69-5

[redacted]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 8
TECHNICAL DEBRIEFING

Prepared by:

MISSION OPERATIONS BRANCH
FLIGHT CREW SUPPORT DIVISION

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS
JANUARY 2, 1969

[redacted]

CONTENTS

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BORMAN No vehicle sway was noticed after the swing arm was retracted.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

[redacted]

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

[redacted]

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.

[redacted]

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

[redacted]

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

[redacted]

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 spacecraft 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

[redacted]

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

[redacted]

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

[redacted]

settings and some red/blue filter experiments were conducted using color film.

[redacted]

[redacted]

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

[redacted]

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.

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

[redacted]

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

[redacted]

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.

3.6.7 Main Chute Deployment

The mains went automatically and were backed up by a manual deployment right on the money at about 10 300 feet. The ride on the mains was very smooth and we could not of course, see the mains because of the darkness until we started dumping the fuel. When we dumped the fuel, we got a good chute check, but there was so much fire and brimstone around those risers we were really glad to see the fuel dump stop. However, there is no indication, of course, that anything was hurt by the fuel dump.

3.6.8 Communications

The communications while we were on the chute were excellent. We heard Air Boss 1 while we were still on the chute. We even talked to Houston once while we were on the chute.

3.6.9 ECS

I think it's worthy of note that the ECS performed beautifully. We noted the temperature in the spacecraft never got hot even though we had no real cooldown. And even though we were unsuited the spacecraft temperatures were always cool, even after we were on the water.

4.0 LANDING AND RECOVERY

4.1 Touchdown

BORMAN The one item that we were perhaps not expecting was the impact at touchdown. There was a severe jolt and we got water in through the cabin re-press valves even though they were closed. A good deal of water - 2 to 3 quarts came in the cabin pressure relief valve.

ANDERS One slight anomaly during entry was associated with the cabin fan problem; we elected not to use the cabin fans for the cold soak, and therefore had both primary and secondary loops going through the suit heat exchanger. The primary loop was not of sufficiently high temperature on the radiators to activate the primary boiler, so we did not know whether it would function prior to separation. After separation, the primary boiler dried out as it had once in lunar orbit. It was reserviced in the prescribed manner and worked but when observed again during entry at about 2 g's, it seemed to be dried out again. The LMP tried to reservice it during the g buildup, but was unsuccessful.

In any event, the suit loop was cooled by the

BORMAN secondary loop. The touchdown was much more severe than we expected, and was accompanied by a lot of water coming in the left hand side of the spacecraft. The commander was diverted by the water drenching him on the left side just long enough that he didn't get the chute release off in time to prevent the spacecraft from going to the stable II position.

4.2 Postlanding Checklist

In the stable II position, we immediately started the postlanding bag deployment and we were uprighted in about 4-1/2 minutes.

4.3 Communications

Communications were good, with the helicopters and the Air Boss airplanes, but the swimmer's jack did not work and I don't know if this was a spacecraft problem or the swimmer's equipment problem. The dye marker was actuated so that they should have been able to plug in.

4.5 Battery Power

The power was adequate. Of course we were only in the spacecraft about 45 minutes and we had only one battery on.

4.6 Postlanding ECS System

The postlanding ECS system worked fine. The first time we actuated after uprighting we got a great deal of water in on the CMP's face, but we turned it off and actuated it again. It worked fine, and the little ball valve worked properly from then on out.

4.7 Ventilation

Incidentally, the cooling and ventilation was good and there was no real requirement for those postlanding ducts; we never put them up. Bill Anders makes a point that we did get a few more drops of water later on, but I really don't think you could design a system any better than that. Bill doesn't think you can either - he just wanted to mention it. The checklist was figured in error on hatch pressurization. It said "pressurize the hatch, pull inboard" - we pulled inboard and promptly vented the cylinder. The cylinder was recharged manually and the mistake was not made again.

4.14 Egress

Egress was accomplished nominally. The swimmers were well trained, there was no water introduced to the spacecraft during egress, and the hatch was closed before the helicopter pickup was made. Manual pressurization of the hatch cylinder was about as difficult or slightly more difficult than we had found in spacecraft testing. We suggest that a different kind of a knob or a tool be provided. We used the drive screwdriver but that didn't seem to help much, with wet hands.

