#6 — I. Martin

Massachusetts Institute of Technology

MEMORANDUM

TO: Crew Debriefing Evaluation Team

FROM: J. L. Nevins

DATE: January 8, 1968

SUBJECT: Crew Debriefing Documents

It goes without saying that the information in the enclosed document is of a very sensitive nature and therefore, should be handled with maximum discretion.

Beside the enclosed crew Technical Debriefing we also have one copy of the Flight Crew Log. Access to the crew log may be had thru Miss Janice Curran on extension 1347.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 8 TECHNICAL DEBRIEFING

Prepared by:

MISSION OPERATIONS BRANCH
FLIGHT CREW SUPPORT DIVISION

GROUP 4
DOWNGRADED AT 3 YEAR INTERVALS
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APOLLO 8 TECHNICAL DEBRIEFING

1.0 INGRESS AND STATUS CHECKS

1.13 Distinction of Sounds - Sequence D.C. to L/O

BORMAN There are no comments until we get to the distinctions of sounds and sequence prior the vehicle checks just prior to ignition. There were no significant sounds, valve openings, or gimbaling that would lead to concern on the part of the crew prior to ignition.

1.14 Vehicle Sway Prior to Ignition

BORMAN No vehicle sway was noticed after the swing arm was retracted.

2.0 POWERED FLIGHT

2.1 S-IC Ignition

BORMAN The S-1 ignition sequence starts at T minus 9 seconds; however, the crew noticed no indication of ignition until about T minus 3 seconds, when the noise level reaches the cockpit.

2.2 Lift-Off

There was no reason for concern on lift-off. There was vibration until the hold-down arm's release, and then at lift-off, you got an acceleration similar to the Titan.

LOVELL That's right, except it appeared that the sense slowed down a little bit after it got off the ground, and I was watching the altimeter and it didn't seem to go up as rapidly as the initial lift-off did.

ANDERS It was my recollection that the vibration continued until slightly past "tower clear" call.

BORMAN After the vehicle was released, the noise in the cockpit got very loud and effective crew communication was impossible. The last call that I heard was a faint "tower clear" call by the LOM. Did you hear it very well, Bill? You heard it, Jim. All three of us heard that call; however, it was really in the background. The noise was loud, but the flight was smooth until we went through MAX Q or Mach 1. After that it smoothed out and the S-1C gave a very stable, smooth ride.

LOVELL I don't think that the vibrations were any greater than they were in the Titan. Although there were a lot of small separate vibrations and a lot of noise, I think the flight itself was very smooth.

ANDERS The thing that impressed me about the early stages of lift-off was the very positive control during the gimbaling of the S-1C engines. It was very positive.

BORMAN All the items on the Crew Debriefing Guide 2.1 to 2.15 were all exactly nominal and were very well simulated by the DCPS. As a matter of fact, the runs were very similar in every way to a nominal run on the DCPS, except the

S-1C noise level was higher.

ANDERS I thought the sideways oscillations during the early part of lift-off were a little bit greater than the DCPS. In fact, it felt to me on the first stage ride like an old freight train going down a bad track.

2.16 S-1C/S-II Separation

BORMAN The S-1C/S-II separation was nominal; the crew was thrown forward in their seat, as you would expect in a staging. Then the g load was shifted from 4 to about 1. Consequently, you noticed the change in thrust quite distinctly.

2.17 S-II Engine Ignition

BORMAN The early stages of the S-II flight were nominal - very smooth and very quiet. However, toward the end of the S-II flight, we did pick up a POGO oscillation. I would estimate the frequency to be on the order of 12 cps, and probably plus or minus 0.25g. Quite frankly, it concerned me for a while, and I was glad to see S-II staging. It never gave any indication of going undamped. It was a noticeable oscillation.

2.21 LET & BPC Jettison

The LET & BPC jettison was nominal. The windows were clear when the tower jettisoned. We had no effect of retrorocket exhaust fumes on any of the windows.

ANDERS These conditions are noted in the crew log book.

BORMAN There was some indication of light flash at staging through the hatch window. It was noticeable, in fact, through the left-hand window. S-II/S-IVB staging again was nominal. The booster performed perfectly.

2.22 Guidance - Initiate

BORMAN The guidance initiate was just as simulated on the DCPS. I noticed about a 20-degree pitch-down; the g-level dropped off again, and there was a smooth flight on the S-IVB.

3.0 FLIGHT OPERATIONS

3.1 Postinsertion To TLI

3.1.1 Evaluation of Insertion Parameters

BORMAN — Insertion parameters were nominal. We read down the apogee and perigee to the Flight Control Center - I believe you read 96 by 101, wasn't it, Jim?

3.1.3 SM/CSM RCS Check

BORMAN — We did an SM/CSM RCS check. It was nominal; we did not fire the SM RCS until after separation.

3.1.6 ORDEAL - Mounting and Initalization

BORMAN — The ORDEAL mounting was accomplished with no difficulty. The CMP unstowed the ORDEAL and handed it up to the CDR. The ORDEAL was initiated and worked perfectly in earth orbit.

3.1.7 COAS - Installation and Horizon Check

BORMAN — The COAS intallation and horizon check was nominal.

3.1.8 Optics Cover Jettison

LOVELL The optics cover jettison worked as advertised; however, when they are first ejected, there is so much debris ejected with them (little sparkles and floating objects in front of the optics) it is hard to tell exactly what occurred. It is very difficult at first to see stars through the optics because of the jettisoning of the covers and the putting out of quite a bit of dust with them. As a matter of fact, during the entire mission some of this dust would come out every time we rotated the shaft.

3.1.9 Optics Check

LOVELL Optics check was nominal and easily accomplished during the period prior to TLI.

3.1.11 Comments on Earth Orbit Operations

BORMAN The Apollo 8 crew firmly believes that TLI should not be attempted any earlier than we attempted it on this flight, that is, on the second rev over the Pacific. It seems that we had a very good timeline, ample opportunity to check the systems without rushing. We were able to have that one pass over the U.S. with a good systems check by MCC.

3.2 Pre-TLI

3.2.9 S-IVB Ullage and Ignition

BORMAN The S-IVB ullage and ignition was exactly as advertised. The S-IVB started smoothly with the buildup to 1g. Guidance was very, very smooth and followed the curve right down the middle. There is just no comment other than to say that the whole booster operation was flown exactly as planned with the exception of the POGO that I mentioned earlier in the later stage of the S-II.

3.3 TLI To LOI

3.3.2 S-IVB performance and ECO

BORMAN The S-IVB performance and ECO was nominal again.

3.3.3 S-IVB Maneuver To Separation Attitude

BORMAN The S-IVB maneuver to separation attitude was as expected, with the possible exception that the S-IVB stopped 10 degrees short of the final pitch attitude. We had been given a pitch attitude of 91.7 degrees, and it stopped at 81.7 degrees. This, of course, had no significance. Lighting at separation was very adequate for docking. The S-IVB was stable. One incident, on that I think is important on this flight, was that the SLA panels jettisoned very, very well. We saw them floating to the rear. There was no danger of recontact from the SLA panels.

