to account for propagation error for the extra rev. Since then there has been a big flap brought about by our discovery that the command module is making uncoupled attitude maneuvers which cause surprisingly large perturbation to the orbit. In order to minimize these effects in the descent targeting for the delayed PDI situation, we have concluded that it is best to redetermine the LM state vector based on the newer MSFN tracking (revs 12 and 13) and uplink it to the LM if PDI is delayed. Since the RLS already has been compensated properly for the associated propagation errors, it does not need to be changed.

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: July 17, 1969

69-PA-T-112A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Gyro calibration and accelerometer bias update and redline values

Chuck Wasson wrote a memo, dated June 27, 1969, to Gene Kranz and me defining in detail the Guidance and Control Division's (G&CD's) position on "in-flight gyro calibration and accelerometer bias update and redline values." In it he pointed out that both the Mission Rules and the Mission Techniques Documents should be brought into agreement with his recommendations. Actually this subject has been discussed endlessly in the Mission Techniques meetings and elsewhere and so there were no surprises in the values and techniques proposed. However, his memo does again draw our attention to the minor differences in official documentation and reminds us that that is a sloppy way to do business. I talked it over with Cliff Charlesworth (FCD) and Mal Johnston (MIT) and we all concurred that the numbers Chuck Wasson proposes are as good as any and we have taken steps to comply with his recommendation. Namely, future issues of Mission Rules and Mission Techniques Documents will conform with the G&CD's recommendations as listed in the referenced memo.

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: August 1, 1969

69-PA-T-114A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: How to land next to a Surveyor - a short novel for do-it-yourselfers

As you know a decision has been made for the H mission to land next to Surveyor III. Considerable amount of work has already been spent in figuring out how to perform a so-called point landing, but a number of computer program and procedure changes are required which cannot be implemented prior to this mission. Accordingly, we have had a three-day Mission Techniques free-for-all starting July 30 to see what we could jury-rig together to improve our chances of landing next to the Surveyor. Obviously, the techniques used on G are not adequate for that purpose, but we don't want to shake them up too badly at this time. If you would like my guess as to how well we will actually do prior to getting any analysis results for the techniques proposed or even much understanding of what happened on the last mission, I would guess that we will probably be able to land within about one mile of where we aim. If we land within walking distance, it is my feeling we have to give most of the credit to "lady luck."

Almost the first question that anyone asks is, How well do we know the location of the Surveyor? The mapping people gave us an excellent briefing on what they know so far about the landing site. They are virtually certain they know exactly where the Surveyor is with respect to the local terrain based on a comparison of photography taken by the Surveyor itself against Orbiter photography of the local terrain pattern. Other data sources confirm these results. They brought out that the sun elevation angle during descent will be such that the Surveyor is entirely in darkness (unless the launch date is changed) and almost certainly will not be visible to the crew. This is because the Surveyor is well inside a shallow, funnel-shaped crater whose sides slope at an average of about 15°. They also informed us that someone has already chosen a landing target point located 1,000 feet east and 500 feet north of the Surveyor itself. There is some question if that is the spot we really want to aim for, but all precision mapping and survey work is being done with respect to this target point. This includes selection of five distinct landmarks which can be used for the sextant tracking required for descent targeting.

We have made a two-pronged attack on the problem of how to land next to the Surveyor. The first deals with improving as much as possible the ground targeting of the PGNCS. That is, providing the best possible state vector and landing point position - telling the system where it is and where it is supposed to go. Hopefully, this will get the crew to within an envelope from which they can fly over to the desired landing point. The second prong, of course, is to increase as much as possible the LM's maneuver capability under crew control so that they can do that.

Regarding the targeting, several things are being done to substantially improve the situation on the H mission as compared to the G mission in this respect. First of all, the fact that the landing site is "16 minutes" further to the west provides time after DOI to update the LM state vector and RLS from the ground. On the G mission we had to do all this on the rev before DOI. Slipping the update this way permits us to use MSFN tracking data one rev younger and reduces the effect of propagation errors significantly. Furthermore, the last pass of MSFN tracking is obtained directly on the LM itself after undocking, thereby reducing the effects of docked attitude maneuvers and the undocking maneuver itself on the state vector.

In addition to the better MSFN tracking situation just noted, we must make a concerted effort to reduce the in-orbit perturbations during the last three revs before DOI and are offering the following nine-step program to do this.

1. While docked to the LM, the command module should use balanced RCS couples for attitude control. (A data book change involving LM plume impingement constraints is required which Bob Carlton will work out.)

2. When undocked, the LM should use balanced RCS couples for all attitude control. (This would have required an onboard computer program change which we can't get for this flight and MIT insists we are better off without it.)

3. Absolutely no venting or dumping is allowed!! For heaven's sake, will all spacecraft system people please take note of this. What seems insignificant to you is a nightmare to orbit determination people.

4. The LM RCS hot firing test should be reduced and modified. Specifically, no translational hot firings should be made and the ACA pulse mode jet firings should be made balanced and with minimum duration. (TTCA checkout should be done with cold firings.)

5. Particular attention should be given to minimizing LM PGNCS "average g" on time during DOI. To do this we have decided to eliminate all residual ΔV trimming (unless x is greater than 1 fps and it shouldn't be). MIT was asked to advise on how to terminate "average g" the best and fastest way.

6. Associated with item 5, program changes must be made in both the PGNCS and the RTCC. Specifically, we are changing the PGNCS coast/align downlist to include the residuals and the RTCC/MCC to process and display them to within 0.01 fps for use in "confirming" the DOI burn.

7. The undocking maneuver should be executed in a radial direction with the LM below the CSM. Docking probe capture latches should be used to eliminate any net ΔV but that technique requires approval of the structures people. (John Zarcaro is following up on this.) If this is impossible, the LM should null all residuals acquired during undocking.

8. The LM 360° yaw around inspection maneuver should be eliminated unless there is a real time indication (barber pole) that the landing gear did not deploy properly.

9. All stationkeeping should be done by the CSM - none by the LM. To permit this, the CSM should use Z rather than X-axis RCS jets to execute the separation burn, thereby retaining visual contact with the LM.

In summary, it is intended to perform the same sequence of tracking and state vector updating as on the G mission in order to assure capability of landing in the event of subsequent problems. However, in the H mission nominal timeline a LM state vector will be uplinked at about AOS + 10 minutes using MSFN tracking from the last two revs before DOI plus a confirmed DOI maneuver as discussed above.

At this time we have no assurance that even the targeting based on these improved state vector techniques will support a point landing. Accordingly, we have examined additional data sources available after DOI which may be used to further tune-up the targeting. MSFN tracking, LM visual observations, and LM radar observations were all considered potential candidates. Of these we finally decided to concentrate only on the first. Although the anticipated errors will most likely be in the state vectors, it is felt to be operationally too difficult to update them again. Accordingly, all adjustments and targeting have to be made to the targeted landing point, which hopefully will achieve the same end objective. A change is being provided in the spacecraft computer program (LUMINARY) to permit updating the landing point location in the downrange and crossrange directions. (Altitude updating capability will also be provided in this new extended verb.) At this time we know of no data source which can be used to obtain a crossrange correction but we have work underway to use MSFN tracking to obtain a downrange correction which will be voiced to the crew for input into the PGNCS prior to PDI - 8 minutes. There are three possible ways for using the MSFN tracking now under consideration:

1. Immediately after AOS, at least three MSFN ranging (not doppler) observations will be obtained on the LM over a six to eight minute period. Since downrange error at AOS is predominently along the line of sight to the MSFN station, range almost gives a direct measurement of the downrange error. In order to obtain this data it is necessary that the LM high-gain, S-band antenna be operating and that the spacecraft Ranging switch to set to "Range."

2. The Lear Processor will be activated as soon after AOS as is possible, consistent with the generation of the confirmed post-DOI state vector. (That is, at about AOS + 12 minutes). The inertial velocity determined by the Lear Processor will be compared to this updated state vector to determine the difference in radial velocity which may be directly related to downrange error. FCD, FSD, and MPAD have the task of defining the RTCC program change required to permit activation of the Lear in coasting flight at this time in the mission.

3. The weighting structure of the Lear Processor may be changed to permit direct measurement of position and velocity as opposed to velocity alone as is now done. There is some hope that this may give us a direct measurement of downrange position error.

The Math Physics Branch has a task of determining the accuracy of these three techniques such that we can choose which, if any, should be used for this job. It is to be noted that the Lear Processor can only be operated in one of the two modes suggested. FCD, Data Select people, and FCSD flight plan guys will work out the detailed timeline to establish how this all goes together.

Given a ground estimate of downrange error from one or two of these data sources, there are two ways to go. The preferred is to voice this correction (in feet) to the crew for direct input into the PGNCS via the DSKY with an extended verb before calling P63 for the last time. This will cause the entire descent trajectory to be slipped by that amount. If the LUMINARY program change required to do this doesn't get in, the flight controllers have been requested to be ready to command up a new, corrected RLS. In either case, it must be done within the period of five minutes or so between availability of the correction and the crew call-up of P63.

It is to be noted that the crew can use this new extended verb even after PDI... If they have the guts! Accordingly, later indications of error could be handled this way, although everyone is reluctant to use that technique now. Alternatively the ground can advise the crew of how to trigger their LPD when it is first activated in P64 to achieve the same objective with the least possible DPS propellant cost. This idea is not universally accepted yet either.

Finally, one word about the LM optical tracking of an upstream landmark. This task was already assigned to the H mission as a DTO. Since the tracking occurs at about PDI - 15 minutes, there is some concern that it will interfere unacceptably with operationally required activity. Hopefully it will not interfere but if it does, it will probably be dropped. In any case, it is anticipated that the landmark sighted will not have been previously surveyed accurately enough to be useful. Accordingly, current plans do not include real time use of the data. If the LM crew does make the observation, it has been suggested that the CMP could subsequently track it and the landing site, thereby providing useful postflight data.

Serious consideration is being given to modifying the descent trajectory to provide as much hover capability as possible for the crew. We feel this could enhance their capability of flying over to the Surveyor. Possible modifications include coming in "hotter." One specific suggestion was aiming at 500 feet altitude for 19 fps sink rate and 80 fps horizontal velocity rather than the 14 fps and 60 fps used on G. Other changes include optimizing the throttle recovery time, moving high-gate higher and things like that. Floyd Bennett's guys and MIT are preparing a shopping list of possible performance improvement items for our selection.

Good luck... and good night, Suzy, wherever you are.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWT:js

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MAY 1962 EDITION
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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: August 29, 1969

69-PA-T-116A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: A lengthy status report on lunar point landing including some remarks about CSM DOI

It is clear that lunar point landing capability is absolutely necessary if we are to support the exploration program the scientists want. That is, mission success intrinsically depends upon it. (The current definition of "point landing" is for the LM to touchdown on the lunar surface within 1 kilometer of a point referenced to specific features on the moon which have been selected preflight.)

For Apollo 12 we have made a number of Mission Techniques improvements which should reduce landing point dispersion significantly. However, we were constrained to implementing only those changes which have small impact on the MCC and crew timelines due to the imminence of the flight.

A primary goal of Apollo 13 is to demonstrate a real, honest-to-goodness point landing capability and various groups have been working on ways of doing that job as well as possible without the minimum timeline impact constraint. This work has been going on for several months now and has led to a number of proposals for changes in the Apollo 12 procedures, software, and hardware. On August 22 and 25 we reviewed these proposals in an attempt to evaluate and incorporate them - and anything else that came up - into the Mission Techniques to be used on Apollo 13. It is the purpose of this memo to present the current status of all that, including items being worked on, and hardware and software changes needed.

It was interesting and encouraging to observe that we really did not come up with any radical changes from the Apollo 12 baseline. In fact, there were only two basic changes involved in the plan we are all now concentrating on. They are:

a. Schedule the LM/CSM undocking about one revolution earlier - that is at about $2\frac{1}{4}$ revolutions before PDI. (This does not mean an extra two hours in the timeline; some activities can be moved from before undocking to after undocking.)

b. Achieve the pre-descent orbit (i.e., 8 x 60 n.m.) on "LOI day" rather than on "descent day." This, of course, means getting into that orbit with the CSM SPS and makes descent the only burn to be done by the DPS.

Each of these individually is beneficial; however, the second probably is not possible without the first. They both require a lot of work to prove feasibility and desirability and - assuming that is proven - to produce the final procedures, plans, and rules to support a flight.

So much for the introduction!

One way of slicing the point landing pie is like this:

a. The MCC must supply accurate state vectors and targeting (i.e., where the LM is and where it's supposed to go to) to initialize the LM guidance system (PGNCS) for descent. Any inconsistency in these parameters will result in an equivalent position error when the crew takes over during the last several thousand feet.

b. The PGNCS must be adjusted and operated during descent as accurately as possible for the same reason. This includes things like pre-descent tuning and optimum utilization of the landing radar data.

c. The crew must be provided with as much terminal descent maneuver capability and control as possible.

Most of this memo deals with the first of these, although a great deal of attention is being given all three.

How can we obtain accurate state vectors and targeting for descent? First of all, experience has shown that the MSFN orbit determination system works best when utilizing tracking data obtained on two successive revolutions. We have also found that the results are better when the LM and CSM are separated. This leads to the first proposal, which Dave Reed (FDB/FCD) has been pushing for a long time, in spite of our ignorance. Namely, undock one rev earlier so that we can get two complete MSFN tracking passes on the LM alone. Although the primary purpose of this is to assure getting the best possible MSFN determination of the LM orbit, some other benefits spin off. For example, the LM crew would be able to perform two PGNCS alignments (P52's) two or more hours apart to get a decent IMU drift check and perhaps even allow the MCC to determine and uplink improved gyro compensation coefficients. We couldn't do that before. It also means the landing site tracking with the CSM optics is done undocked. The significance of this is that undocked tracking is necessary to make the early "DOI" with the CSM possible. More about that later. Anyway, Bob Lindsey (FCSD) and others are busy assembling a revised flight plan to reflect this change and I'm sure all the ramifications are not apparent yet. Hopefully, they will be able to reshuffle the LM activation and checkout activities so that we do not require much increase in the crew work period. Certainly it should be less than a complete rev (i.e., two hours).

The other thing we concentrated on to improve the state vectors was to reduce as much as possible any perturbations to the LM trajectory caused by onboard activity during these last two revs before PDI. And, the importance of these things cannot be too strongly emphasized, particularly to the crews themselves since they are the best and final policemen. The Apollo 12 changes caught most of these (see memo 69-PA-T-114A, dated August 1, 1969); undocking earlier eliminates all the rest of the known ones except that darned LM water boiler venting (we must leave fixing this to the CCB) and the DOI burn itself, which is the next subject.