BORMAN The LMP and the CMP performed admirably after we were on the water, and the commander was taking a vacation.

ANDERS The CMP struggled with the valve and couldn't handle it and said, "I would be a better man than he was if I got it," and I did.

LOVELL I want North American to check and see whether the second bottle was really pressurized or not. I have a sneaky suspicion it wasn't.

[redacted]

5.0 SYSTEMS OPERATION

5.1 Guidance and Navigation

5.1.1 ISS Modes

LOVELL We had the IMU on for the entire mission, did not turn it off at all. We had it continually running and found no problems in IMU operation. We did at one time inadvertently go to a program which removed the attitude from the system. This was Program 01. This was an inadvertent input into the computer which got the no-attitude light. I'll discuss the recovery from that here in a little bit. Coarse and fine aligning: of course, most of our programs alignments were the option 3 for mostly fine aligning. We did two changes, and both of them proved to be adequate. Coarse align worked fine. The fine aligning program was very accurate. Our gimbal angle errors were small. The frequency of aligning the IMU was sufficient. As a matter of fact, it could have been lengthened somewhat. I think that we rather overdid program alignments, especially in lunar orbit. No comments on IMU temperature control other

[redacted]

than the fact there was a possibility of losing the primary evaporator which, of course, would have affected IMU temperature, but we recovered that sufficiently in lunar orbit.

5.1.2 Optical Subsystems

The scanning telescope light transmittance to my knowledge now appear to be less than desired. There are a lot of factors that affect the amount of stars and star patterns that you can see in the scanning telescope. Primarily, the factor that affects it most is the spacecraft attitude with relationship to the sun and, secondary, is the amount of dark adaptation the eye has prior to looking at the stars. In any case, it was difficult to distinguish other than very prominent constellations of four identifying stars. And, in most cases of the REFSMMAT alignment, the option 3 alignment, we did not readily identify the star that appeared in the sextant, but took it on the face of the computer and waited until we got the angle — star angle difference to determine whether they were the two correct stars or not. Sextant

[redacted]

mechanical drive was very smooth, very little hysterisis and completely adequate for its purpose. Again, that's the scanning telescope mechanical drive. The sextant optics mechanical drive was very much the same, much improved over what we had been accustomed to in the simulator. I noticed that it was very easy to center the star in the center of the reticle in the sextant. I do have one comment on the sextant reticle itself. I think that the lines in the reticle are too short, that longer lines would have made finding the substellar points in the stars a much easier task. On the optical subsystem moding the zero optics mode was adequate. One area that I guess did not fully realize during my training cycle was the real necessity for cycling the zero optics switch, especially when you put optics power back on the line again. Several times after optics power was reinitialized and a P52 alignment to be started the computer would not drive the optics to the star. When this first happened, I was very much concerned because I couldn't identify stars in the scanning telescope, and

[redacted]