3.3.5 Separation

BORMAN Now one thing that we did notice at separation: the EMS meter jumped to over 100 feet per second due to the g administered by the separation of the CSM from the S-IVB. We were going to use the EMS to monitor the velocity, and we did use it. But rather than use zero as the basis, we decided to use a 100 feet per second bias and then fly the velocity from that point.

3.3.8 Transposition Maneuver

BORMAN The transposition and return to the S-IVB was accomplished using the SPS. We used a VERB 62 and a NOUN 49 to give us steering signals, and in my opinion, this gave no problem at all in performing a docking maneuver. However we should point out that there would be a greater usage of the SM/RCS fuel in an actual docking maneuver. Since we did not have an LM, we did not close the docking distance. We did close close enough to evaluate the lighting, but we did not perform the final maneuvers that would be required for docking.

3.3.9 Formation Flight

BORMAN Formation flight, of course, was nothing different than we experienced in Gemini. The control systems of the SM are absolutely superb. It was no problem to fly formation with the S-IVB.

3.3.10 S-IVB Photography

ANDERS The first photographic exercise was the S-IVB photography. Prior to TLI, the 17mm and 16mm cameras were prepared for S-IVB photography according to the flight plan. The 16mm camera was started just after pitchover was initiated, and one panel was photographed. Since the CSM was not pointed with the S-IVB on the X-axis, the 16mm camera was stopped. Several pictures, using the 70mm Hasselblad, were taken of the S-IVB. Later, S-IVB venting was photographed with both the data acquisition camera and the 70mm camera. Other photographic targets during the translunar phase of the mission were rare pictures of the earth, rare in the sense that the passive thermal control attitude precluded seeing the earth more than half a dozen to a dozen times through the good windows of the spacecraft, windows number 2 and 4. The window degradation was recorded by 16mm camera in the suggested procedures: holding the camera with the bugeye lens 1 foot from the window and exposing it at 5.6 f stop, that's f/11. Spotmeter readings were taken at the various sequences to provide objective data for correlation. The moon was never seen from TLI until LOI, so no opportunity existed to photograph the moon in route. Also, an effort was made to conserve the high-speed film for earthshine photography, to be mentioned later; therefore, no dim-light phenomena or spacecraft exhaust effects photography was made. It was planned to do this on the return trip.

On S-IVB photography and on all photography, we used the recommended exposures on the film magazines.

3.3.12 CSM Evasive Maneuvers

BORMAN One item that we had a little difficulty with was evasive maneuvers. In order to orient myself or the spacecraft, toward the center of the earth, we lost sight of the S-IVB. When we thrusted back 1.5 feet per second and reacquired the S-IVB, we found that we were not separating from the S-IVB as expected. This resulted in some concern, and actually a delay in starting PTC as required by the flight plan for the translunar portion of the flight. We ended up doing a 9-foot-per-second evasive maneuver which was considerably greater than planned. But, this was effective in providing separation between the S-IVB and the spacecraft. The S-IVB prior to the slingshot maneuver was extremely stable during venting. It was very apparent that the S-IVB did not move.

LOVELL A suggestion that we have concerning the evasive maneuver appropriate for future spacecraft is having the LM's attached. Get close enough to the S-IVB after the docking has been accomplished so that the earth and the S-IVB are both in sight. Then do your evasive maneuver by backing away, say, from the center of the earth and always keep the S-IVB in sight. Then you can assure yourself of adequate separation.

BORMAN I think, in reality, it may be more appropriate to just fly to a predetermined angle on the eight ball, and provide DELTA-V in that respect. When you have a LM on the front trying to find the center of the earth is going to be very impractical. So what you probably ought to do is fly to a predetermined attitude and apply the proper DELTA-V.

ANDERS During the slingshot maneuver venting was quite noticeable from the LMP side of the spacecraft. You could see the cone formed by the angles on the engines, the propellant going out for several miles behind the booster. The booster was observed throughout the venting. There did seem to be some slight attitude excursions during the vent sequence.

3.3.13 IMU and Engine Alignments

BORMAN The IMU and engine alignments were nominal, although I just practiced one. Jim did all the real alignments. He found it easier than the simulator, but, we'll get into that later on when we talk about navigation.

3.3.14 PGA Doffing and Stowage

BORMAN PGA doffing and stowage were easier in zero g on the ground. The stowage bag, and I must stand corrected from a previous flight, the stowage bag worked great, fine. It was a proper way to stow the space suits. I would not recommend stowing the space suits under the individual couches because it would be too cramped in there when you tried to sleep. The stowage bag is by far the best procedure.

LOVELL Concerning PGA doffing and stowage: you have to be careful not to maneuver too quickly after you get out of the couch. When you first get into orbit, it takes a little while for the body to become acclimated to the zero g environment. You can easily become slightly queezy in the actions if you are not careful to move slowly before you become used to the environment.

BORMAN Prior to doffing the PGA, I had to use the UCD and, as usual, the UCD did not work properly. So I ended up urinating all over the spacecraft, my space suit, and myself. I changed the cundrum on the UCD on launch morning, and I was assured it was the one we had tried before, but the first one felt large and the other one felt large also. Unfortunately, it turned out that it was too large.

ANDERS Along those lines, we had the suits off with filled UCDA's. We didn't have time to dump the UCDA's before we had the suits off. We were inhibited from dumping due to tracking reasons. So, we should be provided with a fitting that will adapt the UCD to the normal dump system so we won't have to use a suit to do the urine dumping. We had to unstow a suit to dump our urine the first time.

BORMAN We should re-examine our position on requiring pressure suits for flights that do not include

EVA. I would not have hesitated to launch on Apollo 8 without pressure suits. I think that we should. We wore them for about 3 hours and stowed them for 141 hours. I see no reason to include the pressure suits on a spacecraft that's been through an altitude chamber, and we have confidence in its pressure integrity.

ANDERS I would like to insert one pre-TLI comment - there were some unusual clouds observed 10 to 15 degrees above the horizon while in earth orbit. These are described in the crew log.