Doing the DOI burn with the CSM SPS is not a new idea. It was proposed several months ago by MPAD primarily to save LM DPS propellant. (It can save as much as 70 fps which is equivalent to about 14 seconds of hover.) It also eliminates the wear and tear of the low thrust DOI burn on the DPS engine - particularly throat erosion. The big question is - when should this CSM DOI burn be performed? After several false starts we have finally concluded the only place it can be done in the timeline is on LOI day since on descent day the crew timeline and/or the descent targeting was rent asunder by it - usually both. On the other hand, doing it on LOI day - perhaps combined with LOI_2 into a single maneuver - probably improves the targeting. This is because the MCC/RTCC is given about ten revolutions of stable orbit tracking to psych out exactly what that crazy lunar potential is doing to us and to compensate for it; also there is no last minute DOI maneuver to introduce unknown ΔV errors. Of course, the accuracy of the CSM landmark tracking of the landing site must not be degraded too much or this advantage can be lost.

Actually, it appears right now that finding a way to do landmark tracking is the key to whether or not we can do the CSM DOI. First of all I'd like to make clear that this tracking is mandatory for point landing. Many people have expressed surprise at this but it is a fact. Accordingly, it would be ridiculous to launch a mission on which point landing is equivalent to mission success if we are not confident the tracking can be done. Our problem, of course, is having done the DOI burn with the CSM, we must either do the landmark tracking in the low orbit or we must raise the CSM's orbit at least $1\frac{1}{2}$ revolutions before PDI to track from the higher orbit in time to target the LM. Unfortunately there is no simulator on earth with which we can develop confidence in the low orbit tracking operation. And, certainly the benefits of CSM DOI are not sufficiently great that we would be willing to try low orbit tracking on Apollo 13 for the first time thereby jeopardizing the entire point landing demonstration objective of that flight. That leaves early circularization as our only remaining possibility. On the surface it appears feasible but we'll have to get into the details before we'll know.

There are some other things about which we must satisfy ourselves regarding CSM DOI. For example:

a. Can LOI_2 and DOI be combined? Is there a solution to targeting such a burn? (Incidentally, an RTCC program change would probably be required for this.)

b. How do you monitor this maneuver where one second overburn results in lunar impact? And, what is the contingency recovery plan?

c. Is the post-DOI orbit safe or does it get too low sometime before PDI?

d. How large will the PDI disperions be (primarily Δh)? Can the descent guidance handle them? Are there any crew or MCC monitoring implications? If the PDI dispersions may be too large, must a trim burn be scheduled and when?

e. Is it possible to include a landing radar test a rev or two before PDI which traces out the descent approach terrain signature for us? If so, how do we use it (e.g., real time slope determination and LGC coefficient update, RLS altitude update, part of the real time landing radar enable decision during descent, etc.)?

f. When does the CSM circularize (at 60 n.m., I suppose)? And how are the current abort targeting programs and procedures affected?

Although this memo is already too long, I'm afraid it can't be complete without a comment on the proposal for pre-PDI landmark tracking by the LM to tune up the descent targeting. Attempts to include this and the associated activity into the timeline have been very frustrating. On the other hand, estimates of its benefit have been decreasing to a point where some of us even feel it is more likely to foul things up than to help. Accordingly, it is my recommendation that it be dropped completely from Apollo, including related computer program changes and any premission photographic requirements. I will write another note to document the reasons for this negative recommendation.

In summary, I guess it's obvious but the fact is we really don't know how much benefit we'll get from any of these things we're talking about doing. Our approach actually has been to dream up anything that might help and see if it can be applied without too much strain. It is based on the assumption that the task is almost impossible and so we've got to do everything we can, no matter how little each item contributes. What is our chance of success? Hopeful is my guess. The kind of things proposed here plus optimization of the descent trajectory to squeeze out the last millisecond of hover time on the DPS plus some intelligent handling of the LR data (requiring computer program changes, no doubt) just might do the trick.

Bill Tindall Jr.

Howard W. Tindall, Jr.

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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: September 4, 1969

69-PA-T-117A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Notice of a catch-all Apollo 12 Mission Techniques meeting

We have scheduled a Mission Techniques meeting on Monday, September 15, 1969, to go over the Apollo 12 flight for the "last" time. Although most of the discussion will probably deal with the landing and rendezvous phases, we would like to clean up all open items regardless of mission phase.

Following is a list of some things I know people would like to cover. Perhaps it can be used as an agenda:

1. LOI - Target for circular CSM orbit at DOI or CDH?
2. Descent
   a. Shopping list of descent trajectory and guidance changes to improve DPS propellant margins
   b. Effect of altitude dispersion at PDI on descent trajectory, ΔV, throttle control, etc.
   c. Selection of landing site targeting (do we aim for 1,000 ft E/500 ft N?)
   d. Docked alignment and sun check status
   e. DOI face up for AGS compatibility
   f. DOI residual trimming rules (x or z trim to 1FPS y <5FPS) changed again
   g. Preferred LM attitude hold mode to be used in coasting flight before and after DOI DAP - AUTO - 0.3°
   h. AOT pre-PDI landmark observation - deletion of
   i. LR test (R04 or R77) and how data is to be used (deleted!)
   j. Use of ΔRLS - i.e., when and based on what data source (Lear, MSFN ranging, etc.)
   k. Rules governing use of landing radar (no orbital LR test! Pro if 523 @ hi gate!)

f. Use of DPS low level indication (was it early on Apollo 11?)

3. Lunar Surface

   a. RLS determination after touchdown

   b. Surface alignment and drift check techniques

      (1) Effect of powering down

      (2) AGS azimuth

      (3) AGS gyro calibration with high inclination

   c. CSM plane change scheduling

4. Ascent

   a. Insertion targeting to give near zero CDH (They will adjust to like 45 fps

   b. MSFN coverage

   c. Criteria for H vs $\dot{H}$ switchover lines

5. Rendezvous

   a. Post-insertion alignment - deletion of (Same as 11 [illegible]-LM, [illegible]-CSM

   b. Navigation tracking schedule and initialization ground rules

   c. Use of AGS in place of the manual charts

   d. Rendezvous maneuver voting logic

6. Post-rendezvous

   a. Plane changes for photographic objectives

      (1) trim requirements

      (2) burn monitoring

   b. TEI (with LM attached?) OBP to ("CSM alone") - See action item out. They'll crash the LM!

7. Entry

   a. Entry guidance changes and effect on target range (drag control etc. off.

   b. EMS with reverse bank or not

8. Contingency

a. SIVB Evasive Procedure

b. LOI

(1) Intermediate throttle up on docked DPS burns (They will!)

(2) Docked APS burns (action)

(3) 15 minutes SPS abort - deletion of

c. DOI

(1) Direct return vs TPI with AGS

(2) Targeting with $\Delta V_z = 0$

d. Descent abort coefficient updating and/or use of tweak burns.

e. PDI + 10 to PDI + 15 LUMINARY change vs phasing

f. T_2 phasing maneuver

g. Review of manual ascent status

h. Need for "Collins Cookbook" of abort rendezvous

i. Direct ascent rendezvous plan for LM water problem

j. Docked DPS burn for contingency photographic mission

The fun starts at 9 a.m. in Room 378 of Building 4, probably with a review of interesting Apollo 11 anomalies.

Howard W. Tindall Jr.

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: September 12, 1969

69-PA-T-118A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Invitation to an Apollo 13 Lunar Orbit Mission Techniques meeting

"The time has come" the walrus said, "to talk of many things." This classic quotation apparently now applies to the Apollo 13 lunar orbit mission techniques and this walrus is suggesting Tuesday, September 23. Bob Lindsay has subjected his flight plan to three iterations already and it's shaping up nicely; the FOD guys have a lot of answers regarding CSM DOI, LM descent targeting and general trajectory information, and, if no one objects, we're going to aim for a Fra Mauro landing to break the data flow log jam.

As a result of the modifications to the Apollo 12 baseline for point landing like early undocking and CSM DOI, there are a number of things to be understood and agreed to. For example -

√1. LOI and DOI targeting and subsequent orbits.

√2. PDI dispersions; i.e., trim or no trim.

√3. Is a CSM separation burn needed? If so, when?

√4. The abort situation in general and specifically - should we consider reducing the standard altitude from 60 n.m. to 45 (say)?

√5. Descent trajectory modifications for optimum DPS propellant usage.

√6. Descent targeting objectives.

√7. Use of RLS and LPD.

√8. -- and like that --

Room 378, Building 4, has been reserved for this clambake. We'll start at 9 a.m.

Howard W. Tindall, Jr.

PA:HWT:dpf

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: September 16, 1969
69-PA-T-119A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: We don't have to change LUMINARY much for point landing but there's gold in them hills!

On September 12 we had a spacecraft computer program requirements meeting for Apollo 13. We called it because there were a lot of proposals floating around which had been advertised as "needed for point landing." On the other hand, these programs must be released for rope manufacture on about November 15 and so there obviously wouldn't be time to take much action after Chris Kraft's software CCB late this month. But it turns out that that doesn't matter because we came out with only one or two changes we felt were worthwhile for LUMINARY and maybe one small, unimportant change for COLOSSUS.

We also uncovered what appears to be a DPS ΔV gold mine! Some GCD guys (Tom Moore and Ed Smith) and Allen Klump (MIT) have been working on a scheme which involves temporary throttling down early in Braking (P63) to almost eliminate the need for sustained low throttle operation at the end of P63. If this isn't Fool's Gold the potential saving appears to be in excess of 100 fps. This technique certainly deserves a lot of attention pronto! MPAD will immediately crank up their analysis factory to learn more about the effect on attitudes, monitoring procedures, MCC-H trajectory processing, etc., and to develop confidence in it. An off-line program tape will be made by MIT for the crew to try in the LMS. We must also get a Data Book change to permit operating the DPS this way. (Ed Smith is gonna do this.) And, we'll look for other hardware problems too.

We've requested that, if possible, this descent program modification be designed so that it can be deactivated by changing constants or something if some late discovery scares us.

The other significant change is to compensate for a spacecraft deficiency. Pressurization causes the LM to become bloated and that in turns moves the LPD window markings. Since this can't be corrected on the Apollo 13 LM, we propose to add some biases in the LPD program. (Conrad will have to do this in his head, I guess.)

One other change is still under consideration but will probably be dropped. That is the "co-ordinated turn" feature proposed for P66. The PGNCS would align the z-axis along the velocity vector as a pilot aid. It appears they don't need or want it but they're taking one last look.

Two programs were deleted outright, forevermore. They are:

a. The docked alignment technique - since it doesn't fit in the new timeline and we don't need it anyway. That is, we wouldn't use it if we had it.

b. The pre-PDI landmark observation program in the LM. As noted in an earlier memo, this idea didn't pan out.

The rest of the ideas were rejected for Apollo 13. Maybe some will turn out to be worthwhile on some later flight, particularly the first one. They are:

a. "Delta Guidance" which tends to standardize the terminal trajectory and reduce LPD ΔV costs.

b. Landing radar (LR) pre-filter

c. Addition of a terrain model for use in LR processing

d. Provision for enabling only LR velocity data (without altitude data) into the PGNCS navigation.

e. Changes in the LR weighting structure.

f. Increase in the LR sample rate into the PGNCS navigation.

g. Increasing the LR data rate on the downlist in R77 from 1 to 10 per second.

Neither of the two COLOSSUS proposals are really associated with point landing, nor are they really needed. One is the rate assistance for the optics and the other is a change to permit the computer to accept optics marks when the spacecraft attitude rate exceeds $2/3^{\circ}$ /sec - the current limit in the program. This change increases the danger of CDU transients and we must learn from MIT how much before we buy this one.

I was surprised and pleased to find we could get by so cheaply. I expected we would want more but the message appears to be that we have a good - and reliable - program already. Let's leave it alone! I swear I don't see how I could have been unaware of that ΔV nugget - considering how hard everyone's been looking for them. Had my head up and locked, I guess.

Howard W. Tindall, Jr.
Howard W. Tindall, Jr.

Enclosure
List of Attendees

PA:HWT:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: September 24, 1969

69-PA-T-122A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Apollo 12 Mission Techniques

On September 15 and 16 we had the second (and last) Mission Techniques meeting for Apollo 12. It was advertised to be a "catchall" and it was. It all went smoothly enough considering how many people were there - the place was stuffed (even the projection room!) - and the exhaustion and emotion these things bring. Personally, I think it was productive - lot's of agreements - and complete. This memo is to record what happened - as well as I can remember. Please excuse the length. I've drawn arrows in the margin by the things which fascinated me the most. If you don't want to read it all, follow the arrows.

Cislunar Navigation

On all lunar missions so far, the crew has performed on-the-job training of cislunar navigation (P23) while on the way to the moon. This had the additional objective of establishing the earth horizon altitude that the current command module pilot was using. Although it was suggested that this activity is unnecessary, the crew elected to include it in their flight plan as on previous flights. In fact, they may even try some star/horizon tracking on the return-to-earth phase of the mission to see how badly the sun interferes. Another associated agreement was that Apollo 12 would revert to the Apollo 10 technique for storage of spacecraft state vectors in the CMC. That is, the values transmitted from the ground would be stored in both the command module and LM slots.

LOI Targeting

It was agreed that the LOI targeting would be biased to provide a 60 n. mi. circular orbit at the time of the CDH maneuver in the nominal rendezvous, just as was done on Apollo 11. You recall there were some people who felt that aiming for a circular orbit at DOI would have been preferable. In fact, it was even suggested that procedures be developed to provide a circular orbit on both occasions.

LOI Aborts

The 15 minute SPS aborts from LOI have been dropped just like the TLI 10 minute jobby-dos.

Starting with Apollo 12, most Apollo missions do not have a complete DPS backup abort capability throughout the entire LOI burn. For example, on Apollo 12 there is a period of about 100 seconds in the LOI burn during which the DPS alone would not be able to provide a return-to-earth capability. It is possible to close this gap on Apollo 12 by augmenting the DPS with an APS docked burn. Procedures for doing this were discussed and settled upon, and a checklist is under development. One important agreement was that the crew would ordinarily use what they refer to as the "quick and dirty" procedure to execute the docked DPS burn. It is estimated to take about one-half hour to go through it. If more time is available, they will use the same procedures but will proceed at a more relaxed rate. The only exception to this occurs when two DPS maneuvers are required, the second of which is at least 15 hours after the first. In this case, they might as well go through the full-blown process of aligning the PGNCS and carrying out a targeted burn.

MIT was given the action item of confirming that the CSM DAP was okay for an SPS burn with a fully loaded LM ascent stage since under certain circumstances, it may be desirable to attempt an SPS burn before falling back on the APS.