I had no star in the sextant in which to mark on. After I recycled the zero optics switch we got proper drive mechanization to the star. This is something that should be brought out for future crews. Manual modes were adequate. I found that for cislunar navigation, the best mode to fly in manual was the resolved and low speed of the mechanical drive. I tried also to use the direct mode of drive in order to find the substellar point by driving the shaft back and forth. This proved to be fairly good with a heavy spacecraft, but in a light spacecraft, motions of the spacecraft made it almost impossible to do this. It wouldn't stay in one spot long enough and I had to go to a resolve mode to make the mark. My comments concerning the CMC are strictly from an operator's point of view. I found no basic faults with the CMC. There is an awful lot of programing and DSKY punching required, and I think that in future development programs and future flight-crew training programs, every effort should be made to streamline the checklist to eliminate as much DSKY work as possible. It is very easy to make mistakes, and several times I punched the wrong button which required quite a bit of backpedaling to reacquire the program again and get back on course. At one time, we lost the IMU attitude because of a wrong DSKY punching. Therefore, in this respect, it is a very complicated system and should be simplified as much as possible. In the course of the flight, we've had several program alarms. Several of them were self-induced by improper procedures. Several of them were expected because of stars or landmarks that were out of the angle of capability of the optics, and we were just waiting for the angle to get lowered so that we could use them. One was rather unexpected and that was program alarm 401. This is a case that prior to midcourse correction 4, the last midcourse prior to LOI burn required changing the REFSMMAT to the LOI 2 REFSMMAT. When we first went through the procedure, instead of getting the nominal coarse alignment no-attitude coarse alignment procedure, we got a program alarm 401 which indicated that by trying to drive to the gimbal angles that were requested by the ground, we'd drive through gimbal lock. Our procedure for workaround on this was to keep rolling the spacecraft until we did not get the alarm indicating the attitudes to be driven so we would miss gimbal lock. This was not done in our training cycle. Our training cycle always, in this particular aspect, had the new alignment in when we got in the simulator. And we missed this particular aspect of going from one REFSMMAT to the next, especially with such a change in the attitudes. And I suggest that in the future that we change the reset points to include major changes in REFSMMATS to get the crew used to seeing the various options that might come up in this particular procedure. We received one computer restart during the mission, which happened almost instantaneously and of course, the computer corrected itself. That happened when entering VERB 34 in a Program 22 display, and I believe it was requesting a marking system which is a no-no and would result in a computer restart. After that we had no more problems with the computer restarts. One controller

[redacted]

which worked out much better than I expected was the minimum impulse controller. I had, at one time, thought seriously about taking the right-hand hand controller down into the lower equipment bay. We had a bracket to use that controller down there for spacecraft attitude control for cislunar and earth or lunar orbiting navigation procedures. The minimum impulse controller proved quite adequate to control the spacecraft. It was a well-designed — the human engineering on that was good, and I see no reason for ever having to bring the spacecraft hand controller down into the lower equipment bay unless you want to use something besides minimum impulse control on the spacecraft. In regards to the minimum impulse controller, there is some training required, since spacecraft motions looking through an axis 60 degrees offset from the X-axis requires some change in thought of how to maneuver the spacecraft. Essentially, for lateral motion, the roll mode was used; pitch was natural and, also, yaw would give you some left lateral motion. Yaw is less effective than roll. In going back

[redacted]

over some systems operations — guidance and navigation discussion, my comment on the manual mode operation for lunar landmark tracking again: it appears that with the orbital altitude of Apollo 8, combined with the speed over the ground says that the best mode of operation for tracking ground landmarks is a combination of resolve and medium speed. This appeared to be very adequate. The drive in the optics was very smooth. It was possible to take either the scanning telescope or the sextant, place the center of the reticle on an object and hold it here. I highly recommend that we investigate the use of the sextant for fine tracking on the lunar surface or of objects on the lunar surface, for instance, the LM, because once the LM is acquired in the sextant, it would be very easy to hold the reticle on the LM itself. It was possible to track within about 8 degrees of trunnion drive without having any abnormal operation in the tracking procedures.

5.1.3 Computer Subsystem

Several comments on procedural data on the computer subsystem: with Program 37 with minus MA, had a procedure that was developed by MIT close to the mission launch time, which proved entirely adequate for high-speed reentries and eliminated the constraint of reentry velocity which prevented us from using the straight P37. P37 modified: it was used several times and agreed closely with ground computations. One comment concerning the computer adapt load: we again found that the combination of 11101 with the lower rates than we have been flying in the simulator, proved to be a very adequate mode to maneuver for cislunar or passive thermal control or particular VERB 49 spacecraft attitude.

5.1.4 G&N Controls and Displays

BORMAN The entry monitoring system worked perfectly. The EMS self-check went fine. The first time we checked it was the night before the entry and then twice the day of entry. The reason we checked it twice was the first time I had neglected to slew the test pattern under the arrow. However, the one item that I would like to mention about the entry monitoring system was that the lighting was very bright and unable to be dimmed in this particular system, and I strongly recommend that we have a reostat so that we can get a controllable light situation in the EMS. The entry monitor system was the most valuable monitor of the automatic guidance, and I thought it was entirely satisfactory for performance. The FDAI's worked nominally throughout the flight. They are very well simulated in the simulator, and there was no problem with the FDAI. The gimbal position and fuel pressure indicator again worked nominally and are well simulated. One thing we did notice was that when the TVC switches were in the OFF position, and the servo power switches are in the OFF position, and if you move the hand controller, you do get a jiggling on the gimbal position indicators. We had been briefed that this would happen, and it did happen. Attitude set control panel rotational hand controllers all operated perfectly throughout the flight, as did the G&C switching and G&N power switch which was never turned off.