3.3.15 Cislunar Navigation and Navigational Sightings

LOVELL I'm going to repeat notes that I have from the log book, and these are taken at various times during the flight. So I'll just repeat them as one note after the next. First sightings were delayed because of the second S-IVB evasive maneuver. Now, the first thing I noticed was that it was almost impossible to get a star calibration, with the technique that we had planned to use, mainly because of the tremendous venting of the S-IVB and the particles that left the optics when we jettisoned the covers. I had to use Program 23 by turning the shaft by trunnion to Sirius and then use Sirius for the first sextant calibration. There was a lot more light scatter in the scanning telescope than I had believed there would be prior to flight. At first this appeared to be the case at almost any attitude. In many occasions the light appears as a bar or a shaft across the scanning telescope -- a horizontal shaft. At other times it appears as random light, either on one portion of the sextant or scanning telescope. During the first star sightings, the earth had a very indistinct horizon. The line-of-sight filter appeared to help define it clearer, more than I had been lead to believe. It appeared that the sharpest line of the first sightings, about 4-1/2 hours from the earth, was actually the junction between the earth and the horizon area, the atmospheric area. The area where the atmosphere fades into space was very indistinct. It was very difficult to find a good horizon to place a star on. My first view of the moon appeared as a light blue thin crescent through the telescope which I happened to get by chance. The space around the moon appeared light blue. I could not see the night side of the moon. I might add that the light blueness of the area around the moon was due to the sun which was near vicinity and caused scattered light through the optics and caused the space around the moon to appear blue. We started out with Program 23 using a DAP load of 11102. We soon found out that for automatic maneuvers it is much better fuelwise to use 11101. We did use the smaller rates for navigation and we recommend this as standard. Program 23 and cislunar navigation seemed to do quite well. Spacecraft maneuvers from the substellar points to the stars occurred as planned. The impulse control is a fine device to use once you get used to the offset axis compared to the spacecraft. At no time did I think that I should be using the regular hand controller by bringing it down to the LEB. I think the minimum impulse controller is sufficient for the work involved in the cislunar navigation. I was impressed, also, by the fine control it gave when the spacecraft was very heavy (full of fuel). Later on I found that the impulses of the minimum impulse control were a lot more effective with a light spacecraft and made tracking and star navigation a little bit more difficult. There's been a lot of discussion concerning what you can see through the scanning telescope as far as recognizing stars and constellations. During the early part of the flight I could not see anything through the scanning telescope that I could recognize, for instance - a constellation. I could see several stars, but I couldn't pinpoint them because I didn't know the surrounding stars. As long as we did not move the spacecraft around, got some distance from the earth and its light, it was possible to see constellations in the scanning telescope. Several factors are involved here. One, of course, is that you must become dark-adapted. You must be dark-adapted before you can see stars. When you first look through the scanning telescope, you see nothing but blackness. A second factor is the spacecraft attitude with relationship to the sun and/or the earth and the moon. When we're close to the earth and we're maneuvering near the earth, there's enough reflected light in the scanning telescope to make stars not visible in the scanning telescope. This is very similar to earth orbital flights. As we moved away from the earth, about halfway between the earth and the moon or a little bit less, it was very easy to see constellations or stars in the dark areas of the sky. As soon as we got close to the sun then sun shafting was very noticeable, and light in the sextant was noticeable and the stars are washed out. Then we had to rely on the auto optics to pinpoint the proper star, which we could easily see in the sextant. I had no problem in almost any attitude seeing stars in the sextant, the bright ones. But I did have a hard time identifying the stars in the scanning telescope. Several times the scanning telescope eyepiece unscrewed itself in zero g and was found floating in the cabin. It is very loose and should be tightened up. Throughout most of the translunar phase of the mission, I noticed that every time the shaft was rotated, particles floated out into view of the scanning telescope, which were about the same magnitude as Sirius and affect star recognition. The use of Program 30 and Program 21 in determining pericynthian altitude seemed to work quite well. Depending on the accuracy of our state vector, we could determine very closely what the ground determination of our pericynthian altitude was. Aside from the particles shaken loose from the spacecraft due to shaft rotation of the optics, there was also regular venting which hindered star sighting through the telescope. On my first initial moon sightings, we had a thin crescent moon. The moon was very hard to distinguish because the area around it was a whitish color due to proximity again of the sun. The stars that were picked were so close to the very edge of the crescent that I almost had to imagine where the moon horizon was located. Consequently, this probably affected the accuracy of these measurements. The stars were star 33 and star 40 approximately 44 hours GET. Another interesting aspect of the lunar sightings was that no dark side of the moon was visible through the scanning telescope or the sextant. I could see the crescent, a lot of whitish area because of the eclipse of the sun, but I could not see the dark side. Again, I thought it was very difficult to use the scanning telescope in the cislunar work and that the sextant was almost completely white when we looked through it with very little distinction of the crescent. It was possible to always see the star in the scanning telescope. I might add that reflection of the sun through the sextant almost washed out the orange dimmer that we had for the landmark line of sight. At this point in the flight, about 52 hours, it would be helpful to perform the optics calibration just after Program 52 when the spacecraft has been stopped from its passive thermal control roll in an area where the scanning telescope does not have any light scatter. This is pretty important. Then we go through Program 52, and after that we zero the optics and pick one for our optics calibration. We had no trouble at all doing the optics alignments with the REFSMMAT option.

The optics worked quite well. With the star in the sextant field of view it was easy to move the star into the center and get good alignment. One glitch that we did see concerned getting the preferred alignments just prior to MCC-4. This was an area which we had never duplicated in the simulator. We had always, in the simulator, started out at that particular spot with the alignment for LOI #2 and we had always ended up in the simulator with the alignment for the REFSMMAT. We have never gotten to do one. It turned out when we went through the perferred alignment technique, fired MCC-4, we got a program alarm 401. Now, we kept the spacecraft from rolling. We rolled up again until we ... the alarm. The course alignment which we did fineline to the capella, and at least that was in the sextant field of view. We ... and noticed on Aldebaran and Rigel that a big change was required. The star was very large, and we did not accept this. We again selected the P52, and at the same time we cycled the optics to ZERO pitch. I think we came up with number 10 and it drove to the other side of the compass to the proper spot. Then we also got number 12 and we figured that the REFSMMAT and optics were operating correctly, and we did get our preferred alignment. One more comment: the DSKY problem and the lack of me getting stars in the sextant, or, more specifically the scanning telescope: it is my opinion that the light transmission to the scanning telescope is too small. We should have full visibility there to identify constellations. During translunar sightings, several other items were noticed. First of all, just as it is on earth the moon washes out stars around it. Prior to the moon getting into the scanning telescope you can see stars. But once the moon gets in the telescope it is very difficult to recognize individual stars or constellations. In sighting on the moon, a difficulty arose, especially close in, ... was the irregularity of the moon horizon. When you took your first sightings, you could bury the star completely in a hill or a part of the horizon that is actually not the average horizon. During the transearth phase I noticed that the sextant reticle was very hard to see against space here and the earth's horizon. The reticle light was not bright enough when we were very near the earth at approximately 130 hours, there was too much light around the earth to see the reticle. And, actually, the way we had to do it was to superimpose the reticle onto the earth. Then you could see the black reticle against the light earth background.

3.3.16 Navigation Housekeeping Operations

LOVELL The way we planned to do the cislunar navigation sightings was to have one person in the LEB take the sightings with one other crewman recording. We recorded our DELTA-R, DELTA-V, trunnion angles and the time as read up by the computer for each mark. A good idea would be to have a sheet of paper taped next to the optics with the stars, the horizon data and the number of sets located right next to it so you could quickly run through the program. It becomes quite rapid after you get used to doing cislunar or Program 23, but you must be careful that you don't occasionally punch the wrong button like I happened to do one time.