Pre-DOI Stuff

The crew has currently scheduled four times at which they will obtain CDU angles simultaneously in both spacecraft to be voiced to the ground for precise determination of the LM platform orientation while docked to the CSM. The ground support programs and displays are said to be in working order. It is intended that prior to LOS before the undocked LM IMU alignment (P52), the MCC will relay the anticipated gyro torquing angles for comparison with the crew's P52 results. If the torquing angles they actually experience differ from these values by more than 0.5°, the PGNCS will be considered NO-GO for DOI. (Rick Nobles has the action item of confirming acceptability of that limit or of proposing a better value ASAP.) Because this procedure provides an accurate IMU drift check before DOI, we have agreed to delete the post-DOI sun check used on Apollo 11.

The crew has changed the AGS targeting procedures for the DOI burn such that they use the ground relayed pad values rather than the PGNCS N86 values. The importance of this change is that the AGS will now be targeted correctly and post-burn AGS residuals will have meaning.

DOI

The flight controllers requested that the crew call up P40 for the DOI burn before LOS and hesitate long enough for the MCC to obtain the actual intended PGNCS DOI maneuver on the downlink. They need this data when confirming the burn in the LM state vector after DOI.

As a result of the briefing by MPAD on the effects of PDI dispersions on the powered descent trajectory, it was concluded that there is never a need to trim any component of the DOI burn. This decision modifies a previous proposal that any ΔX residual in excess of 1 fps was to be trimmed. Essentially, we have established that as long as the residuals at DOI are small enough to indicate that the PGNCS/DPS is not broken (currently set at 5 fps) we are willing to absorb the residual dispersion in the descent trajectory.

DOI Abort

The Apollo 12 crew was completely unhappy with the procedure we had developed for the DOI aborts on the last two flights. It is their intention to use a guided rendezvous in this situation instead of the old brute force technique. Specifically, they will use the AGS rendezvous programs executing a TPI type maneuver at DOI + 10 minutes with a transfer time of 20 minutes. Use of this technique will result in a braking maneuver of no greater than about 30 fps, which is much smaller than the brute force technique yields and which was their major objection with it. Bob Carlton (FCD) was asked to resolve the open item of whether or not it is acceptable to attempt braking with the Z-axis RCS jets without having staged the DPS. Specifically, it was thought that this would cause considerable X-axis thrusting for attitude control which might exceed thermal constraint limits. If that turns out to be the case, we will probably modify the procedure to include jettisoning the DPS before TPI.

Point Landing

There are several new things we learned with regard to our attempt at point landing on Apollo 12. Analysis based on a typical spacecraft attitude time history shows that an estimated 0.16-lb. thrust from the LM water boiler will result in a 6,000-ft. miss. Grumman is now reporting that it may actually be more like a .25-lb. thrust. If this data is right, we are in deep trouble with a capital "S".

This basic spacecraft design deficiency, along with other unknown perturbative effects, have forced us to accept a proposal which worries a lot of us. Namely, it is now felt necessary that a final correction to the descent targeting be carried out during powered descent through use of the new program capability (ΔRLS) that we requested at our last meeting. Furthermore, this manual input will only be done at that time, never before entering P63 as we had previously planned. We put preliminary upper and lower limits in the magnitude of this correction. Specifically, it will only be applied in the downrange direction if the correction falls between 2,000 and 20,000 feet. It was felt that the accuracy was not sufficient to support smaller corrections and that the effect on the guidance makes larger corrections unacceptable. Two action items were issued on this subject. One was for me to schedule a Data Select meeting to work out precise procedures for determining the ΔRLS correction. (It was held September 17.) The other item was for MIT to concentrate heavily on testing this program change during the powered flight phase to develop high confidence that this procedure won't blow the whole mission.

Allen Klump (MIT) has recommended that some procedure be developed to determine a crossrange correction to be computed as a function of measured platform drift. And, he was promptly given the action item of finding out how to do this. I would like to emphasize that if a way can be found, it may be the solution to one of our more serious problems because current indications are that we are much worse off crossrange than downrange. It is Klump's feeling that the biggest contributor to that is platform misalignment.

It was reported that the crew set the updating AGS altitude at 7,000 feet rather than 2,000 feet which the Apollo 11 crew used. (This was a CPCB action endorsed at our meeting.)

Descent Trajectory Changes

Mission Analysis Branch briefed us on recommended descent trajectory changes, some of which have been incorporated and some of which still enjoy "proposal" status.

a. Most of the changes which could be considered for improving the DPS ΔV situation were so ineffective that they were rejected. One which deserves considerable attention, however, is the elimination of the descent trajectory constraint which provides insensitivity to a failure in the DPS propellent valves. A potential saving of about 52 fps can be obtained from this, and first indications are that most concerned organizations will agree to it. (ASPO is working on this.)

b. The only other trajectory change involves increasing the LM targeted horizontal velocity at 500 ft. altitude from 60 fps to 80 fps to increase the LPD redesignation capability. The vertical velocity at 500 ft. will remain unchanged at 16 fps. This trajectory change creates no real difference in the ΔV budget.

One particularly interesting item that came from this presentation was the refutation of a commonly held belief that it was impossible to redesignate short. MPAD shows that to the contrary substantial redesignation short is possible without unacceptable loss in visibility of the landing point. I believe this fact has quite a bearing on choosing the PGNCS target location with respect to where we really want to land and should cause a significant change in the way people have been treating this subject.

Landing Radar Operation

Four significant changes are being made to the crew procedures involving the landing radar.

a. During the pre-DOI landing radar test, the crew will not drive the antenna to determine if it will move properly. (This is an endorsement of a recent CPCB action.)

b. The crew will not normally backup the landing radar antenna reposition command from the LGC in P64, as was done on Apollo 11. However, if the antenna fails to reposition automatically, they will attempt to manually command it. Regardless of whether this works or not, if they get a 523 alarm, it is the consensus that they should enable landing radar data to be processed during the rest of the descent by hitting "proceed".

c. A modification to the Apollo 11 procedures was previously recommended to include a landing radar test at about 9 minutes before PDI. It was for early evaluation of the landing radar as well as a direct measurement of spacecraft altitude at that time. After considerable discussion at this meeting, it was concluded that this landing radar test was really not worthwhile, and it is now recommended that it be deleted from the procedures. Because a specific LM attitude had been selected to support this test, it may be advisable to pick a new optimum value. Accordingly, Rocky Duncan was requested to work with Ed Fendell to determine this new LM attitude to be relayed to the flight planning guys.

d. The Apollo 12 crew - bless their hearts - are anxious to avoid any unnecessary diddling with the DSKY during powered descent. In line with this splendid goal, they have requested that the flight controllers monitor Δh (the difference between landing radar-measured and PGNCS-estimated altitude) and advise them when they should inhibit and when they should enable the landing radar data so that they do not have to call up that parameter on the DSKY.

Low Level DPS Propellent

The Apollo 12 crew has requested that the flight controllers call out the DPS propellent situation during hover somewhat differently than was done on Apollo 11. Whereas the Apollo 11 crew wanted a countdown of time remaining, the Apollo 12 crew has requested a call out of time since low level. Specifically, they would like reports at 30 seconds, 60 seconds, and 90 seconds since the low level indication and "commit time" - all properly biased for communication delays.

Descent Aborts

Although there were a lot of words spoken on the subject, it was obvious that descent abort techniques have been changed very little since Apollo 11. In fact, the only significant difference is the substitution of the variable insertion targeting for aborts after PDI + 10 minutes in place of a variable phasing burn one-half rev after insertion. This simplification was possible due to a program change made to the Apollo 12 version of LUMINARY. All descent abort targeting is based on the assumption that the LM will perform some perigee-raising maneuver before going through perigee again. For aborts after PDI + 10 minutes it will be a 10 fps burn performed 50 minutes after insertion.

The tweak vs. trim rules were discussed again and it was agreed that the MCC would only relay a tweak maneuver in the event of one or the other of the following circumstances:

a. An abort after PDI + 10 minutes on the AGS (because the AGS program discontinues variable insertion targeting after that point).

b. If the PGNCS is degraded but is still working well enough to avoid switchover. (We define the PGNCS as being degraded if its trim maneuver differs from the ground computed value by more than 10 fps.)

Although all of the abort rendezvous procedures follow a pattern very similar to the nominal rendezvous there are slight differences which could create problems if they are missed. As a result, the command module pilot intends to carry along the same "Descent Abort Rendezvous Cookbook" originally developed for Mike Collins on Apollo 11. This handbook of assorted rendezvous procedures is essentially unchanged from the last flight except to reflect slight changes in the descent trajectory and new MSFN coverage times.

Lunar Surface Activities

After considerable discussion, a proposal for extending the lunar stay two hours was rejected. The advantages cited for this proposal were better MSFN coverage during ascent and a timeline less sensitive to real time extension of the EVA. On the other hand, we would either have to reduce the subsequent sleep period or delay TEI one rev in order to satisfy the photographic objective. In addition it is said to violate a mission directive limiting the stay to 32 hours, which we would have to get changed, and would delay development of the operational trajectory, crew training data package, etc. Since the current MSFN coverage is operationally adequate (although the ALSEPscientists may not agree) and the other advantages were of marginal benefit, we decided to leave it as is except to recommend that the IMU be kept powered up throughout the lunar stay as long as real time computations of electrical power confirm it is adequate. Accordingly, the Apollo 11 IMU lunar surface alignment procedures will be used without change on Apollo 12. If in real time it is necessary to power down the IMU, the only modification to the alignment procedures would be to change the first Alignment Technique 3 performed after powering up the IMU from a REFSMMAT option (3) to a T align option (4).

Due to the high inclination being used on this flight the AGS lunar surface calibration drift estimation can be in error as much as 1.3° per hour. TRW has recommended that the AGS lunar surface calibration be dropped unless the crew is able to apply some biases to the corrections, which they must input into the AGS during this procedure. It is currently planned that the crew will apply these corrections which will be provided them within a week by TRW.

Ascent

One particularly interesting piece of information reported at this meeting was that the current ascent profile assures us of losing S-band steerable antenna lock-on for the last three minutes of ascent! Wouldn't that have been a surprise? Anyway, it has been agreed that the crew will yaw right 20°, four minutes after lift-off (I now hear this should be two minutes) in order to provide solid high-gain coverage. (This, incidentally, also applies to late aborts from descent.) There is some question as to what should be done about the AGS since it does not provide a manual yaw attitude override feature like the PGNCS and thus we would lose high-gain coverage if we switch over to the AGS which would be undesirable. The crew will work with Jerry Thomas (TRW) to sort out the AGS operation. Specifically, they will input new vaues for W_b which controls spacecraft yaw attitude during a burn even though this screws up the FDAI ball. There are some obviously horrible implications on manual ascent when high-gain coverage and a window view of the horizon are both particularly necessary.

Another ascent agreement is that the targeted radial velocity at insertion will be adjusted to compensate for CSM orbital dispersions to provide a nominally zero CDH maneuver.

Rendezvous

Consideration has been given to deleting the platform alignments (P52) by one or both of the spacecraft immediately after LM insertion into orbit. Although it is agreed that these alignments are not by any means mandatory, we have decided to leave them in the flight plan. That is, both spacecraft will continue to do the post-insertion P52. To assure adequate rendezvous navigation at this critical time it was emphasized that the LM should discontinue the P52 if it has not been completed within 38 minutes before CSI. Pete Conrad indicated that they had also modified the checklist to continue rendezvous navigation to within 8 minutes instead of 12 minutes of CSI providing about four more marks.

Also associated with the rendezvous navigation was the agreement that in all cases the crew would reinitiate the W-matrix immediately after each maneuver before taking any additional observations. This applies to both spacecraft not only in the nominal case but even when the instrumentation is operating in a degraded mode. (This is another endorsement of a CPCB action.)

The rendezvous maneuver voting logic has been changed slightly to reflect fully active participation of the AGS in place of the manual charts. In order of decreasing priority, the maneuvers will be performed as follows:

a. Burn PGNCS if it agrees with the CMC.

b. Burn PGNCS if it agrees with the AGS (or charts).

c. Burn CMC solution using whichever LM guidance system is better.

In all cases, the same ΔV comparison values are to be used as on Apollo 10 and Apollo 11.

Post-Rendezvous

After the rendezvous, the CSM makes a plane change in order to obtain photographic coverage of future landing sites. It was agreed that the crew would monitor this plane change burn using the same attitude and attitude rate limits as other maneuvers and a manual backup of engine cutoff if the burn exceeds the predicted value by more than 1 second. The EMS is not included in this shutdown logic.

Entry

G&N program changes have been made which result in a guided entry that more nearly approximates the ideal 4g tragectory. As a result of these changes, it is necessary to reduce the nominal entry range to 1250 n. mi. to assure no "up control".

Once committed to a G&N entry, we have decided not to change the target point even if the G&N subsequently fails. In order to make the landing point obtained with EMS guidance consistent with this, the EMS procedures are being modified for this specific case to include a bank reversal at 20,000 fps velocity. If the G&N has failed earlier than about EI - 10 hours, there is time to move the recovery force the 70 or 80 miles north and no EMS bank reversal will be used. This makes this EMS entry compatible with its backup - the 4g constant manual technique.

That's it for Apollo 12. Bring on 13!

Howard W. Tindall, Jr.

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: September 29, 1969
69-PA-T-123A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Status report on Apollo 13 Mission Techniques - or "Go for CSM DOI"

Based on the September 23 Mission Techniques meeting, it appears that the command module DOI type mission should be adopted for Apollo 13. At this meeting we reviewed all facets of this approach and could find none that would keep us from going this way; on the other hand, the advantages appeared to be substantial. As a matter of fact, it appears to me that the mission techniques for Apollo involving a CSM DOI are essentially almost complete - long before the mission. I would particularly like to bring your attention to the fine work that Bob Lindsey has done in the development of the detailed flight plan. This had a very important part to play in proving feasibility of this approach and it appears to be in excellent shape. Our next step is to present our plans to the CCB for their approval.

As you recall, it is our desire to place the CSM/LM into the pre-descent orbit on LOI day. In fact, the LOI maneuvers should be designed to accomplish this. There appears to be no reason why they couldn't. In fact, one of the more important decisions made yesterday was to rename the LOI maneuvers: the terminology LOI_1 and LOI_2 will be discontinued and LOI and DOI will be used instead. The current plan is for LOI to do the job of LOI_1 - that is, to provide an intermediate lunar orbit of about 60 by 170 n. mi. DOI will achieve the combined objectives of the old LOI_2 and DOI; that is, it will bring the spacecraft into a 58.5 by 7.5 n. mi. orbit. It is this shape, according to Math Physics Branch (MPB) of MPAD, which will precess to the desired 58.6 by 7.8 n. mi. orbit at the time of PDI about 1 day later. Incidentally, this was a point of particular interest to us. MPB expressed considerable confidence in their estimate and are convinced that the orbital altitudes will never become dangerously low but will only vary a little over this period. MPAD also confirmed that there is no problem in targeting the new DOI maneuver. Apparently, the computational procedures do not differ from those used for LOI_2.