5.2 Stabilization and Control System

5.2.1 Control

The SCS control rotation was almost exclusively used in the minimum impulse position. This was the basic control mode for flying the spacecraft, and it worked very well. Prior to separation when we were pitching down for the horizon check was the only time that I used the rate command control mode, and it's exceedingly accurate, very easily handled. You could tell the jets were firing and firing a great deal, and I imagine it would use a lot of fuel. Except for the docking and the rendezvous, the entire mission could be flown in the minimum impulse position. Translations were made without difficulty, and all the translations were made using the G&N control mode, that is, with the exception of the separation. The separation and translations worked fine; in the SCS they were just small magnitude. When you are in the CM mode only, the spacecraft suffers somewhat from the lack of control harmony in that the pitch jets are much more responsive than the roll or yaw jets, however, this was no great problem once you became accustomed to it. We flew the CM again using the minimum impulse mode, and we were able to track the horizon very well. The nominal mode for accomplishing PTC was to fly to a predetermined gimbal angle in pitch and yaw and kill all the rates; establish maximum deadband and maximum rate, pitch, and yaw; minimum impulse in roll; and then start a 1/10-degree-per-second roll rate. This worked fine, and it usually took some time before the initial coupling had caused the gimbals to drift more than 20 degrees from their predetermined values. The hold/rate command worked fine. Channel selection was no problem. Minimum impulse was the primary control mode. SCS was never powered down.

5.2.2 Thrust Vector Control

Thrust vector control: the DELTA-V's control was outstanding for the longer burns; for instance, on the TEI burn which was over 3000 feet per second, the residuals were less than a half a foot per second. We did have one high residual on our first burn. It was a burn of around 20 some odd feet per second, and we had to burn out an additional 4 feet per second in order to trim it out. This was minimum impulse burn with the SPS.

5.2.3 Displays in Loop Control Functions

Displays in loop control functions: nothing of any significance.

5.3 Service Propulsion System

5.3.1 DELTA-V Thrust Switches

The DELTA-V thrust switches worked properly. All of our burns were started on the A-bank, and then with the longer burns the B-bank was brought in 2 to 5 seconds later. This was a perfectly acceptable operational way of doing things and supposedly cuts down the chamber pressure excursions in the engine at start.

5.3.2 Engine Thrust Vector Alignment

ANDERS In discussing the gimbal motor's switches, a note for the simulator people is that the starting current shown in the fuel cells was less obvious than that simulated and the stopping current transient was more obvious.

5.3.8 PUGS

BORMAN Just for information, the PUGS was deactivated (both primary and auxiliary system) for the entire flight. We felt on this particular flight there was no requirement to have the PUGS. It might be a requirement in the situation where you have a critical fuel situation.

5.4 Reaction Control System

5.5 Electrical Power

5.5.1 Fuel Cells

All the items on page 18 of the crew debriefing guide, that's paragraph 5.4 and 5.5, worked as advertised. They are all well simulated in the simulator, and the training that we received there was adequate. Now on the fuel cells: we never had any of the problems that are noted here. On ocassion, during fuel cell 3 purging, we did get a high O_2 indication, but that's the only problem.

ANDERS Fuel cells worked magnificently. The only minor anomaly noted was that each fuel cell was at a slightly different gas consumption rate and current output rate; fuel cell number 1 was slightly lower than 2 which was slightly lower than 3. Purging was accomplished nominally; the kitchen timer was found to be most satisfactory.

5.5.3 Battery Charger

The battery charger worked fine and the batteries were charged prior to SEP. The powerup and powerdown prior to CM/SM SEP worked very fine. The batteries were approximately 27 volts immediately after separation. One slight suggestion is possibly the secondary loop should be left on during the SEP rather than having to power it up and power it down. All other electrical components worked as advertised. I noticed approximately plus or minus 4 volts ac difference in the various inverter phases.