3.3.17 Midcourse Corrections

LOVELL During the translunar phase of course, navigation precluded any correction or any opportunity to determine midcourse corrections. However, during the transearth phase using Program 37 we were able to do our own midcourse corrections and we then compared it with the ground. I am personally pleased with the results of P37. I think the workaround procedures completed by MIT shortly before the flight for the fast return worked quite well. The results that we got from P37 would have safely brought us home had not the ground communication and uplink been available to us.

BORMAN Our midcourse corrections were done using the G&N external DELTA-V mode. The first midcourse, we had no ullage. Accuracy was recorded at MCC. We shut down 4.4 feet per second short, and consequently we had to trim out 4.4 feet per second.

3.3.18 Passive Thermal Control

BORMAN We found the barbecue mode to be the most acceptable using a wide deadband for pitch and yaw and minimum impulse for roll. We established a roll rate of about 0.1 degrees per second. It worked very well, and the spacecraft would usually stay in a plus or minus 20-degree cone for half an hour or so before requiring trimming to get back to PTC gimbal angles. We tried passive thermal control without using any rate or attitude hold damping and the spacecraft diverged very rapidly. I believe this would be unacceptable, particular with the LM/CSM combination.

LOVELL Considering passive thermal control, one other method should be considered in setting up the yaw and pitch angles is the ability of the optics to see through an area of the sky that is unencumbered by reflective light from the sun. This, in most cases, was done on Apollo 8, that is, in some modes and some attitudes. We spent much of the time rolling and then it was impossible to see stars in the scanning telescope. Also, it appears that it would be highly advantageous for future crews in the translunar and transearth areas of the flight to set up normal daylight cycles such that passive thermal control could be more or less automatic. We ought to have ground control awaken us in case of gimbal lock during passive thermal control rather than have someone on watch all the time.

3.3.19 TV Camera Operation

ANDERS The TV camera operated well, but we did not have the proper filters for the lenses. The TV camera should have a lens with a stop setting on it very similar to camera 1 so that we can take a spot-meter reading of the light and set the lens accordingly. We were able to salvage the outside pictures by taking lenses that were designed for the cameras and taping them onto the TV lenses. I am a little bit surprised that we were not aware before launch that this light situation might be bad. Perhaps, now that we have discovered this, the future TV's will have the proper lenses on them. Other than that, the TV operated very well, and from what we understand, the quality of the pictures was good.

The TV camera bugeye lens inside the spacecraft was most satisfactory and easy to operate. Picture quality was good, but an effort should be made by future crews to hold the camera more steady in one position for longer times due to the slow scan rate of this camera. The telephoto lens was most unsatisfactory in that it was difficult to point. A sight must be provided on the camera if this lens is intended for further use. A lens of the "eyeball" caliber, that is, one that will see on the screen about what the eye sees, should be provided for out-the-window views. Also, some sort of AGC or filter arrangement to cut down saturation from bright surfaces must be provided.

3.3.20 Communications

BORMAN

If there was one thing that surprised me considerably it was the excellent quality of the communications throughout the mission. The OMNI's worked very well for voice transmission at lunar distances and the high-gain antenna worked well throughout the flight. The clarity in the spacecraft was outstanding. The few times that we did break S-band lock, we were notified by the ground and the lack of squelch was not objectionable. As a matter of fact, it was desirable because it gave you an indication that you had broken lock.

LOVELL

My only comment concerning the OMNI switching antennas concerns the work/rest cycle. It would be highly advantageous in the future if the ground had the capability to switch to all four OMNI antennas.

3.3.21 GO/NO-GO for LOI

BORMAN GO-NO/GO for LOI was given promptly as planned and as simulated.

3.3.22 Pre-LOI Systems Check

BORMAN The Pre-LOI system checks same way.

3.3.23 Prethrusting Programs and Maneuvers

BORMAN PLSS 22 Program 30, Jim has already talked about, but Program 30 worked fine, and there was no problem.

3.3.24 SPS Burn for LOI No. 1

BORMAN We performed the LOI number 1 SPS burn with no ullage using Program 40, G&N external DELTA-V. We started the engine on bank A, and after approximately 2 seconds I threw on bank B. When we threw it on there was a noticeable surge, but the engines from then on were extremely smooth. The guidance was smooth and the cut-off was very accurate. I don't have the specific details of the cut-off now, but it required no trimming. There was no oscillation or swaying of the space-craft at the initiation of the burn. It seems that the gimbal angles that were called up from the ground must have been very close to the center of gravity because we had no initial oscillation at all.

3.4 LOI to TEI

3.4.1 Rev Number 1

BORMAN

We have already discussed the service propulsion ECO. The systems verification of burn parameters, in general, were very well worked out and the simulations worked very well. MSFN acquisition with high-gain antenna was never a problem. We used VERB 64, acquired wide beam, and then switched to narrow beam. Comm operation performance during lunar operation was nominal. The ORDEAL was a great help in lunar orbit. I am very glad we had it on board. COAS ground track determination and star tracking in lunar orbit is even easier than it is in earth orbit. The minimum impulse was adequate for the tracking we required. I hope we got some good film of the COAS tracking determination. I picked a landmark with a high spiral on one side. It was very obvious, and we should have some good film on that.

BORMAN General comments on LOI: we should point out that we never even saw the moon until we had completed burning LOI. When we saw it, we were in exactly the right position. I don't know the exact altitude. The onboard computer read 69.5 as I recall, which is very, very close to what was given to us.

One problem - the windows hampered our lunar orbit operations. The hatch window was frosted over completely. The number 1 and number 5 windows were useless for photography, although you could see out of them if the sun wasn't shining on them. We did take pictures of the windows. I hope this will help in solving the problem. The two rendezvous windows were clear throughout the flight and were entirely acceptable for the whole 6 days. The condensation on the hatch window appeared to be on the inside of the outer window, which I am convinced was frost and moisture coming out of the area between the two panes. The coating on the 1 and 5 windows was again a whitish coat, translucent, that was more like a light fogging or moisture than I saw on the Gemini VII windows, which were more amber in color. Due to the fact that we could not use the hatch window for landmark familiarization, Jim Lovell was forced to share the rendezvous window number 1 with me. It made the first rev difficult as far as determining landmarks.

LOVELL Concerning landmark familiarization, I might add that the Lunar Orbiter photographs which we had on board were quite adequate. There was no problem at all in determining objects particularly on the near side of the moon. There are suitable landing sites. They are very easily distinguished. We could pick them up. We could work our way in. The landing site itself was quite visible, and a little bit later on I will talk about the lighting conditions. On the back side of the moon, the Lunar Orbiter photos again were helpful, along with the map which was a composite of the photographs. During the first pass, it was possible to check the craters on the back side, especially those that had some distinctive feature to them. The altitude we were at was lower than what the photographs showed. Consequently we saw what was large craters in the photographs whereas we were actually, almost inside them so that the major features were smaller craters. They were quite familiar and it was possible to chart our position on the back side by referring to onboard Orbiter photographs and maps.