Considerable discussion was devoted to monitoring DOI and providing a contingency bail-out technique for a G&N failure that produces an overspeed. Although this work is not complete, it seems that procedures which guarantee safety can be developed. This is true in spite of the fact that an overburn of only 1 second will result in lunar impact which means there is no way for the crew to insure a safe DOI, at least in the sense that it is insured for the old LOI_1 and LOI_2 maneuvers. On the other hand, since the crew can certainly prevent overspeeds in excess of 40 or 50 fps, it is only necessary to provide a contingency, canned maneuver to be executed which will preclude lunar impact if an overspeed in this range has occurred. Accordingly, we reached agreement that the crew will give the G&N a chance to do its job and will not manually shut the SPS off until burn duration was at least 1 second longer than predicted. If the crew is unsure about whether a G&N failure has occurred, they will properly orient the spacecraft and prepare for the contingency maneuver while awaiting confirmation from the ground after AOS as to whether they have a safe or unsafe situation.

The next question concerned the possible magnitude of the dispersion at PDI if no adjustment (trim) maneuver were provided between DOI and PDI. More to the point, the question was whether a trim maneuver must be included in the nominal flight plan. On lunar missions so far, the altitude dispersion, which is the only one of significance to us, has averaged about 630 feet per revolution. (The largest was 900 ft. per rev.) If this is a one sigma value, the largest dispersion that should be expected in altitude at PDI on a three sigma basis is about 23,000 feet. We tried to think of all the possible adverse effects on descent which could result from a <u>known</u> altitude dispersion at PDI. These included guidance capability, landing radar availability, crew visibility, onboard and ground monitoring, crew training, effects on aborts, and ΔV costs. Of these, only the last seems to be effected significantly, and even that one is not too bad. Specifically, it appears that if we arrive at PDI 20,000 feet higher than we desire, the DPS ΔV penalty is in the order of 35 fps. If we are 20,000 feet low at PDI we actually save about 16 fps. Based on all this, we concluded that it did not seem necessary, or even desirable, to include a trim maneuver in the nominal timeline but we would establish a contingency procedure to handle excessive PDI altitude dispersions. Thus, if during the crew sleep period MCC predicts the altitude at PDI will be outside of acceptable limits, the crew will be awakened 30 minutes early in order that they may make the small CSM RCS maneuver required. Initially, we have established the acceptable region of acceptable PDI altitude to be between 30,000 and 70,000 feet (the nominal, you recall, is 50,000 feet). The RCS burn objective would be to raise the altitude, if too low, to 30,000 feet (since it's wasteful and unnecessary to go higher) or if it is too high, to lower it to 50,000 feet.

The Flight Crew Support people have revised the LM activation and checkout timeline extensively from the Apollo 11/12 baseline. Since we are undocking one rev earlier, a special attempt has been made to move as many activities as possible from before undocking to after undocking. By doing this, and slightly reducing the crew eat period, it is only necessary for the crew to start their work period 30 minutes earlier than on Apollo 12. Those of you interested in specific details should get in touch with Bob Lindsey.

Some of the activities we spent a good deal of time reviewing dealt with undocking, LM inspection by the CMP, and the separation burn. It had already been agreed that the LM inspection by the CMP could be substantially reduced unless there had been some earlier indication of problems in landing-gear deployment. This being the case, it seemed desirable to combine the separation burn with the undocking. Accordingly, we proposed that with the spacecraft in the undocking attitude (i.e., X-axis along the local vertical with the CSM below the LM) a soft undocking would be executed, followed by a CSM -X RCS 1 fps by the command module using P47 to set up a separation rate. It is noted that the sun will be behind the LM but this was felt to be acceptable. Separating like this will place the CSM in front and above the LM three-quarters of a rev later at the time of his circularization burn.

Having moved the separation maneuver earlier like that, the CSM is relatively free to perform landmark tracking on the landing site while in the pre-PDI low orbit two revs before PDI. The longest discussion of the day dealt with whether or not they should do this. It was clear from the start that it would not contribute much, if anything, to the Apollo 13 operation, but on the other hand, it provides sort of a free opportunity to gain valuable experience which could be used for planning a future mission. Final resolution was that it would be included in the current timeline with the understanding that it was not a mandatory requirement. If simulations show that it interferes with required activities, it will be dropped.

It is very interesting to note the relatively unbusy timeline the LM crew has after undocking. And that's nice. In spite of that, we are proposing to delete two other activities from this period. The first is the LM rendezvous navigation (P20), primarily because it requires extra LM attitude changes with the possibility of perturbing its orbit. The second was a test of the landing radar during the last pass over the landing site which would also provide an opportunity for mapping out the lunar terrain on the approach path to the landing site. Although, intuitively, it sounded like nice data to get, nobody could offer a concrete use for it and so it was dropped.

One item that I am sure will be getting plenty of attention by the time you read this deals with the crew's request to change the mission profile in order to provide a higher sun-elevation angle during descent. Everyone, - Jim Lovell in particular, is concerned about using the old minimum sun-elevation angle constraint when going into a mountainous region like Fra Mauro. The whole area is likely to be bathed in shadows and that sounds poetic but like bad news. MPAD and others should be looking into the tradeoffs in terms of SPS ΔV required and translunar transient time, etc. to relieve this undesirable characteristic.

Another thing that gets changed by the CSM DOI is descent abort. This is brought about by the fact that we really do not have confidence that CSM landmark tracking can be done in the low orbit. Accordingly, we have scheduled CSM circularization $1\frac{1}{2}$ revs before PDI. This makes the abort situation from powered descent different from on previous flights. Specifically, it will be essentially identical to descent aborts from the second PDI opportunity on Apollo 11/12. I don't feel that this is a particularly bad situation. As a matter of fact, aborts from hover are actually better - that is the resulting rendezvous is more nearly nominal than aborts from hover on a first opportunity Apollo 11/12 descent. One thing we are looking into is a use of the variable insertion targeting capability such that aborts early in powered descent would take an extra rev to rendezvous, in order to obtain navigation tracking data before CSI.

In summary, I think we can proceed with this plan with confidence. There is plenty of detailed work to do primarily regarding the DOI monitoring and contingency procedures. However, many products like the flight plan are in good shape today. Unusual, but nice, this far before the flight date.

Howard W. Tindall, Jr.

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: October 20, 1969

69-PA-T-129A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: What can be done about the AOT?

One of the largest error sources affecting precision landing on the moon is the LM platform alignment accuracy at PDI. The AOT is adequate to fly an Apollo 11 type mission but it is simply not designed to support precise landings; AOT alignments, as currently carried out, leave something to be desired. The result is we must depend more on the LPD to get us where we want to go - that is, to correct the terminal descent trajectory for errors built up during the braking phase. This is undesirable, of course, particularly in the crossrange direction. Another unfortunate fact is that the lousy alignment accuracy obscures inflight IMU drift determination and virtually forces us to depend on the preflight compensation for anything but gross changes. This is good enough for flight safety (i.e., abortability) but can also screw up the precision landing. (Here are some numbers: 0.1° out-of-plane alignment error at PDI causes a 2,000 ft. crossrange error. A 3 sigma PGNCS drift will cause this misalignment. AOT alignments experienced in flight haven't been much better than that either.)

Aside from making sure you are aware of the situation, I am writing this snowflake to solicit any ideas you might have to improve this business. Is there some way we can improve the AOT? Or its alignment in the LM? Or the way we get and use the marks in the computer program? Or should we ask the crew to make more marks - (Note: without a DOI burn, the crew timeline is tolerant)? - or something?

If you think of something, do it - or give me a call and I'll put your name in lights, Baby!

Howard W. Tindall, Jr.

PA:HWT:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: October 21, 1969

69-PA-T-130A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Let's hear it for "Delta Guidance"!

As part of the Apollo software team's contribution in the search for extra LM hover time and/or payload capability, they are vigorously working on the development of a new descent guidance and throttle control technique. The pay off could be impressive compared to things like trying to decrease LM weight. Specifically, a ΔV improvement on the nominal mission of as much as 100 fps might be realized, which is equivalent to 18 seconds of hover or 300 lbs. increase in descent payload. There are also some other substantial benefits to be gained from this new program formulation. It is the purpose of this memo to make sure you know about this business as well as to give you a report on its status.

Sometime ago a couple of Guidance and Control Division (GCD) people, Tom Moore, Jay Montgomery - and others I am sure - conceived the basic idea of what they called "Delta Guidance." The unique characteristic of this guidance scheme, as I understand it, is that given a dispersion it attempts to guide the spacecraft back to the <u>nominal</u> trajectory as opposed to looking for a new way of achieving the targeted end conditions like most guidance techniques do. It appears that this can be done without significant penalty in terms of payload or undesirable transient trajectory characteristics. Their work has been further developed by a group of MIT people, led by Allen Klump, which has resulted in a finished set of guidance equations in our hands at this time, which only await the thorough analysis and testing required for final tuning and to develop flight confidence. In addition, a complex targeting program has been developed for use in pinning down the various guidance coefficients and targeting parameters.

On October 16 MIT, GCD, and MPAD people got together to discuss and understand the program formulation and to layout plans for the analysis work ahead. The specific products we are aiming for are an off-line LUMINARY assembly which can be exercised in the various simulators within a month or so and an agree-to analysis plan which will yield all of the understanding and confidence required to permit addition of this program into the LM spacecraft computer for the Apollo 14 flight. Release of that program, I suppose, will not occur until March, which may seem like a long time from now. But it's clear that substantial changes to the descent guidance program - the program controlling the most critical phase of the mission - will certainly not be approved unless we have the absolute confidence of everyone involved that we are doing the right thing. And that is going to take some time.

In addition to the nominal ΔV improvement (that is, increased hover or payload capability) there are some other benefits from Delta Guidance.

1. Although N69 (Δ RLS) corrections during P63 are relatively cheap with the present system, the new guidance technique allows us to perform them with no ΔV cost.

2. Redesignations are improved in two ways. First of all the ΔV required to relocate the landing point a specific distance is markedly reduced. Furthermore, massive redesignations can be performed both long and short without unacceptable loss of landing site visibility.

3. The fact that the guidance is attempting to return the trajectory to nominal means that we are essentially providing a standardized terminal descent for the crew. For example, it eliminates the drooping characteristic that sometimes occurs as a result of dispersions or landing radar updates during P64 which in the worst cases could even lead to lunar impact. A standardized terminal trajectory should also have a beneficial effect on crew training in somewhat the same way the standardized rendezvous terminal phase has done.

The second and third benefits just listed will be available if Delta Guidance is implemented, regardless of whether or not we obtain permission from the DPS people to operate their engine in the new way I am going to discuss here. And, they are probably sufficient justification in themselves to implement it, particularly because redesignation apparently will play an important role in providing a point landing capability. However, we can only get the big ΔV saving dangled tantalizingly before you in the first paragraph if we can operate the DPS engine differently than we are currently allowed. Actually we have two choices we can give the DPS people; it doesn't make much difference to us which they choose. The first involves no hardware changes at all, as far as we know, but I am sure the Propulsion people will want to do some qualification testing on the DPS to permit it. The thing we want to do is to throttle the engine from the full thrust position down to 50 or 60 percent thrust (their choice) and back to full thrust periodically during the descent braking phase (P63). With a nominal engine, this throttling would occur about one per minute for a duration of about six seconds each time. Lower thrust engines will do it less often and higher thrust more. The alternate approach involves providing a small throttleable region around FTP large enough to compensate for the engine thrust dispersion. This so-called "shallow throttling" can be used with the same guidance technique and it eliminates the need for throttling through the forbidden zone. Intuitively, this would seem to be a superior approach since it compensates continuously and directly for the engine characteristic that is giving us all the trouble. However, it only saves ΔV if good engine efficiency is maintained within the shallow throttling zone. I have heard that in order to do that, some sort of DPS hardware change must be made. (According to Allen Klump it involves a precise shaping of some propellent valve pintle, whatever that means.) Engine requalification would no doubt be required for that too. Mr. Apollo Spacecraft Program Manager, if I still have your attention, I would like to urge you to exert whatever influence you can spare toward clearing the DPS for this kind of operation. The benefit to be gained is expected to be worth the cost and effort (converted to lbs./buck) particularly since our informal data sources indicate the DPS can hack it.

One other area requiring immediate attention, which I haven't mentioned so far, involves descent monitoring both onboard and on the ground. The LGC commanded thrust will be entirely different than now which means that some of the MCC displays and Flight Control Mission Rules will become obsolete and will require replacement. It may be desirable to change some of the onboard displays also. Nothing at all has been done so far in this area.

In summary, it appears our guidance people have conceived and are developing a technique for descent guidance which has real advantages over the existing system if it works as advertized. It is possible to get it ready and implemented by Apollo 14 provided we place high priority and continuous effort on it. In order to reap one of the greatest benefits, it is necessary that the DPS be qualified to operate in a new way and so that must be vigorously pursued. Why are you still sitting here reading this stupid thing when there is all that important work to be done?

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWT:js

UNITED STATES GOVERNMENT

Memorandum

NASA - Manned Spacecraft Center
Mission Planning & Analysis Division

TO : See list below

DATE: October 21, 1969
69-FM-T-131

FROM : FM/Deputy Chief

SUBJECT: Apollo Spacecraft Software Configuration Control Board meeting number 32

On October 9 Chris Kraft convened the first Software Configuration Board meeting since June 5 at MIT. We had a real pot full of PCR's to discuss, some of which were approved for Apollo 13, some for 14, and some were put in a category in which MIT was to continue development to a point where their value could be assessed, perhaps for Apollo 14 implementation.

This memo is to document briefly what happened there:

1. <u>COLOSSUS Apollo 12</u>

PCR 960 - In case you weren't aware, a 49-word erasable memory program has been developed which will permit the CMC to start Time Base Six (TB6) in the S-IVB. This relieves the crew of a somewhat dangerous manual setting channel bits, if they ever encounter this absolutely impossible-to-encounter S-IVB inertial reference failure.

2. <u>COLOSSUS Apollo 13</u>

There were seven program changes approved for this program, some of the more interesting ones were:

PCR 936 - This change relieves the crew of the task of keying in TIG when he needs to apply an out-of-plane component as part of the CSI or CDH burn. The LM program was fixed this way too.

PCR 949 - Software fix for the split pulse problem in the VHF ranging equivalent to the fix for the two radars on the LM.

PCR 966 - This makes Option 3 the nominal option in P52. This saves the crew some DSKY key strokes.

PCR 967 hopefully will fix the pulse torquing program so that it will execute a 90° REFSMMAT change three time faster than it currently does and without screwing the FDAI ball around like a drunken sailor's Augekugle.

3. COLOSSUS Apollo 14

About 14 program changes were approved for Apollo 14 (that's fitting, isn't it?). Some of the more interesting ones are:

PCR 869 provides rate-assisted optics for the landmark tracking program (P22) which should be especially useful in the low orbits currently planned.

