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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 C.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.

PA:HWT:js