ANDERS Now, begin the discussion of the photography in lunar orbit, starting with Rev number 1. Prior to the LOI burn, the data acquisition camera and the 70mm camera were configured for Rev 1 targets of opportunity. Target 90 was accomplished at the end of the rev, and possibly target 72, though this is not logged on the map. Several other targets, prior to target 90, unlisted on the map, were photographed and can be recovered from the onboard tape recorder. It was most difficult to do pilotage along the track due to the errors in the mapping on the backside. Therefore, the delta time past the prime meridian technique was used and found to be reasonably acceptable in locating targets. In lunar orbit, an attempt was made to use the recommended exposures of the particular photographic task as shown on the side of the photographic map. These f stops were based on a 250th second exposure and were a function of longitude. Some errors were made in using the wrong film or the wrong f stop, but it was found that this technique was generally acceptable and superior and easier than using the spotmeter. Spotmeter readings in lumens were taken at several positions when time permitted and logged on the map at the appropriate longitude.

Rev Number 2

ANDERS

Prior to Rev number 2 on the dark side, the 70mm camera was configured with the high-speed film for possible earthshine targets of opportunity, none of which appeared. Prior to sunrise, the camera was reconfigured according to the flight plan, and preparations were made to pick up more opportunity targets on the south side of the track. Also, the TV camera and equipment was unstowed for the television pass during the latter part of the dayside, Rev 2 pass. The

16mm camera was started at the terminator; 70mm camera was used to photograph targets numbers 10, 12, 14, 16, 19, 21, 20, 23, 26, 28, 31, and 40. Photography was then stopped to prepare for the TV operation. Effort was made to log target number versus camera film frame on the DSE for later correlation. During the reconfiguration of the cameras, it was found that the high-speed film for the night pass had inadvertently been used to photograph some of the initial targets, using the 250mm lens.

Rev Number 3

ANDERS Therefore, an attempt on the next rev was made to rephotograph these targets using the proper film. And targets 10, 14, 16, 19, 21, 23, 26, and 28 were rephotographed using the ASA 6480 film. Also, targets 58 and 63 were acquired, as were 65 and 68. Preparations were made to accomplish the training photography using the f stop schedule determined preflight. This was utilized for both the 16mm camera and the 70mm camera. Tracking was made on the target near the terminator and followed through until past 90-degree pitchdown. Again, the cameras were reconfigured for possible nightside targets of opportunity on earthshine photography, but it became apparent that the spacecraft attitude for the P52, coupled with the poor quality of the windows and spacecraft internal lighting, would preclude satisfactory earthshine photographs until a definite effort was made towards this task. It was therefore decided to suspend reconfiguration of the cameras for the nightside pass until one pass later in the flight where nightside vertical strip photography could be made of Copernicus, and other targets of opportunity could be taken with the spacecraft blacked out. It probably should be mentioned at this time that the conditions of windows number 1 and 5 indicated that poor quality photos would be obtained using these windows for oblique shots. Therefore, an attempt was made to restrict photography to the rendezvous window, but when tempting targets went by, these were photographed, accepting the haze condition on the window. This haze can be described as purplish smears, as if a service station attendant had attempted to clean a windshield using an oily rag. The sun was shining on the window. During the nightside of Rev number 3, cameras were prepared to do vertical strip stereo photography. The f stops, according to those recommended on the maps were to be utilized, and the cameras were started at the terminator spacecraft sunrise plus 6 minutes with the 16mm camera running at 1 frame per second and the 70mm camera running at 1 exposure per 20 seconds, driven by the intervelometer. The intervelometer worked magnificently throughout the flight, was a very useful item, and freed the crew from a very tedious task. Extra photographs were taken on roughly 5-minute basis, but in the confusion, the times were not recorded. It will require working back from a known point, in order to determine positions accurately. It also should be noted that about this time, during Rev 3, I believe, the crew was advised that the voice quality of the DSE was NO-GO, and that only high bit rate voice was intelligible. Because of this, it was determined that all photography would have to speak for itself, in that locations and targets would have to be identified from the picture. There was not enough time to photograph the targets as they became available at a rapid rate and also log in the appropriate information. General comment was that the recommended exposures would be used and that recommended techniques would be employed. I might also note that on Rev number 3 the terminator photography, both the nearside and the farside terminators to the south, were photographed.

Rev Number 4

ANDERS

At the beginning of Rev 4, the farside terminator to the north was photographed, all on the six-exposure series of 10-degree increments towards the horizon. During the vertical strip pass, additional targets of opportunity were taken as were on all previous revolutions. No attempt was made to record position of these targets due to difficulty of pilotage along the track and the lack of time for handwritten recording. It was quite evident as the spacecraft looked into zero phase that there was some obscuration of detail, but this obscuration was not as great as had been anticipated or had been simulated at the Boeing simulation. It was estimated that detail could be seen quite well by the eye within several degrees of zero phase, particularly at low sun angles. Another phenomena noted was that near the subsolar point, it was more difficult to see detail even away from zero phase than it was where shadows were longer towards either terminator. Revs numbers 4, 5, 6, and 7 all involved landmark tracking with spacecraft heads up, slightly pitched up, and operations using the optics. This precluded using the rendezvous windows for photography and put the LMP on the south side of the spacecraft with sun shining on window number 1 in a position for possible targets of opportunity. It was determined that probably this window would be unacceptable for detail resolution photography, and, therefore, the additional target photography was postponed until the convergent stereo revolution photography planned for Rev number 9. 16mm photographs were made on most revolutions of the various sites, but will be commented in more detail by the CMP.

Rev Number 7

ANDERS

At the end of revolution number 7, the CMP was becoming quite fatigued from looking into the optics for so long. The CDR attempted to sleep prior to that without much success; therefore, the commander made the decision to terminate all lunar orbit activities in preparation for rest prior to TEI. It was suggested by the LMP that the 70mm and 16mm cameras be run on automatic at a medium f stop level. This suggestion was accepted and the cameras were set for f/5.6 and the CDR activated the intervelometer and started the 16mm cameras with these settings at the 8th rev sunrise terminator on the far side and ran them to the darkside terminator on the near side with the spacecraft pointed straight down and heads forward. No attempt was made to adjust the f stop, and the spacecraft was essentially quieted down for a rest period. This decision precluded any further darkside or earthshine photography or zodiacal light

Kodachrome photography and the convergent stereo photography. Also, any further target of opportunity activity was precluded including red/blue filter work in lunar orbit. Because of the location of the LMP on the south side of the track, very few, if any, targets of opportunity to the north of the track were photographed creditably except targets number 51, 55, and 57. One point missed: in one of the earlier revs, a few zero phase photographs were taken from a position of about 70 east longitude, taken to the west looking into zero phase in the area of the Sea of Fertility. After the TEI maneuver, the CDR gave the go ahead to unstow the camera equipment, and a concentrated effort was made by the whole crew to expose the remaining film as we departed the moon. Our altitude rate was pretty great at this time; therefore, the number of pictures taken during this period was very great. Unfortunately, the rate was such that some confusion existed, and again, the high-speed film was inadvertantly exposed at the normal ASA black and white settings and some red/blue filter experiments were conducted using color film.