PCR 868 consists of several cis-lunar navigation program (P23) changes, some of which are probably useful since they help the crew orient the spacecraft to get good star/horizon observations. One improvement involves making the altitude of the horizon a function of range which doesn't leave me particularly warm. I would suggest that Math Physics Branch take a look at that.

PCR's 822, 917, 916, and 857 were all deletions yielding a total of about 700 words. Specifically, they are the stroking test, P31, TPI search (P17/P77), and a chunk of the pre-flight performance test flight program.

PCR 867 makes it possible to carry out orbit rate torquing with any roll attitude using R64.

4. COLOSSUS Off-line Assemblies

The two programs in the development hopper are PCR 876, a new pre-launch technique, and PCR 927, the Universal pointing routine which will be needed by at least Apollo 16 to support the CSM experimental package.

5. LUMINARY Apollo 13

About 9 changes were approved for LUMINARY, including:

PCR 882 to replace the DSKY display of horizontal velocity during P66 with the horizontal velocity component in the spacecraft X and Z plane.

PCR 285, submitted by yours truly, to remove the check for the auto throttle discrete. Essentially this change eliminates program P67 and makes it possible for the crew to use the manual throttle at any time during descent. It also makes the program insensitive to failure of the auto throttle discrete. (CCK requested that MIT look into making the LGC commanded thrust a DSKY display as a part of this PCR.)

6. LUMINARY Apollo 14

Approximately 11 changes have been approved for Apollo 14, including:

PCR 896, which not only saves about 50 words, but should increase descent navigation accuracy by centering the readout of landing radar velocity at PIPTIME.

PCR 892, which deletes the rendezvous radar automatic acquisition capability during ascent. It is already inoperable during descent and descent aborts. Deletion of R29 frees 390 words of memory. Incidentally, Routine 29 does not work in the Apollo 12 program and will not be fixed for Apollo 13. In other words, it never worked and never will!

7. LUMINARY Off-line Assemblies

There is some interesting development work going on with LUMINARY. The one that appeals to me the most is Delta Guidance (PCR 969), which I have written about in another memo. Work on a landing radar pre-filter (PCR 941) and addition of a simple lunar terrain profile (PCR 940) are also under consideration for descent program changes. The so-called coordinated turn during a manually controlled lunar landing (PCR 884) is still in the mill.

PCR 888 is under consideration to modify the DAP control authority model to include the effect of RCS plume deflectors.

PCR 890 is supposed to improve the slosh stability of the LM DAP to be used when docked with the CSM.

A very interesting endeavor underway at MIT that you should be aware of is an attempt to develop a CSM rendezvous program which will operate as nearly automatically as is possible. If the off-line program proves dramatically successful in the crew simulations, the efforts may be expanded to other computer programs including those in the LM.

Another substantial effort at MIT has been devoted to recoding the CSM program much more efficiently than COLOSSUS. This effort has been completed, resulting in a program called Artemis which they have in their hands now, but which has not been tested. It provides at least 2,700 words of available memory and with some program deletions could cough up as much as 4,300. Since we have no foreseeable need for this extra storage and we don't want to give up the considerable confidence we have in the current operationally proven COLOSSUS program, MIT was directed to discontinue further work on Artemis. Incidentally, no equivalent effort has been done on LUMINARY and no such work is planned now. It was stated, however, that the LUMINARY savings potential is estimated to be much less than for COLOSSUS.

Bill

Howard W. Tindall, Jr.

Addressees:
(See attached page)

FM:HWT:js

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MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6
UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: October 21, 1969

69-PA-T-132A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Apollo 12 Newsletter

So many things have changed - some subtly, some considerably - that I thought a newsletter might be useful. It is written particularly for those of you who have not been directly involved in preparation for Apollo 12.

LM IMU Drift Check

Based on providing a safe (not point) landing with abortability, MPAD has established the LM IMU drift rate tolerances to be .35°/hr. about the pitch axis (Y) and 1.5°/hr. about the roll and yaw axes (X, Z). Using the new docked alignment technique followed by the pre-DOI/PDI AOT alignment (P52) about 2 3/4 hours later, the allowable differences in the actual torquing angles from those predicted by the MCC are 0.8° around Y and 3.6° around X and Z. These are nice and wide, making a NO/GO improbable. However, if they are exceeded, DOI must be delayed one rev and the crew will repeat the P52 about two hours after the first. Based on these torquing angles, the crew will compute and update the IMU compensation parameters in the LGC using standard techniques and a decimal-to-octal conversion chart they have been supplied. If the P52 repeat confirms a changing drift rate greater than 1.5°/hr. in any axis, the IMU is broken and DOI is NO/GO for the mission. Otherwise, there is no further check and the mission is continued. (Note: it is necessary for the crew to update their own IMU compensation since the P52 occurs shortly after LOS and it is important that the new compensation be in operation ASAP after the P52 to avoid a misalignment build-up before PDI.)

DOI

A change in the Mission Rules has been agreed to which clarifies action in the event of large DOI residuals. As noted previously, we're willing to accept PDI altitude dispersions resulting from DOI residuals less than 5 fps. There are failures which could cause larger residuals than that, though, that do not preclude descent. For example, failure of the PGNCS to shut off the DPS. Manual backup for this could result in about 8 fps overspeed with perfect PGNCS, AGS, and DPS still available. RCS (-X) plume impingement prevents trimming more than about 5 fps so the rule says:

a. If PGNCS residual is greater than 10 fps - abort

b. If PGNCS residual is greater than 5 fps but less than 10 fps - trim to 5 fps and continue if the PGNCS is working okay.

c. If PGNCS residual is less than 5 fps - continue if the PGNCS is okay.

DOI Aborts

FCD has determined that the X-axis RCS plume impingement is marginal to support LM Z-axis braking from a DOI abort rendezvous, so the procedure is to jettison the DPS at TPI.

Landing Radar

Since our September 15/16 Apollo Mission Techniques meeting we have had second thoughts on how we should handle a 523 alarm, which indicates that the landing radar antenna has failed to reposition correctly after high gate. At the time of our meeting, consensus of those present was that processing landing radar after high gate was a desirable thing to do even when it was actually near Position 1. Since that time independent analysis by MIT and MPAD has indicated that, although we wouldn't be in bad trouble allowing the landing radar to come in, we are better off to inhibit it in some cases, provided we have had good landing radar data until high gate. It is true that with the recent spacecraft computer program changes there are some occasions when we would be slightly better off to process the data but the operational complexity of sorting out which situation we have in real time is not warranted. We also preferred, if possible, to keep the crew procedure the same, regardless of whether communication with the control center was available or not. Therefore, in the event of a 523 alarm, the precise crew procedure is V58 (to inhibit the landing radar) and "Proceed" (to clear the alarm) and then an "Error Reset."

Lunar Surface

Everyone must know by now that the CCB decided the PGNCS should be powered down on the lunar surface. Before powering down, though, the crew has agreed to do two (rather than one) AOT alignments (Technique 2) to provide data which gives the MCC a substantially better chance of determining LM position on the moon.

MSFN Orbit Determination

It has been found that by adding one more term in the RTCC lunar potential model, we are able to improve the orbit determination and descent targeting significantly. It even permits high-quality, single-pass solutions! There was some concern that the incompatibility of the RTCC with the spacecraft computers might present some problem but as of now we can't think of any so - it's in the RTCC, but won't be in the spacecraft for either Apollo 12 or 13.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWT:js

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: October 29, 1969
69-PA-T-133A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Spacecraft separation procedures

I blundered into something the other day which is probably none of my business but is interesting, so I thought I would bring your attention to it. Some time before Apollo 10 the trajectory flight controllers assembled a "Cookbook" of spacecraft separation recipes condensed from the myriad of proposals and recommendations that have been floating around - both written or verbal - dealing with all of the possible separation operations involving all of the various spacecraft and booster pieces during nominal and contingency missions. Apparently this had become an overwhelming business, obviously requiring understanding and preflight agreement. And, they reacted on their own to be prepared. Subsequent to that, they requested MPAD to refine their Cookbook into a formal document presenting each of the different separation sequences in a standard format, including such things as crew procedures, diagrams of spacecraft attitude in various stages in the sequence and relative motion plots. As this work progressed, a great deal of simplification resulted due to the similarities of the various situations. On October 22, we had a pseudo Data Priority meeting at the flight controllers' request with MPAD and FCSD people to review this document (MPAD's Internal Note 69-FM-262, which Flight Analysis Branch prepared for Apollo 12) and to reach final agreement on the procedures given. Although the document proved to be in excellent shape, as well as complete, several substantial modifications were agreed upon, and it will be updated in the near future to reflect them. Currently it includes all of the separation situations that could ever be encountered on Apollo - not just Apollo 12. Furthermore, it is planned to have those dealing just with Apollo 12 included in that crew's checklist at their own request.

In order to maintain control over this business, which up til now has been informal, it is my understanding that Carl Huss intends to put this document under the authority of the Crew Procedures Control Board if they're willing, such that changes can only be made with their approval. That certainly sounds like a good thing to do to me.

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: October 29, 1969

69-PA-T-134A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Don't turn off the landing radar

A ripple just passed through our system, which I probably ought to document for the record. Pete Conrad called the other day suggesting that it might be a good nominal procedure to inhibit (V58E) landing radar data from the PGNCS at about the time it exits the Descent visibilty phase (P64). Ordinarily, this would be when they initiate manual control (P66) at about 500-ft. altitude. After polling interested MSC and MIT people on this, we have recommended against it and the crew has concurred even though it was agreed that the accuracy of the navigation probably would not be significantly affected and there is a slight possibility of some spurious data getting in, particularly below 100-ft. altitude. (In fact, I think everyone agreed that if there were a way to inhibit the velocity data at that point, that would be a good thing to do.) The primary reasons for advising against this procedure were:

a. Landing radar altitude data is highly desirable during this part of the descent and V58 stops everything.

b. DSKY operations are undesirable if they can be avoided.

Consideration was given to changing the landing radar velocity weighting factor to zero in P65/66/67 but this is also not recommended (although it may be before the flight) because that technique stops the velocity data too early in the descent.

Although the decision is to leave the crew procedures as they are, this was probably a worthwhile review of this volatile subject and may yet result in a change in the weighting factor as Apollo 11 landing radar analysis is further defined.

Bill

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: October 29, 1969
69-PA-T-138A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Automatic CSM Rendezvous

Partly because of Mike Collin's post-flight criticisms and partly because we don't have anything else to do anymore, some of us MSC and MIT guys had a little meeting the other day to discuss implementation of a quasi-automatic CSM rendezvous capability in the GNCS. Of course, it is impossible to provide a fully automatic rendezvous system in the CSM because of the manual optics which are required for rendezvous navigation. Our objective at this meeting was to review and endorse an MIT proposed design of a system that comes as close to fully automatic as is reasonably possible. Based on the agreements reached at our meeting, MIT is going to develop an off-line COLOSSUS assembly and associated support documentation which we can try out on the CMS. Although MIT was noncommittal on schedule, the impression given was that it would be available around the first of the new year. If it turns out really great and doesn't shake up the program too much we will probably add it to a flight assembly and perhaps look at some of the other programs the same way, including those in the LM. At the least, it is a good source of experience for future projects.

To give you a little idea of what is being done, let me just list some of the operations which the computer will relieve the crew from doing.

a. Automatic W-matrix initialization

b. More judgment in the automatic data editing

c. Automatic cycling from program to program

d. Automatic loading of "Target ΔV" to update the LM state vector when it has maneuvered

e. Automatic DAP (R03) initialization

f. Automatic attitude maneuvers without crew authorization (but with displays to tell what it's trying to do)

In addition to these specific items, there is also a general clean-up of the program such as eliminating the need for the crew to input standard parameters we are unlikely to ever change (such as elevation angle and terminal phase transfer angle) and a number of displays which the crew ordinarily has no interest in seeing. Altogether it is anticipated that the total number of DSKY key strokes would be reduced from the 850 or so required on Apollo 11 to under 300.

There is some question as to whether it would be necessary for a crew to learn how to operate the system in the old non-automatic mode. It appears there is a good chance that the automatic mode will be capable of handling not only a standard rendezvous, but also any of the abort situations that can be imagined as well. We will have to await completion of the program before we will know that. Provision is being made, of course, to interrupt the automatic mode to permit non-nominal things such as unscheduled platform alignments (P52) and up-links from the ground (P27) or anything else that might become necessary in real time. This is being done by providing standard reset points throughout the sequence, each identified and callable by a new program number. (MIT's current plan is to use the P8X's for this purpose.)

Two new programs or routines were strongly endorsed for addition into this system, if they aren't too difficult. The first is a new targeting (prethrust) program to permit onboard computation of the height adjustment maneuver used in a number of abort sequences. At present the crew is required to use a chart in conjunction with the CSI program (P32) to back-up the ground targeting, which is prime. Provision of this program would make the spacecraft independent of the ground for all abort rendezvous sequences currently planned. The other would provide automatic sequencing of the G&N for a command module SPS plane change, including IMU pulse torquing and spacecraft attitude control. At present this is a really messy procedure which the CMP would have to carry out by himself in a time critical period if that need ever occurred in flight. Incidently, these capabilities would be good additions to the present system!

It was interesting to note the enthusiasm most of the people had for this undertaking. But, of course, I was careful to invite only those whom I thought would be friendly since we are not necessarily designing a flight system but rather a trial system based on a philosophy new to MSC operational people. It will be easier to deautomate it later if that's a good idea than to go the other way.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWT:js

OPTIONAL FORM NO. 10
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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: October 29, 1969

69-PA-T-139A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: AGS licks PGNCS for RCS Insertion

Pete Conrad has discovered and, if necessary, intends to do something that Dan Payne and others around here got squared away a year or more ago. Unfortunately, due to the press of more urgent business, we failed to advertise it enough. This note is to make sure you know that the AGS does a better job than the PGNCS of guiding the LM into orbit using the RCS if the APS stops prematurely and can't be restarted. And, it should be used in this unlikely and horrifying event.

It may surprise you to learn that if the APS fails during the last minute of LM ascent, insertion may still be achieved using the RCS. For this specific case, a 4 jet RCS burn about 9 minutes long would be required to pick up the remaining 1,000 fps. (This obviously far exceeds the 85-second constraint currently limiting +X RCS operation, but who will quibble over that?)

The proper procedure for RCS insertion is to switch to AGS AUTO, since AGS will steer the vehicle automatically at RCS thrust acceleration levels while PGNCS will not. Meanwhile, the PGNCS velocity-to-be-gained display may be monitored to verify that AGS is performing adequately. When the PGNCS velocity-to-be-gained is small (i.e., less than 25 fps) control could be switched back to PGNCS and the standard velocity residual trimming procedures could be employed. Use of AGS AUTO relieves the crew of manually maintaining attitude such that the PGNCS display of total velocity-to-be-gained is along the X-axis during a long RCS burn. Also, AGS guidance has cross-range position control assuring insertion into the CSM plane while PGNCS does not.