5.5.10 Cryogenic System

ANDERS

Cryo system worked fine. The fans were running on manual and cycled with the pre-lift-off determined schedule. They were cycled prior to long burns and there was no cryo caution warning indications.

5.6 Environmental Control

5.6.2 Water Supply System

ANDERS No anomalies with the water system except that approximately 1 hour prior to CM/SM SEP, the potable water tank quantity began to decrease. Due to the concern for waste water loss during entry, the potable inlet valve was closed to isolate the waste system. The quantity indication continued to decrease and was last remembered at approximately 10 percent. No water was observed in the CM. Some water samples were removed after recovery, but we have not heard what the total quantity in the tank was, so, we can't tell whether it's the indicator or an actual leak. We got 4-1/2 gallons of water in the spacecraft, but most of it was — that was salt water, yes. Chlorine procedure was a pain in the neck and I think a dangerous one in that you might squirt chlorine around. There was some chlorine on our hands. It is unfortunate we have to do this. The injection port adapter seems to be loose in the pipe neck and was tightened once by the LMP. Water removal after chlorine injection worked satisfactorily and the taste of the water was reasonably good, though there was considerable gas in the water. Drinking water supply at the food preparation unit in the water gun worked quite well though, again, there was gas.

LOVELL At one time we did get a little leakage when I put in the buffer ampule, and the smell of chlorine permeated the spacecraft for a short period of time. It wasn't too bad, but it should be eliminated in the future. The drinking water shutoff valve was opened during earth orbital operation and never shutoff.

5.6.3 Water-glycol System

ANDERS The cabin fans were quite noisy during the initial part of the flight and were turned off. The cabin temperature was quite stable. On the translunar phase of the flight, it became rather chilly in the CM, and manual diverting of the mixing valve was attempted with good results. Later on, possibly not connected to this, considerable water was noted on the hatch and on the cold pipes in the oxygen supply and glycol systems. When the cabin fans were turned on, on the transearth phase of the flight, there was a considerable amount of noise in the unit. Both fans were turned off immediately and selected one at a time. Cabin fan number 2 appeared to have a very noisy bearing. It was immediately turned off again and was not used during cold soak. The return temperatures were very comfortable and the cabin was quite dry. ECS radiators performed nominally. We did not use the secondary proportioning system.

5.6.4 Suit Circuit

The suit heat exchanger secondary valve and primary valve worked as advertised. The primary and secondary loop were run through the suit heat exchanger for entry due to problems with the primary evaporator experienced in lunar orbit. Secondary evaporator worked very well; the primary evaporator had a tendency to dry out. Cabin air return valve collected considerable lent and trash; it was cleaned approximately once every 12 hours with a piece of tape. Towards the end of the mission, the cleaning rate was required to increase due to additional food particles in the cabin. LiOH canister removal was satisfactory and no sparks were observed. We feel that our technique of recording LiOH canister usage and stowage worked most satisfactorily, and we recommend this procedure to future crews, in order to keep track of what the PCO_2 level was at the time of canister removal. The used canister was then stowed in the event that the used canister might have to be reselected for use later on in the flight.

5.6.5 Gaging System

The only gaging system anomaly was an apparent failure of the primary radiator outlet temperature indication which pegged full scale high during the flight.

5.6.6 Waste Management System

LOVELL Some comments on the waste management system, first of all, we had no problems with the waste management system: as we know, we went back to a Gemini-type waste management system for the urine collection. It is still a very complicated system, overly complicated for what we have. We found out that by leaving the urine heater on at all times, we did not have a urine hose freezeup or a line freezeup; the system worked perfectly each time we dumped urine and waste water. We dumped both through the normal system. We never had to use the hatch dump system. We did use a system where we purged the lines after dumping the liquid, then we allowed cabin air to flow through the lines for a while to purge any of the moisture in the line and make sure we had a dry system. The procedure for dumping urine would be to urinate into the collection device then put the device on the system, but first of all, venting the waste stowage area and the battery vent, making sure that they were down, and then going to dump. It is a complicated one, and we feel that we should attempt to try to go back to the Myrtle system of direct overboard dump through the waste management system. I feel now that we probably could utilize the system and make it a simpler waste management system.