3.4.2 Rev Number 2

BORMAN The GO-NO/GO for LOI 2 was given as advertised, and the LOI 2 burn was a G&N/SPS with no ullage. Again, the system worked perfectly and required a minimum amount of trimming. The burn report was given to the ground, so it's available; we have it in the flight plan also.

ANDERS Concerning the primary evaporator anomaly on Rev 2 after passing the subsolar point: the MCC-H advised us that our radiator outlet temperatures and evaporator outlet temperatures were about equal running about 30 degrees Fahrenheit. I checked the steam pressure then at that time noticed that it had dropped to full-scale low, which indicated that the primary evaporator was not boiling. The back pressure valve was closed manually and water serviced for 2 minutes. After this, the evaporator was put back on into AUTO and the water control put to AUTO. The steam pressure was observed to go up during the water charging process. But once that thing was back in order, the steam pressure again dropped, throwing the temperature down somewhat. The steam pressure did not stabilize and continued a full-scale low indicating another evaporator dryout. The back pressure valve was again closed manually, and since a possible over service and freezing was a possibility, a 1-minute water service was attempted late in the dayside pass with similar results. The back pressure again dropped to zero, and during the nightside pass, the ground advised us to reservice the evaporator again for 2 minutes and let it sit, which we did. It worked fine on the next revolution and subsequent revolutions. We recorded residuals for LOI 1, the burn was minus 1.4 VG_X, zero VG_Y, and 0.2 VG_Z, the DELTA-V_C minus 20.2. The residuals for LOI 2, plus 0.6 VG_X, minus 1.8 VG_Y, minus 0.2 VG_Z, and minus 9.4 for DELTA-V_C. The VERB 82 perigee and apogee determination after LOI 2 gave us a 62-mile apogee and a 60.8-mile perigee. The lunar surface from earthshine was read by about a two-thirds earth. It was very possible to determine lunar features, craters, and terrain in the light available from the earth provided you were dark adapted. However, I would definitely say that the night landing or landing on the moon in an earthshine condition would be unacceptable from a visibility standpoint. One other comment that I had on lunar lighting is: I thought that the shadows were not nearly as black as there appeared to be in the simulations that I've seen on earth, particularly the Boeing simulation. We could even see the features that were on the shadow-side of some rills and rims. So, although it's dark, it's not a complete black and white situation.

LOVELL Again, considering lighting conditions on the lunar surface from the optics point of view, the best control point for optics tracking were the conditions about 30 degrees on the light-side of the terminators. Once you got to the subsolar point as had been explained before the mission, the earth seems to disappear in a haze, and it's harder to see distinct features from small control points on which to track. This proved to be the true case in most of our orbits that the control point 3, for example, was more difficult to track than 1 or 2.

ANDERS Zero phase elimination appeared to be much less a problem than the Boeing simulation would lead one to believe. I think there was some washout at zero phase, but detail was possible within at least plus or minus 5 degrees. I think the eyeball could handle it in even closer than that. And this was particularly observed at the low sun angles for LM landing, so I do not feel that the lighting problem is as great as we had thought it was in the beginning.

BORMAN General Systems Operations in lunar orbit were excellent. I might point out there that we did notice a considerable cycling of the thermal system, but the spacecraft was able to cope with it very well. There was a definite heating and cooling trend during day and night around the lunar surface. As a matter of fact, it was remarkable that the radiators and ECS system could handle the wide range of temperatures.

ANDERS: On every rev the primary evaporator came on the line after passing the subsolar point when the heat lag caught up with the radiators.

3.4.4 Rev Number 4

LOVELL: During Rev no. 4, the prime objectives were to look over the selected landing site and find out whether it was possible to use that particular sun angle minutes of spread for a good landing. In my opinion, sun angles for about 20 degrees down to about 2 degrees are suitable for lunar landings. The terminator is much more abrupt than it is on earth and than I thought it would be on the moon. It seems we have good lighting conditions down to very low sun angles and then suddenly we're cut off completely from light. It appears that the angles of about somewhere between 7 and 4 degrees or 8 and 4 degrees is perhaps the best lighting situation. It's very easy to see objects on the surface; all craters were visible. The rims of craters are still visible due to the light crescent on one side and the darkness on the other side. I could see patterns very nicely. I could not see, in the landing site area, boulders even though I scanned the areas around the rims of craters and down into the floor to see if I could see anything of boulder size. I did look though the sextant in that area, whereby I could see things a lot better than with the scanning telescope. It appears that lighting conditions as far as viewing from the command module were excellent. I suspect that landing with the LM in that particular area presents no problem. Control point landmark sighting is considerably helped by the charts, Orbiter photos, and charts we had onboard. It was always a little bit more difficult, though, to pick up the control points we had been designated before the flight. It's not so much that the particular small craters could not be seen, but the photos which we had were not adequate enough to sufficiently point out the proper small speck of crater which was supposed to be designated as the control point. I therefore picked my own control points, control points which I thought were a lot smaller, more easy to find than what had been given to me, and also control points that could be easily relocated on subsequent revolutions. With these control points, I did the orbit tracking with the Program 22.

BORMAN General landmark observations: I was surprised by the relative ease in distinguishing terminal landmarks. I thought it was a much simpler task than indicated by the maps. Even though I was not trained in this the way that Bill and Jim were, I thought that there would be no problem to pick a landmark that is readily discernible on the lunar surface for use as an IP or any other immediate thing you want for a lunar landing. I'd rather let Bill Anders comment a little bit about general landmark observation.

ANDERS One thing that I noticed concerning pilotage during the initial revs in determining spacecraft position with respect to the map on the back side was that the map made it somewhat difficult with the visibility available out of the spacecraft to pick up craters that were not particularly prominent. Some of the larger ones, the one called America, were so big that we really couldn't distinguish it. And since it didn't really fit right on the place that I thought it was, we missed a lot of the features around it. I think the vertical strip photography, though, will tend to pin this down a lot better for future maps.