As I said, Pete found all this out for himself and intends to act according with our blessing if this happens. This is another example of a low-probability contingency procedure cleared away. We'll have to be careful we don't carry this kind of effort too far or we'll be arrested for violation of the law of diminishing returns!

Howard W. Tindall, Jr.

PA:HWT:js
FM:JDPayne:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: November 4, 1969

69-PA-T-142A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Apollo 12 Descent - Final comments

There are a couple of new developments you should know about the Apollo 12 descent.

Back in July somebody decided to offset the landing-site targets 1,000 ft. east and 500 ft. north of the Surveyor, primarily based on the assumption that it would be easier for the crew to take over manually from a position biased that way and fly over to the actual point they want to touchdown. Since that time, simulation experience and descent analysis has shown that biasing the descent targets like that is not only unnecessary, but is actually a little undesirable. For example, it appears for visual reasons that short redesignations may be even better than redesignating long. In response to Pete Conrad's request for eliminating these biases, I have polled everyone I can think of who has interest in this subject and have found that everyone either feels it is a good idea or they don't think it makes any difference. And so we are going to remove the biases in the descent guidance targets. This does not change any crew procedures, onboard data packages, or ground procedures. It only involves changing some constants in the control center computer program and the basic philosophy of how we want to do the job.

The other modification deals with the LM venting. For one reason or another, GAC has made a precise measurement of the LM water boiler thrust level. According to Ron Kubicki, the results of their tests will be added to the data book. The preliminary estimate of the effect on the PDI state vector, if the venting is ignored in the RTCC orbit determination and integration programs, is an error in the order of 4,000 ft. in an uprange direction (i.e., short). As you know, we have established a routine procedure of adjusting the PGNCS landing-site target (RLS) during powered descent based on MSFN tracking immediately prior to PDI. This procedure, hopefully, will compensate for up or downrange state vector errors resulting from any source, including venting. As a result, if we were certain the MSFN tracking will be working and able to support this procedure, there would be no reason to even consider compensating for the venting in the initial descent targeting. However, to cover the possibility that the system might fail at that critical time, we have decided to bias the landing-site targets (RLS) transmitted to the LM prior to powered descent. The Math Physics Branch of MPAD has the responsibility for determining the magnitude of this correction and for including it in the Data Select procedures.

I would like to take this opportunity to modify a prediction I made in writing early in August. At that time I thought our chances of landing near the Surveyor were very low. That if we landed closer than about a half mile, we would have to credit Lady Luck. Based on things that have happened since then, including the addition of the ΔRLS update during powered descent, and particularly the confidence the crew has now developed in the LPD since the visual capability of their LMS is working so well - and for whatever it's worth - my feeling now is that as long as the systems work as well as they have in the past, we have a pretty good chance of landing near the Surveyor. And I would rather be on record as predicting that, than predicting a miss. If we do miss, I'll bet it's because of errors in the crossrange direction, so large that the crew does not recognize where they are after high gate or beyond this redesignation capability. The MSFN targeting is weakest in that direction and crummy AOT alignments hurt us most in that direction too.

Howard W. Tindall, Jr.

PA:HWT:js

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: November 17, 1969
69-PA-T-145A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: LM high-bit rate telemetry data is not mandatory

A somewhat controversial mission rule is on the books for the Apollo 12 flight dealing with LM high-bit rate data. Specifically, it indicates that it is all right to proceed with the mission (e.g., undocking, DOI, PDI, etc.) in the absence of LM high-bit rate data with an implied provision that some sort of procedures would be carried out to verify the PGNCS is operating properly. On November 13 Chris Kraft, Sig Sjoberg Gene Kranz, Cliff Charlesworth, Steve Bales, and I reviewed that mission rule and concluded that it is proper and will be used on Apollo 12. I'm writing this memo at CCK's request to record that fact.

Prior to the meeting, Steve Bales prepared a rev-by-rev listing of the procedures to be followed to certify proper PGNCS operation from power-up through lunar surface operation, which showed that it is possible through use of voice communications and some special onboard procedures to check the computer, the gyros, and the accelerometers. It is obvious that these procedures impose an additional workload on both the crew and the flight controllers, which could force delay of DOI. Under no circumstances would DOI be performed prior to the satisfactory completion of the checks. The most significant impact would result from loss of command uplink capability since that would force the crew to manually input a lot of data into the computer via the DSKY, which they ordinarily do not have to pay any attention to at all. The LM state vectors (twice), RLS, and perhaps the REFSMMAT are the most significant of these. However, as I understand it, loss of high-bit rate telemetry does not necessarily mean the uplink wouldn't work; for example, it should be operational if the failure is in the high-gain antenna. And, it was agreed to use it to avoid the voice read up of the data and the crew input task. The new thing brought about by absence of high-bit rate telemetry is that it would be necessary for the crew to read out and voice down all of the data for the MCC to verify complete and accurate receipt.

Subsequent to the meeting, it was recalled that the Luminary program has the capability of computing its own Descent REFSMMAT - (P52 Option 4) - using a landing time supplied by the ground. This capability should probably be used although it may introduce other problems. Steve is checking this out.

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Another item requiring further investigation deals with the erasable memory. As you know, it is standard procedure to dump erasable memory to the ground for a complete check to make sure none of the parameters loaded preflight have been lost. It is not obvious that this is a mandatory requirement since in no flight has a single parameter ever been found to be in error. Furthermore, MIT conducted a special test involving numerous off-on cycling of the LGC with a check of the E-memory on each cycle. Again, no loss of data was observed. (The test exceeded 10,000 cycles when it was terminated due to test-equipment failure.) Steve was given the action of identifying E-memory critical parameters which the crew must check if an E-memory dump cannot be performed.

Incidentally, it will be necessary forthe crew to synchronize the LGC clock without MCC assistance. They should be able to do this using the CMC as a reference to within 0.3 seconds which is considered acceptable.

In summary, the mission rule is correct as written. This meeting confirmed that but also uncovered some open items which we must have squared away before descent without high-bit rate data.

Howard W. Tindall Jr.

Howard W. Tindall, Jr.

PA:HWT:js

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GSA GEN. REG. NO. 27
5010-107

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: November 24, 1969
69-PA-T-146A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Apollo 13 Odds and Ends Meeting

This memo is to notify you of an Odds and Ends Mission Techniques meeting for Apollo 13 on December 5, 1969, starting at 9 a.m., Room 378 of Building 4. Very likely it will be the last big get together we will have for that mission. Generally, subjects to be discussed result from the effect of the CSM DOI on the mission techniques: specifically, the DOI monitoring, the contingency bail-out maneuver, the descent abort rendezvous plans and things like how to align and check the LM IMU, the attitude time history, and so forth. Obviously, feedback from the Apollo 12 mission could also have quite an influence. I will put together some sort of an agenda before the meeting and welcome your suggestions.

Howard W. Tindall, Jr.

PA:HWT:js

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UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: November 24, 1969

69-PA-T-147A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Rover Navigation

I poked my nose into the Rover Navigation System and so Dave Pendley invited me to a meeting at MSFC on November 21, 1969. The purpose of the meeting was to try and firm up the basic design of the Rover Navigation System with the Boeing people who are responsible for building it. It was strongly emphasized that time is very short to provide any system at all if they want to fly the Rover as currently scheduled. In fact, the Seattle Boeing people seemed very reluctant to consider any system other than the one they originally proposed because they insist there is not enough time. (Curiously enough it doesn't seem as though they really have a detailed design for even their proposed system. At least that is the impression I got from their responses to questions.)

It was interesting to observe that Marshall, the local Boeing management, and MSC people were completely in agreement on everything. What we all wanted to do was to simplify the system as much as possible. For example,

a. Eliminate the automatic sun-seeking azimuth alignment device.

b. Use the astronaut to reinitialize the system periodically throughout the traverse, thereby relaxing the accuracy requirement. They will want to check it periodically anyway.

c. Decouple the components such that failures in one part do not wipe out the entire system. Specifically, we would like some way of determining Rover heading and distance travelled - the most useful outputs - if the computer fails. This makes use of a directional gyro logical.

Boeing (Seattle) acted as if they never had heard of a directional gyro and almost certainly will come in with a negative response on their action item of looking into this simpler system. However, there were some guys from MSFC with heavy German accents who said they intended to check back into their labs to come up with some proposals. And the local Boeing guys will too. Then they are all supposed to get together in a week or two to decide what they are going to do. I would be amazed if Marshall is not put into a position where they must either:

a. Direct Boeing to implement the simpler system, which of course also gives Boeing a blank check for cost, schedules, etc.

b. Permit Boeing to implement the system they want to use.

My opinion is that it really doesn't matter what happens because after listening to the Apollo 12 EVA and John Cooper's description of how the operation is conducted, I am convinced that we don't need any navigation system at all! The important point was that prior to starting a traverse, the ground and the crew will have jointly laid out the whole thing in detail. Then as the traverse progresses there will be a joint, step-by-step tracking of current position on their maps. There should never be a time when the crew and the ground people don't know exactly where they are and if any uncertainty ever arises, the number one task will be to reestablish their location somehow - by retracing their steps to a known benchmark if necessary. Visualize then what you would do if it ever became necessary to return directly to the LM. If the navigation system's displays agree with what you see on the map, there is no question about it. If the navigation system's displays do not agree with the map, again I don't think there is any question - you have got to believe the map and act in accordance with it! I have come to the conclusion that the navigation system is not required to get the crew back to the LM. Certainly it would be helpful, but not necessary. It doesn't seem necessary to establish where you are for scientific purposes either, since again the crew's eyeballs and map will have highest priority along with their photography. It seems as though the most useful function of the navigation system is to make their EVA more efficient by helping them keep track of where they are on their map. Of course, all that is required to do that is an indication of their heading and distance travelled - a compass and an odometer. All of these points were made very clear to the Marshall and local Boeing people, who understand them completely and intend to proceed accordingly.

In summary, I don't think we have anything to worry about from an operational standpoint, regardless of what kind of navigation system we get on the Rover. There may be some problem in getting the system they are most likely to try for, but those problems will be in terms of cost, weight, and schedule which are the business of others who are well aware of the situation and apparently competent. I was quite impressed with the quality of the Marshall and local Boeing people who are in charge of the overall Rover program.

Howard W. Tindall, Jr.

PA:HWT:js

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5010-107

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: December 17, 1969
69-PA-T-149A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Apollo 13 Mission Techniques are in good shape

On December 5 we had what I expect to be our last full-blown Mission Techniques meeting for Apollo 13. This memo is to tell you about it.

As you probably know, the recovery people would like to move the end-of-mission landing point closer to their support base in Samoa. Accordingly, the TEI and entry targeting will be aimed at 172° W rather than the 165° W longitude used on previous missions. The Retrofire Officer pointed out that this change does not apply to the targeting for all the block data nor will it be used if due to a G&N failure it is necessary to perform the TEI maneuver with the SCS. In these cases they want the landing point well clear of any land at all and they'll use the old mid Pacific line. A more important change, from the crew's standpoint, was their agreement to be prepared to fly the EMS and 4 g manual backup techniques, banking either to the north or south. On previous missions they have only been prepared to go north. The reentry planning people (MPAD) felt that this additional capability was required since the more westerly landing site is close to a bunch of islands and could get us in a bind if we were not prepared to go either way. Unlike previous missions, steering to the south will be the prime mode unless land or weather is unacceptable there. I would like to reemphasize that all this only applies to entry without the G&N.

One of the techniques that is significantly changed on Apollo 13 deals with LM IMU alignments and drift checks. The change is due to: a) we are undocking 1 rev earlier, which makes it impossible to carry out an accurate inertial alignment while docked like we did on Apollo 12, but it does permit two undocked AOT alignments; b) the smaller size of the acceptable landing site makes it necessary to reduce the allowable drift rate about the vertical (x) axis since that results in an out-of-plane dispersion at landing. Until this flight we used a limit selected to protect against continuing the mission with a broken IMU. We must reduce this limit now to make sure the guidancesystem will deliver the LM to within the 1 kilometer radius of the desired landing point for both crew safety and mission success reasons. The final result of our deliberations, at this meeting and at a subsequent meeting, yielded the following technique. We concluded that by far the most accurate drift determination could be carried out by comparing the LM system to the CSM while still docked to the CSM. Accordingly, we will use that data to determine whether or not it is necessary to update the IMU drift compensation in the LGC and to determine the new compensation values. If new compensation is required, it will be uplinked from the ground prior to the first undocked AOT alignment. We will then confirm that the IMU is operating acceptably to proceed with descent based on the torquing angles calculated at the second undocked AOT alignment. (I am writing a detailed description of all this for those interested in more detail.)

As a result of the excellent landmark tracking the Apollo 12 crew carried out, we feel confident we know the Apollo 13 landing site location accurately enough to recommend the following mission rule: landmark tracking is not mandatory for descent. Obviously we intend to use whatever landmark tracking is obtained and plans call for attempts to be made in both revs 12 and 13. The point is that if for some reason we do not get this tracking, the landing should not be delayed. Although this data will significantly reduce dispersion, we do not need it badly enough to go an extra rev thereby clobbering both crew and ground procedures.

By far the most emotional discussion of all involved monitoring of the CSM DOI maneuver. The basic question was, should the EMS be included in the monitoring techniques? Our final resolution was that it should not and that the CSM DOI monitoring would be carried out exactly as was done during LOI_2 on all previous lunar missions. Namely, the G&N will be given every opportunity to do its job and the crew will manually command engine off if either the predicted burn time is exceeded by 1 second or the G&N itself indicates that an overburn is occurring because the automatic cutoff failed to get through for some reason. In the event the burn is apparently completed satisfactorily but the EMS indicates an overburn, it will obviously be necessary to convince ourselves beyond a question of a doubt that the EMS is wrong and that the G&N has achieved the targeted orbit. This determination will be made by the crew's observation of time of earth rise above the lunar horizon compared to a prediction provided by the ground before DOI. The details involved in this ground determination must be worked out and the technique will be rehearsed in flight during the lunar orbits before DOI. (For your information, a 1 second overburn will produce an extra 10 fps which just results in lunar impact. Earth acquisition time will be delayed 14 seconds due to a 1 second overburn thus it is this kind of time difference the crew must be able to discern with absolute confidence.) If an overburn actually occurs, the crew is to make canned SCS/SPS posigrade maneuver of 100 fps. Execution time is 30 minutes after DOI.

MPAD currently predicts that the perigee and apogee altitude should only change about $\frac{1}{4}$ mile between DOI and PDI. It is their estimate that at DOI they will be able to predict the PDI altitude to within 9,000 feet. Associated with this was a discussion regarding necessity for trimming DOI residuals, which also affects the PDI altitude. It was decided to trim x to within .2 fps and z to within 1 fps. However, since then we have reconsidered and agreed that the rule should be to trim both x and z to within 1 fps. Out-of-plane (y) is not to be trimmed at all. The objective of this is to make it almost certain that trimming will not be required since we want to save the RCS and it is not really necessary.