3.4.5 Rev Number 5

LOVELL The sextant camera adapter was sufficient. The cord was long enough, and the results of such photography will only be known after the development of the pictures. I might add after I took about two revs of sextant photography, I took off the camera and again put on the sextant. There was no requirement on this flight to track the landmarks by sextant. The scanning telescope only was to be used. However, I felt that the tracking task was so smooth and easy and since the point on the surface could be more easily distinguished by the sextant I tried to track with the sextant. I found out it was a more superior method of tracking than was the scanning telescope. You can see a lot smaller objects with the sextant. You still have the fine control and resolves at medium speed, at lunar orbital speeds, to accurately pinpoint the object you were sighting on through the sextant. I highly recommend that this procedure be investigated in pinpointing the lunar module for sightings on subsequent missions. The only problem I foresee is the initial acquisition of the lunar module in the sextant. One more comment to reiterate what I have said before: the photography and the maps, especially the photography of the landing area landmark which we were to track on, were quite adequate for training prior to the mission and for actual use in the flight. The backside orbital maps were for orbital photography and were not good enough to pinpoint the control place which was designated to me. However, they were good enough to point out big craters and general areas of interest. They are not good enough to look at, to find, small objects like control points designated, but they are good to find the big craters with which to point your path to the back side. I might add that for visual observations the scanning telescope and the sextant was superb, and it was possible to see the terrain features of the moon through these instruments. A few further general comments concerning lunar surface observations as I saw them through the optics and through my window: first of all, there is to my knowledge absolutely no color to the lunar surface. There are various shades of gray; the maria on the lip of the near side are not quite as dark as they appear from the earth. There are a tremendous amount of craters that are not picked up in earth-based or earth orbital-based photography. There are many more new craters to be seen in lunar orbit. The new craters are we think new craters. Their characteristics are a large amount of this fresh white material around the craters with the rims and some of the interior of the crater shelf showing black streaks. There were quite a few of these craters in the area. Most of the area, though, was a rounder appearance, of many, many years of erosion. I did notice, in passing through the control point, near the crater designated America, a sort of larger crater whose rim seems to have collapsed showing jagged areas of what appear to be rock of some sort that were sticking out. And throughout many of the areas I saw what appeared to be terraced craters and rims and hills of material that had slid down through some manner.

BORMAN The craters appeared to me to be almost universally impact craters. There were some that were very, very bright, indicating that they were probably new. The surface, except for the dark maria region, appeared to be homogeneous. I would expect you would find the same surface any place on the moon. In other words, it would appear, at least over the orbit that we traveled, that these surface materials were the same throughout the moon. General qualitative assessment of the lunar surface it appeared like a great glob of ... You could, of course, see that it wasn't. But the appearance, the color, and the structural appearance gave that impression. You could see walls, terracing, evidences of large fragments, everything that we had seen from studying the Orbiter photographs were very clear. And, of course, the terrain evaluation and sighting was much better than studying photographs.

3.4.6 Rev Number 6

BORMAN It is important to note that we were able to track the landmarks without ever pitching the spacecraft. We found that the best attitude for landmark tracking was about 10 degrees pitchup, using the ORDEAL. The man that was operating the telescope had a very good field of view and he was able to track very well. Of course, this is fortuitous from a LM/CSM standpoint because it should be very easy to obtain this tracking attitude and fly to it. The entire lunar orbit tracking operation was accomplished very successfully using minimum impulse.

LOVELL In our discussion of lunar tracking operations with the optics, it was noted that manual optics were used on the control points quite successfully. After we initially got the coordinates of the control point; the auto optics worked perfectly to reposition the scanning telescope reticle to pick up the target as the landing site came around for the second time. Again, the mode was resolve and medium. This appeared to be the best mode for good tracking. We originally started with a pitch-down of 5 degrees which we found is difficult from the navigator's point of view for the fact that he did not see the horizon. The horizon is a good indicator of what's coming up, and the optics angle capability is such that it is perfectly acceptable to have the horizon in the field of view. The only comment I do have about the landmark ground track determination program is that it combines the computer program and optics tracking which is sometimes difficult to do since you're punching the computer at the same time you are trying to track a landmark, and since, there are three different procedures which we had onboard: i.e., manual, landing site, code tracking, auto tracking, and landmark auto tracking. It got to be a little bit difficult there for a while.

3.4.8 Rev Number 8

3.4.9 Rev Number 9

BORMAN The operations to be performed on these revolutions were deleted because of the crew rest considerations, and we took a break here and prepared for TEI.

3.4.10 Rev Number 10

BORMAN A little while after the beginning of Rev 10, the TEI checks were nominal ... throughout the flight. P30 EMS tests and Program 40 all worked nominally. The TEI burn was executed on time, the residuals were minus 0.5 VG_X, plus 0.4 VG_Y, minus zero VG_Z, and the DELTA-V_C meter was minus 26.4. We did use a 15-second jet four ullage on this ullage burn, and the guidance and the engine performance was superb. I don't believe that the spacecraft varied a hundredth of a degree, and the engine was smooth as glass throughout the entire burn. The engine was started on ball valves A, bank A, after 4 seconds ... bank B was switched in, and there was no surge noticeable this time. It was a remarkably smooth engine.

LOVELL TEI presents a particular problem for getting the sextant star check because you are behind the moon for most of the final rev. That stage in the checklist where we came up to a sextant star check, I dialed in the trunnion and shaft in our computer, the optics program spotter, I just sat down with the optics. I could see through the scanning telescope the lunar dark horizon. I could watch the stars come up, and I could then tell exactly when the star, which was Peacock, had come up and then checked it with the sextant. I think that's probably a pretty good procedure.

3.5 TEI to Reentry

3.5.1 SPS Performance

BORMAN

Another comment on TEI, it's extremely doubtful to me that we could successfully monitor a TEI burn by using the lunar horizon. If you had to do a manual TVC I think you would be better off using an alternate ball and flying off the ball. The position of the windows and the horizon view in this spacecraft make it very difficult to monitor out the window and the gimbals and the rates at the same time. The comments on the TEI burn: It certainly is a fine system and a wonderful engine, completely nominal in every respect.

3.5.2 Acquisition of Moon in Window

The acquisition of the moon in the window, as I mentioned before, was exactly as predicted. We then pitched up after TEI and acquired the moon, watched it separate, and took some pictures as per flight plan.

As the activity quieted down, and during the transearth phase of the flight, sequential photos were made of the earth whenever it was observed in the rendezvous window. The PTC attitude during initial phase of the return was such that the earth was seen a considerable number of times and during some of the star horizon navigation sightings; the moon was also seen, and additional red/blue filter and polarizing filter experiments were conducted. Unfortunately, the PTC attitude was changed a day or so prior to entry, and the earth was not seen until after the cameras had been stowed; so additional sequence photography on the 70mm camera could not be conducted. During the return voyage, a series of IVA 16mm reels were exposed at f/2.8 using the 5mm lens, showing the crew during various activity such as lithium hydroxide canister changes, sighting through the telescope, zero g maneuvering in the spacecraft, and other activities. All of the film was exposed, our magazines were exposed or partially exposed except for five reels of 16mm film which had been planned for use during the latter revolutions of lunar orbit for general lunar landscape vista-type photography.

3.5.3 Establishing PTC

BORMAN We then went to the PTC. PTC attitudes as given from MCC were adequate. It's difficult to establish, in my mind, any better way of doing it than just using gimbal angles. It would be impossible to monitor out the window on a star and continue to maintain an initial position with any degree of precision out the window because as you rotate or revolve, first the moon, the sun, and the earth wipe out a considerable portion of the sky. It is true you can see stars out the window in the daytime, but this is only when the window is shielded from the sun, the moon, or the earth, and when you are quite a distance from the earth.

3.5.5 Midcourse Correction Number 5, 6, and 7

At TEI midcourse number 5. It was a 5-foot-per-second burn and the VG_X was plus 0.3. VG_Y was minus 0.1, VG_Z was zero. A good thing to note is that was the only midcourse that was required in the entire transearth portion of flight.

3.5.9 Caution and Warnings During Coast

The only caution and warning lights that we had on the entire flight was the high-gain scan limit, the O_2 high-rate during water dump, and the fuel cell 2 during O_2 purge, and one crew alert light that worked quite well. It indicated to the crew that they had to check their COMM leads. Their COMM leads were checked and one was found to be loose and communications were reestablished.

3.5.11 Pyro Battery Check

Pyro battery check: We did not have the pyro batteries hooked up. We had the circuit breakers pulled on them for the entire flight prior to entry. We had a new system using the pyros in order to prevent inadvertent CM/SM SEP or SM JC problems. That worked out fine. Even though it was a change relatively late in the game, we had no problem in handling this situation.

3.5.12 Final Stowage

Final stowage was accomplished by putting a helmet in the food compartment and two suits under the left and right hand couches with helmets aboard. We put two suits in the hammock and strapped them down. The third suit remained in the LK bag under the center couch. Another anomaly we had on a system that was noted on the way back. We had used the cabin fan once during the translunar portion of the flight in order to warm the cockpit up. On the way back we just turned them on to cool it down prior to reentry. Cabin fan number 2 had a high squeal to it and a bad bearing and number 1, when it revved down, sounded like it had washers or bolts loose in the fan blade. One comment, the cabin fans are extremely noisy. They add little to the circulation in the cabin, and we certainly proved on this flight that they are not needed to keep the spacecraft cool during entry. I know that they should never be used in flight. The final stowage then was accomplished as mentioned. The three temporary stowage bags were quite filled with waste, disposable waste paper, film, and irritates. The entire preparations, final preparations for entry and stowage took approximately 1 hour and were accomplished without any problems.

3.5.13 EMS

EMS DELTA-V counter, when they were place in a DELTA-V position and the switch was turned on automatic, occasionally you would get a jump in DELTA-V indication as high as 29 or 30 feet per second. This problem could be averted by taking a switch .... to the automatic position. The tie for the EMS was exceptional. The self-test on the scroll worked out perfectly. We had one the night before entry and two prior to entry. So we went past the first test prior to entry and it was within the pattern because the Commander forgot to align the scroll for the 10 position, so I ran another test on it and it tracked in beautifully. RSI to GDC alignment worked out fine. It was exactly as the flight plan indicated and exactly as the simulator simulates.

3.5.14 Entry Corridor Check

The entry was accomplished exactly according to the procedures that were written by the procedures boys and they went with a lot of good. It's interesting to note that the horizon was visible. First it was lighted, then it was unlighted, nevertheless, they were able to monitor the horizon in the view of the window.

3.5.17 Maneuver to Entry Attitude

The only control mode required was minimum impulse as far as keeping the horizon in the top portion of the window until we got the error needle zeroed. At that time the dump was given control and performed the entry perfectly. Let me get ahead of myself here. The maneuver to entry attitude was done using a VERB 49 as planned.

3.5.18 CM/SM Separation

CM/SM separation was done in the proper attitude. It was not a great jar, as a matter of fact, the pyros were not as loud on this one as they were on Gemini, in my opinion. We were unable to see any of the service module and were, of course, unable to tell whether the SM JC operated properly.

LOVELL Before we enter any further into the earth's atmosphere, let me fall back and talk about P37 and the return to earth program to get the spacecraft back to a good entry attitude. We ran several P37 program cycles after cis-lunar navigation to compare onboard navigation with what the ground gave us. It appears the more sightings you take, the better off you are in P37. You should take sightings just prior to doing P37, which would then lead into a burn. For example, when we first determined the MCC-6 maneuver for 122 hours, it came up with a change of about 2 feet per second. After taking some more sightings and a lot closer to the proposed planned burn times, it came out to 0.2 foot per second and, consequently, we did not feel on board that it required a burn, neither did the ground, and consequently we didn't. The only big difference we had with P37 with the ground was at 144 hours and 46 minutes when the MCC-7 was proposed and we consistently came up with a DELTA-V_X at plus 2.8 feet per second. It turned out that the ground came up with a considerably smaller value than that and we decided not burn.

3.5.19 GO for Pyro Arming

BORMAN The GO for pyro arming prior to CM/SM SEP and also for the RCS activation was properly given by MSFN, as a matter of fact, it was given at the same time it was requested.

3.5.20 Entry Interface Check

The entry interface check, monitoring the horizon, was beautiful. It came right at the 31.7-degree line as expected.

3.5.21 0.05g EMS & Corridor Check

The 0.05g EMS and corridor check was exactly on time again, just perfect.

3.6 Reentry

3.6.1 Reentry Parameters

BORMAN Our entry, of course, was made entirely at night and I can say that it was very well simulated by our simulator. It was very well simulated by the centrifuge, it was very well simulated by the ME103 simulator at North American. Of course we had practiced this many times. I can also say that it is impossible to monitor your entry attitude out the window.

3.6.2 Ionization

The ionization on these high-speed entries is fantastic. The whole spacecraft was lit up in an eerie irridescent light very similar to what you'd see in a science fiction movie. I remember looking over at Jim and Bill once and they were sheathed in a white glow. It was really fantastic. The lighting was much, much greater than the night entry that we experienced in Gemini.

3.6.3 Attitude Control Modes

The attitude control mode, as I mentioned before, was minimum impulse, so I gave it to the DAP at just about entry interface when the DAP indicated zero attitude errors.

3.6.4 Guidance

The guidance was absolutely beautiful. The EMS scroll worked perfectly. It was the most useful monitoring device of the guidance and it was very well simulated in the CMPS and all the other simulations that we had done.

3.6.5 Visual Sighting and Oscillation

I think it would be impossible to use the horizon for a night entry reference. I also wonder about using it during the day because the ionization on these high-speed entries is tremendous. Guidance, as I said, worked exactly as simulated. When we went through 100 000 feet we started picking up an oscillation, a slight oscillation, but it was damped. The thrusters started firing more frequently to damp out the rates. Also, Bill's method of checking the altimeter by using the steam pressure from 90 000 feet worked out right to the second. The Apex cover jettisoned automatically.

3.6.6 Drogue Chute Deployment

The drogues went automatically. The ride on the drogues was smoother than it was on Gemini but with a noticeable oscillation on the drogues. We could not see the drogues because it was dark.