You are probably well aware of the special effort we have been making to reduce trajectory perturbations as much as we could. Our objective was to improve the ground targeting for the descent to provide a pinpoint landing capability. We have now proven, both analytically and on Apollo 12, that we are able to compensate for these perturbations by use of the targeting update (ΔRLS) during powered descent. It also seems unlikely that we are ever really going to be able to eliminate the perturbations. That is, we must plan on continued use of ΔRLS. If we accept this as a fact of life, there is no justification for fixing the LM vent in an attempt to make it non-propulsive. It is also possible to live with venting from the CSM water boiler if the systems people decide it's necessary to run it, although it is certainly better if we don't have to. One thing for sure. If the CSM G&N performance degrades due to the higher operating temperatures, we must make sure that that is not worse than venting on the overall trajectory control problem.

Although the Apollo 13 LM LPD is supposed to have been fixed to compensate for the effects of LM bloating, we concluded that it is still desirable to check it in flight as was done on Apollo 12. A change had been made in the LM's computer program to take into account misalignment of the LPD. We established a rule that if the in-flight check shows that the LPD is off by more than 1^o, in either pitch or yaw, the ground will update the parameters in the erasable memory. MIT was requested to inform the MCC Guidance Officer exactly how this is to be done.

We discussed establishing an alternate flight plan to be used in the event LM/CSM separation is delayed for some reason, but finally concluded that it could best be worked out in real time. It seems, as a rule of thumb, that delays in separation of up to 40 minutes could be tolerated fairly well - beyond that would probably require delay of the descent for an extra rev.

Descent aborts are a little different than on Apollo 12 because the earlier undocking changes the CSM/LM separation distance substantially. Actually, the situation is better. During the first 5 minutes and 40 seconds of descent a 2-rev rendezvous is required; after that it changes to 1 rev through T_1. T_2 is 2-rev and occurs at about 20 minutes and 45 seconds after PDI. (This compares favorably to Apollos 11 and 12 when we had a 1-rev rendezvous through 10 minutes, then 2 revs through T_1 and 3 revs for T_2!)

Aside from some rumbles about knocking 2 hours out of the rendezvous, Apollo 13 techniques seem pretty firm. Although I'm sure there'll be the typical diddling til the flight, we probably won't get together again.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

PA:HWT:js

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GSA GEN. REG. NO. 27
5010-107

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list attached

DATE: December 18, 1969

69-PA-T-148A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: LM IMU drift checks prior to descent for Apollo 13 and up

We are making some fairly substantial changes to the way we are aligning and checking the drift of the LM IMU before descent on the Apollo 13 mission. Just for the record I would like to document what it is we are doing and why.

Two things have happened as we progressed from Apollo 12 to 13 which have made it necessary to change the techniques. Probably the most significant is performing the DOI maneuver with the CSM. This in turn presented a problem with regard to landmark tracking by the CSM since we aren't sure it can be done in the 60 x 8 n. mi. pre-descent orbit. So, in order to assure getting the landmark tracking, we decided to recircularize the CSM orbit to the 60-mile altitude. And to get the tracking done in time to use the data, we are forced to undock from the LM 1 rev earlier than we did on Apollo 12. Undocking earlier means that less time is spent while docked during the LM activation and checkout which precludes our making an accurate docked alignment of the LM platform. (We have neither sufficient time nor the necessary attitude changes in the new timeline.) On the other hand, undocking early gives us an extra rev of LM free flight which allows carrying out two AOT (P52) alignments during each of the last two darkness passes before PDI.

The other significant thing that made it necessary to change the techniques is the fact that we are landing on a rough area on the moon in which the acceptable touchdown conditions are constrained to a very small area. For planning purposes it is defined as a circle with 1 kilometer radius. The point is, whereas on previous missions we could miss the targeted-landing point by many miles and still land and achieve the primary mission objective, on this flight we cannot even land safely very far from our 1 kilometer circle. This obviously imposes a demand for superior performance from the PGNCS than was needed on previous flights. In particular, we must make sure misalignment of the platform at PDI about the vertical (x) axis is about an order of magnitude smaller than was acceptable on Apollos 11 and 12. On those missions the maximum acceptable x misalignment was based on protecting against continuing with a broken system. Specifically, we were able to tolerate a platform drifting at a rate up to 1.5 °/hr. The fact that this would cause a very large miss in landing point location was not sufficient justification to delay or scrub out the landing. Now we are not willing to go on if the guidance system is going to miss our little circle. An analysis shows that a misalignment in excess of 0.19° at PDI is all we can tolerate. By moving our last platform alignment as late as possible before PDI, we can pinpoint our largest acceptable drift rate. Assuming the latest we can do the P52 is 1 hour and 20 minutes before PDI, the maximum allowable drift rate turns out to be .145 °/hr. (that is about a 4.4 sigma system).

Our number one problem comes about when determining first of all if the system is working better than that, or not. Secondly, if it isn't, how do we get the new compensation to the spacecraft? After a good bit of head scratching, the consensus is that our best determination of drift rate (not absolute inertial alignment) can be made using the CSM platform as a reference while the LM is still docked. If you can assume there is no slipping or bending between the two spacecraft while docked, the MCC is able to detect drift rates in excess of .04 °/hr. dependably. We feel this is at least as good as two P52's spaced 1 rev apart. In fact, it's probably better. So we plan on using the crew's readout (N20) of LM and CSM gimbal angles while docked to make the determination of whether or not the LM IMU is working well enough to support a landing. Furthermore, if we find the drift in excessive, we intend to use that same data to determine new values of drift compensation which will be uplinked to the LM after undocking, but before the first AOT alignment. This procedure should not only be the most accurate way to do it, but also avoids another problem. Namely, there is no straightforward way of using the data obtained from the two AOT alignments, the last of which occurs in back of the moon 1 hour before PDI, and uplinking the new compensation values, if that turned out to be necessary, without delaying the landing 1 rev. Of course we have every intention of rechecking the system for acceptable performance based on the undocked AOT alignments but the procedure outlined above should preclude finding it unacceptable at a time when it is difficult to do anything about it.

We are not changing our criteria used to establish acceptable drift and misalignment about the other two axes, y and z. As before the y limit was chosen to provide a safe descent abort capability since pitch misalignment does not significantly affect landing-point accuracy as long as the landing radar data comes in. The z-axis limit is still based on making sure the system is not broken since we can stand massive misalignments around the braking thrust axis. (Note: IMU z is approximately along the LM x-axis.)

Howard W. Tindall, Jr.

Enclosure

PA:HWT:js

M. Johnston

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

UNITED STATES GOVERNMENT

Memorandum

NASA Manned Spacecraft Center

TO : See list below

DATE: December 31, 1969

69-PA-T-152A

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT: Can we cut 2 hours out of the Apollo rendezvous?

As you no doubt are aware, there is a movement afoot to shorten the Apollo rendezvous by 2 hours. This would be done by eliminating the CSI and CDH maneuvers and executing TPI about ½ hour after insertion. The reason this is being considered is to reduce the crew's workday which currently is really pretty bad. Of course the thing we would have to accept is a reduced capability to tolerate dispersed conditions. In any case, at the urging of members from several of the upcoming crews, Ed Lineberry and his people have been working on a new trajectory and timeline. We would like to get together on January 14 to go over this business and decide what to do next. I am sure it is too late to consider a change of this magnitude for Apollo 13, but I don't believe it is too late for Apollo 14 unless the new plan has some major drawbacks. If you're interested, call me in a week or so for time and place.

Bill

Howard W. Tindall, Jr.

Addressees:
AC/C. C. Kraft, Jr.
PA/J. A. McDivitt
FA/S. A. Sjoberg
CB/T. P. Stafford
CB/D. R. Scott
CB/A. B. Shepard
CB/E. A. Cernan
CB/E. D. Mitchell
CF24/P. Kramer
CF24/M. C. Contella
CF34/T. W. Holloway
EG7/C. T. Hackler
FC/E. F. Kranz
FC/C. Charlesworth
FC/G. S. Lunney
FC4/J. E. Hannigan
FC5/J. C. Bostick
FC5/P. C. Shaffer
FM/J. P. Mayer
FM4/J. C. McPherson
FM5/R. E. Ernull
FM6/E. C. Lineberry
FM6/R. Regelbrugge
FS5/J. C. Stokes
FS5/L. Dungan
NASA HQS./XS/R. Sherrod
MIT/M. Johnston, IL

PA:HWT:js

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

IN REPLY REFER TO: 70-PA-T-2A

January 5, 1970

MEMORANDUM TO: See list attached

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT : A small change in CSM DOI confirmation procedures

We ran into a little snag on confirming the CSM DOI maneuver which has forced us to change the mission technique a little bit and I think you should know about it.

The CSM DOI burn brings perigee to about 8-miles altitude and it only takes an overspeed of 10 fps to cause an impact. Accordingly, we must have absolute confidence that such an overspeed has not occurred. On the other hand, we strongly desire to give the G&N every chance to do its job since it almost certainly will do it right. For this reason we have retained the simple crew technique for protecting against a malfunctioning G&N by manually shutting down the engine if the predicted burn time is exceeded by 1 second, and we are not including the EMS in the logic. If at the conclusion of the maneuver the EMS confirms that the G&N did right, we should have confidence that everything is okay since that has got to be more than just coincidence. Our only problem occurs if both the G&N and EMS appear to be operating properly, but the EMS indicates an overspeed. Then something must be done to determine which of the two systems is correct. If the G&N proves to be correct, we should press on with the mission. If the EMS is right, an emergency maneuver must be executed within ½ hour to get out of there and, since the G&N must be broken, the landing will probably have to be abandoned. Originally we intended to solve this dilemma in the unlikely event it occurred by having the crew note the time of earth rise. It was originally felt that this observation would provide the crew an absolutely dependable, simple onboard technique for making this critical decision. We have since found that that is not so dependable and have chosen to use an alternate procedure. Namely, we have been unable to find dependable onboard techniques and have decided to depend on the MSFN tracking and MCC processing to determine which of the sources is correct if the G&N and EMS disagree with each other. This can be done dependably to inform the crew in time for them to execute the bail-out maneuver. This procedure has been agreed to over the phone by key flight controllers and the prime Apollo 13 crew, and it will be used during the simulations starting this week. Work on earth-rise procedures is being terminated.

Howard W. Tindall, Jr.

PA:HWT:js

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

IN REPLY REFER TO: 70-PA-T-1A

January 7, 1970

MEMORANDUM TO: See list attached

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT : Important LM computer program change for Apollo 13 descent

There were some things about the terminal descent on the last mission that kind of spooked a lot of people. One of the things suggested as a result of this was to add a capability to the LM guidance and control system which would assist the crew during the last 100 feet or so of the descent. Specifically, fix the PGNCS so that it will provide an automatic nulling of the horizontal velocity while the crew controls the descent rate with the ROD switch. This memo is to inform you that we are adding this capability to the system for the next flight - Apollo 13 - and to describe briefly just what it is we are doing.

A modification is being made to P66 which will eliminate P65 or, if you like, replace it with a similar but superior capability. We are retaining the current P66 mode of operation exactly but are adding the following feature to it. If the crew switches from "Attitude Hold" to "Auto" the PGNCS will null horizontal velocity to zero - both fore/aft and lateral. It does this, of course, just as the crew would in the manual mode by controlling the spacecraft attitude. There is no restriction for switching back and forth between "Attitude Hold" and "Auto" in P66 as often as the crew desires.

It is anticipated that the crew would fly the descent to an altitude of about 100 feet exactly as has been done on both previous missions - that is, they will exit P64 and go into P66 (Att. Hold) and manually control rate of descent and attitude to place the spacecraft over the desired touchdown point with small horizontal velocity remaining (say about 3 fps and certainly not more than 10 fps). At this point they can switch to Auto which would cause the PGNCS to take over attitude control to get and maintain the horizontal velocity as near zero as it is able, leaving the crew free to monitor their systems, watch out the windows, control the rate of descent, etc. MIT also fixed the system so that the attitude

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errors are always displayed on the FDAI "error" needles in P66 so the crew will know what the PGNCS plans to do when they enable it.

Since there is no programmed constraint keeping the crew from switching to Auto when the horizontal velocities are quite large, spacecraft attitude limits have been programmed to insure that the LM does not suddenly pitch or yaw to an extreme attitude in an attempt to kill off these velocities, if the crew were to select Auto under those conditions. This limit is in erasable memory and is currently set at 20°.

100 ft?

An associated feature we are implementing is the inhibiting of the landing radar data at about the same point in order to insure that spurious velocity data does not cause undesirable attitude or translational transients.

Since there is no apparent reason P65 would ever be preferred to the new Auto P66, the PGNCS logic is being fixed so that if the P64 target conditions are met prior to the crew taking over in P66, the automatic program switching from P64 will be to P66 Auto rather than P65. Thus, with this change and the one previously implemented so that the PGNCS ignores the throttle mode switch position, we have essentially eliminated both P65 and P67, and have remaining two modes of operation in P66. Most experts involved seem to feel that if we had been clairvoyant the programs would have been implemented this way in the first place.

One final word, this program change was not seriously considered until December 12 at which time a group of us got together here and pinned down specific functional requirements which we then discussed over the phone with MIT's Russ Larson and Allan Klumpp. It was interesting to note that they had also thought about this and had arrived at almost exactly the same conclusions. At our request they set about implementing this change in an orderly but expeditious way, resulting in an offline assembly delivered to MSC at the break of dawn on December 23. Gene Cernan and Pete Conrad exercised it in the LMS that day and proclaimed it to be outstanding. Jim Lovell has also played with it at the Cape and is said to have expressed his pleasure and burning desire for it. MIT, in the meantime, has completed their detailed reverification of the program. GAC's Clint Tillman has also exercised it on their simulator and John Norton has reviewed the actual coding and I am told declared it to be a work of art. In other words, although we are messing with absolutely the most critical part of the most critical phase of the mission, we are confident that the change has been made correctly and are releasing the tape to Raytheon to make the new Module 5 rope to be delivered to KSC before CDDT.

Although I'm certain there are others, I personally know that a large dose of special credit should go to Allan Klumpp and Tom Price for getting this job done so well and so quickly!

Howard W. Tindall

Howard W. Tindall, Jr.

PA:HWT:js

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

IN REPLY REFER TO: 70-FM-T-4

January 13, 1970

MEMORANDUM TO: See list attached

FROM : FM/Deputy Chief

SUBJECT : AAP Rendezvous Mission Techniques

In order to help solidify requirements for the AAP CSM computer program we are having a Mission Techniques type meeting on Tuesday, January 27 at 9 a.m., in Room 378 of Building 4. The specific subject to be discussed is the rendezvous phase of the AAP mission. The thing we are particularly anxious to pin down is the type of maneuver sequence we feel should be utilized, since that will define onboard programs required. It will also probably help clarify other aspects of mission planning such as crew procedures and onboard charts, trajectory and attitude profiles and even some hardware requirements such as the flashing beacon and VHF specification. A basic assumption, which I believe has been accepted without argument, is that a completely onboard capability for performing the rendezvous should be implemented since the ground support may be marginal. In fact, as a spin-off from this meeting, just how well the ground should be able to help with the rendezvous may become better understood.

This is a working session and attendance should be limited to people directly concerned with this subject.

Howard W. Tindall, Jr.

PA:HWT:js

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

IN REPLY REFER TO: 70-FM-T-5

January 13, 1970

MEMORANDUM TO: See list attached

FROM : FM/Chairman, Apollo Spacecraft Software Configuration Control Board

SUBJECT : AAP CSM Computer Program Requirements meeting

I thought it might be fun to have an overall AAP CSM Computer Program Requirements meeting so we've scheduled one on Wednesday, January 28, 1970 at 9 a.m. in Room 966 of Building 2. At this time we would like to reach agreement upon a list of deletions which can be made to a particular mainline Apollo Colossus program established as the baseline. We would then like to identify all additions and/or modifications required to support AAP. This definition should be in the form of functional requirements although it should be advantageous to carry their definition to a fairly fine degree of detail when possible to do so. We are also anxious to understand just what these programs are going to be used for.

Based on the results of this meeting, the Flight Support Division of FOD will generate the formal requirements documentation to be forwarded to MIT for implementation and the program will be placed under configuration control as soon as possible - over two years before the flight!

Howard W. Tindall, Jr.

PA:HWT:js

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

IN REPLY REFER TO: 70-PA-T-8A

January 20, 1970

MEMORANDUM TO: See list attached

FROM : PA/Chief, Apollo Data Priority Coordination

SUBJECT : The Apollo rendezvous can be shortened by 2 hours

As you no doubt are aware, there is a movement afoot to shorten the Apollo rendezvous by 2 hours. This would be done by eliminating the CSI and CDH maneuvers and executing TPI about ½ hour after insertion. I thought the reason this was being considered was to reduce the crew's workday, which has been pretty long. Apparently it is also to permit more EVA time on the lunar surface. In any case, a gang of us got together January 14 to talk it over. We were interested in hearing about what work has gone on, what the feasibility of doing this is, and to decide where to go from there. This memo is to briefly describe the technique (Ed Lineberry's people are documenting this in detail and if you are interested you should call him) and to let you know that it does appear feasible. I will also note what has to be done now - the first thing being, to obtain MSC management approval to go on with it.

Following is a brief description of what the technique is:

a. Both the CSM and LM platform are aligned prior to LM lift-off. They are not ordinarily realigned during the rendezvous.

b. The CSM orbital should be 60 n. mi. circular as before. The LM insertion orbit will be 10 x 48 n. mi., instead of 10 x 45 n. mi. This small change will cause the post-TPI trajectory to be virtually identical to that utilized in the past.

c. Lift-off will be timed to provide the proper relative position of the LM to the CSM at the time of TPI execution which will occur 38 minutes after insertion. Thus, lift-off would be about 2½ minutes earlier than on previous missions.

d. It should be possible to obtain at least 25 marks by each spacecraft for their rendezvous navigation. Since we intend to always use the time option of the TPI targeting program, it should be possible to continue navigation significantly later than in the past. It can't slip early on us.

e. The TPI maneuver is significantly different than before. It is about 85 fps and rather than along the line-of-sight, it is almost perpendicular to it (i.e., pitched down about 45°). Also, in order to provide an in-plane braking, the TPI maneuver will be made to force a node 90° later, that is, at the second midcourse maneuver.

f. We concluded that, since the LM TPI maneuver is RCS, the probability of an unexpected LM inability to execute the maneuver is almost zero. Accordingly there should be no requirement for the CSM to prepare to execute a mirror image TPI maneuver. Of course, if a LM failure has occurred which would preclude its performing TPI, the CSM would do it. It was noted that, since a CSM TPI would result in a very low orbit, it must also be active for braking.

Although we probed all related areas, we could find very little adverse impact by going to this plan. Certainly we have not changed the descent aborts and their associated rendezvous techniques - that is, one and two rev plans, including the CSI and CDH would still be utilized exactly as before and, of course, the crew and ground control must be trained and prepared to do them. This plan essentially consists of eliminating part of that standard rendezvous and, therefore crew training is unaffected. One area that FCSD will probably look into is the provision of TPI charts for the crew to backup the PGNCS and AGS. If these are required, they must be substantially different from the current ones.

The only other open area deals with changes to the RTCC. Only two were identified - the lift-off time computation and a program to determine a trim maneuver after LM insertion into orbit. The former should be extremely simple, if it is required at all. The need for the latter will depend to some extent on the sensitivity of the rendezvous to small errors in actual LM lift-off time and other insertion dispersions. Ed Lineberry's people will continue their work in pinning down this sensitivity. The three involved FOD divisions will then establish whatever new RTCC requirements are really needed. This should be done within a week or so.

One pseudo-mission rule we agreed on was that this rendezvous approach should only be used in the nominal case when all important systems and trajectory conditions are as they should be. That is, if things like the rendezvous radar, the tracking light, or any of the other systems used for rendezvous are known to be broken, or if we have targeting problems, such as poor definition of the LM's position, or of the CSM orbital elements we would, in real time, switch from this quick rendezvous to the standard approach used on all previous flights. Of course, this switchover must be made before lift-off since after that time we will have created a phasing situation that pretty well commits us to go on with the shortened plan.

In summary, a simple approach to shortening the Apollo rendezvous by 2 hours was agreed upon by just about everyone interested in this subject. The impact seems quite limited and, to me, well worth paying for the rather attractive benefit. I would be surprised if we have overlooked anything that would change this picture although, of course, it is possible, I suppose. Accordingly, we will continue working on this approach - cleaning up the loose ends noted above and will approach our leaders to see if it should be incorporated into the Apollo 14 mission. Essentially what we are offering is an increased capability which can be used either to extend the lunar surface work or to just shorten a long, tough day.

Howard W. Tindall, Jr.

PA:HWT:js

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

IN REPLY REFER TO: 70-FA-T-13

February 12, 1970

MEMORANDUM TO: See list attached

FROM : FA/Chairman, Apollo Spacecraft Software Configuration Control Board

SUBJECT : Software for the AAP CSM spacecraft computer

The time appeared right to try to find out exactly what the program requirements are for the CSM computer for AAP and we had meetings on January 28 and 30 to do that. As a result of these meetings, a number of PCR's will be prepared and submitted to the Apollo Spacecraft Software Configuration Control Board (SCB) meeting to be held early in March. At that time we will approve or disapprove these changes and the program will be essentially under configuration control. One thing that seems clear from our discussions is that program changes required for AAP are very few in number and, except for the docked digital autopilot, seem to be quite simple. This is no surprise, of course, but it is nice to confirm it.

Before getting into the detail of these meetings themselves, I would like to state a couple of ground rules which we established associated with the AAP computer program and how we intend to manage it. First of all, we selected the Apollo 14 command module program as our baseline since it is the latest, completely defined program we have right now. It is our intention to approve automatically any PCR for AAP which is approved for Apollo. In the case of program changes for Apollo which are not desirable for AAP we will issue an AAP PCR at the same time which deletes that particular capability. By this paper-work device we will maintain a complete list of PCR's defining the AAP program changes required for the current Apollo program to make it ready for AAP if we were to break off a flight program from Apollo for AAP at that time. In addition, it will provide an up-to-date definition of the capabilities of the AAP CSM program we plan to implement.

To get this list off with a big bang, we went through the entire Apollo 14 program and identified all those programs, routines, and extended verbs which we felt should be deleted. This list, which will be covered officially by PCR's, accompanies this memo for your information. The criteria used to decide just what should be dropped from the Apollo program for AAP was simple. If someone could not identify a firm requirement for a particular capability, it was automatically deleted. It should be pointed out that by deletion we mean that the capability will not be available for use in flight. We are not insisting that every word of code associated with that particular program needs to be torn from the assembly, but we are asking that all references to these capabilities be eliminated from all AAP program documentation such as the GSOP's, Test Plans, User's Guides, Flow Charts, and so forth. Of course, the thing we are trying to do is to minimize the work of the program developers. Obviously under certain circumstances it will be easier to leave some of these capabilities in the program, including testing them. In that case they should be retained. However, this will be by exception only and will require approval of the SCB.

By far, the largest discussion dealt with the rendezvous and how it should be performed. Basically the question was, should we use the standard Apollo techniques involving a CSI and CDH maneuver or, as some people suggested, should we change to a more flexible sequence of maneuvers used on occasion on Gemini, namely the NCC/NSR combination? The advantage of the former is that it exists in the current program. The advantage of the latter is that it provides a great deal more capability to maintain a nominal terminal phase in the face of dispersion. Its advocates expressed concern, that dispersion could be rather large on AAP due to the limited tracking available for targeting the early phasing-type maneuvers. The eventual outcome of all this was that we decided to go with the NCC/NSR sequence and this program will be changed accordingly. It should be noted that this decision also impacts the mission planning; that is, future reference trajectory documentation will reflect this decision. In addition to agreeing to the change to NCC/NSR, which is said to be rather trivial as far as the programming is concerned, we also agreed to add a new targeting program for computation of two earlier phasing maneuvers.

There were only about 6 or 8 other program changes suggested specifically for AAP and they are all pretty simple, like extending the VHF ranging input capability beyond 327 n. mi. and improving the SPS short burn logic to support the small rendezvous maneuvers. I might also point out two rather substantial Apollo changes which AAP will automatically inherit. They are the rendezvous improvements to simplify the crew's procedures and the universal pointing program being added to P20. Special attention will be given this important one to assure that there are no unique requirements for AAP which have not been provided by this routine since it will probably be used for attitude control of the docked configuration.

We also assigned some action items:

a. Make sure there is no special problem involved in aligning the CSM IMU prior to launch from a Saturn I-B, rather than a Saturn V pad. (Charley Parker, FCD).

b. Verify the interface from the CMC to the Saturn IU is identical to Saturn V to make sure our P11 program is all right. (Tom Lins, GCD)

c. Identify any coarse alignment program requirement we might have for aligning the command module IMU while docked to the Cluster, using the Cluster as an attitude reference.

d. Prepare a complete PCR identifying the functional requirements for the docked DAP. This big job, of course, is the responsibility of the GCD and Tom Lins will see that it gets done.

e. Jack Williams will get everyone concerned together to scrub the telemetry downlist, identifying spares and additions, if any.

I think everyone at the meetings agreed that we are in pretty good shape with respect to the definition of the AAP programs and should have little trouble in preparing the program from the Apollo assembly at the time we decide to do so. Although that won't probably occur for at least another year, it is expected that some off-line assemblies and documentation will be prepared by MIT as often as their effort on Apollo mainline permits.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

Enclosure

FA:HWT:js

DELETIONS FOR AAP

DELETED PROGRAMS

P15	Initiation of IU TB6
P22	Orbital Navigation
P24	Rate-aided optics for landmark tracking
P32	Co-Elliptic Sequence Initiation (CSI)
P33	Constant Delta Altitude (CDH)
P37	Return-to-Earth (RTE)
P38	Stable Orbit Rendezvous (SOR)
P39	Stable Orbit Midcourse (SOM)
P52	IMU Realign (Option 4 only)*
P65 P66	Everything used exclusive for V> 27,000 fps can be deleted from the Entry program such as Up Control and Ballistic
P72	LM Co-Elliptic Sequence Initiation (CSI)
P73	LM Constant Delta Altitude (CDH)
P74	LM TPI Targeting
P75	LM TPM Targeting
P76	Target ΔV
P77	LM TPI Search
P78	LM SOR Targeting
P79	LM SOM Targeting

DELETED ROUTINES

R05	S-Band Antenna Acquisition Angles
R33	CMC/LGC Clock Synchronization
R57	Optics Calibration
R64	PTC/Orbital Rate

DELETED EXTENDED VERBS

V44	Set Surface Flag
V45	Reset Surface Flag
V52	Marked on Offset Landing Site
V59	Please Mark (Optics Calibration)
V64	Start S-Band Ant Calibration
V68	CSM Stroke Test On
V94	Enable Cislunar Tracking Recycle

*General - Delete all lunar and cislunar capability such as numerical integration and anything that requires use of the lunar ephemeris which will not be provided.

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

IN REPLY REFER TO: 70-FA-T-16

February 19, 1970

MEMORANDUM TO: See list attached

FROM : FA/Chairman, Apollo Spacecraft Software Configuration Control Board

SUBJECT : "For whom does the bell toll?" ... "Delta Guidance" ... "Oh!"

A couple of years ago, before any of the lunar flights, GCD started looking into improvements in the LM descent guidance and navigation (G&N) computer programs to compensate for possible problems in rough terrain, landing radar performance, descent targeting by the ground, etc. Actually, they were quite successful; they conceived the so-called delta guidance, prefilter, and terrain model package which substantially increases the LPD capability at a very reasonable descent propellant cost. Since then we have performed two lunar landings, including the pin-point Apollo 12, which have pretty well eliminated the original need which the modifications were to satisfy.

But, delta guidance does provide a chance to make a big ΔV saving in the earlier braking phase of descent by compensating for the inability of the descent engine to throttle near the max-thrust setting. So the decision had to be made - is the ΔV saving (i.e., 90 fps which is equivalent to 300 lbs payload to the moon's surface, or to 20 seconds of hover time) valuable enough to extensively revise the LM G&N program and to modulate the descent engine through the non-throtteable zone up to 10 times?

An additional data point to be considered before making that decision is the fact that about one-half of that ΔV savings can be obtained in other ways. One way is to change the targeting, which has no effect on the on-board guidance or procedures at all, but is not so conservative about protecting against simultaneous DPS valve failures and a low performing DPS engine. A second approach is to develop a procedure for throttling the DPS engine down only once during the braking phase for a period to be determined at the start of descent based on either on-board or ground-computed estimates of actual DPS performance.

The decision is - do not implement delta guidance (tearing up the LGC program is not worth the 40 or 50 fps extra that it would provide); do implement one or a combination of both of the alternates noted above.

Some small program and display changes may be implemented to provide an on-board capability - either auto or manual - to throttle the DPS.

Incidentally, there is one survivor from this delta guidance program change "package". There appears to be unanimous agreement that we should add the terrain model of the specific landing site we're going to in place of the present "billiard ball" moon. This will eliminate some objectionable pitch excursions and will make the LPD work better.

Howard W. Tindall, Jr.

Howard W. Tindall, Jr.

FA:HWT:js