5.7 Telecommunications

5.7.2 Individual Audio Center Controls

Some comments concerning the audio center controls for the command module pilot on lift-off are warranted here. Essentially we had the problem of not being able to get to the audio center once the center man is strapped in. Consequently, our final technique consisted of being on intercom and press-to-talk during the period when the backup LMP was in the spacecraft, and prior to his egressing, he pushed the intercom system to press-to-talk only. For the CMP the S-band was turned way down. The volume on the S-band was turned way down and the CMP had VHF only with press-to-talk on intercom. This worked quite well for the launch phase and presented no problems.

5.7.4 Operation of S-band High Gain Antenna

ANDERS We recommend the same technique for use in the future. The S-band high gain antenna worked much better than expected.

5.7.5 Antenna Pointing Angles

The manual tracking was very easy and lockon using DSKY suggested pitch and yaw worked quite well. The auto mode performed as expected, but the re-acq mode did not. Re-acq was used on several occasions, and it was found that the antenna would continue to attempt to track the earth even though the one-way lock had been broken and the antenna was up against a mechanical stop. The antenna was allowed to ride against the mechanical stop for one complete revolution of PTC. The antenna on its own followed the earth as best it could through the spacecraft and reacquired back on the other side without ever going to the re-acq positions on the reostats. Tracking and — lockon and narrow beam width on several occasions required assistance by going to medium to get the fine pointing and then back to narrow, but if left there it would eventually home in on the target.

5.7.6 S-band

The television camera functioned properly and all modes in which it was used, with the exception that premission planning had not included the proper filters for either the high-gain or wide angle lenses when viewing out the window. This problem was circumvented in flight by taping filters designed for the Hasselblad onto the lenses of the television. I recommend strongly that future flights be sure that they have either proper filter for the television or some system so that you can insure the proper light levels into the TV.

ANDERS Another problem with the television was that we had either a bugeye or a very high power lens. There was no normal lens that would give you eyeball views of the items that were being televised. We need some sort of a sight on the television camera for better aiming. Also we should work out a system prior to launch with the ground control so that the crew can properly maneuver the camera with respect to the receivers on the ground. We had some difficulty when they said that the image was up to the right - whether to move the camera up to the right or down to the left - and we ought to work this out prior to launch.

5.7.7 Tape Recorder

ANDERS The tape recorder, the DSE was used during the initial lunar orbits as a data recording device in an attempt to record the considerable quantity of photographic and observation data. The ground gave us a NO/GO on the low bit rate voice; therefore, no further attempt was made to record data at low bit rate. The recorder was turned on in low bit rate at LOS to record systems values. It was later found and advised from the ground, on the return leg of the flight, that actually the low bit rate voice during these and other times was of sufficient quality for comprehension, but that the problem was on the ground playback between Madrid and MCC-H. It is strongly urged that some method of determining voice quality, real time for each rev, be worked out for the ground. An effort was made to avoid power amplifier switching in order to preclude failures that have been experienced preflight in this mode. The backup COMM check was conducted on the most powerful power amplifier and the system was left in this configuration. Lift-off was made on the least powerful transponder and switched to the most powerful one in orbit and that configuration was maintained through the flight. The only time the power amplifier was switched was prior to CM/SM SEP where the primary power amplifier was put into low.

LOVELL Concerning the S-band antenna selector switch, my only comment is that I feel that we should give the ground the capability of selecting any one of the four S-band OMNI antennas. This way the ground can maintain continuous communication with the spacecraft without the necessity of the crew having to switch antennas.

ANDERS S-band antenna tuning capability was reasonably easy to accomplish, but for future spacecraft, some effort should be made to make the yaw pointing indicator more meaningful with spacecraft direction.

BORMAN In comparing USB and VHF upvoice quality, the VHF was good and the S-band was good. The VHF faded quite rapidly, but we expected that. The other item that we should mention here on the S-band is the fact that the breaking lock did cause a noise in the headset. This was not particularly objectionable, particularly on the translunar flights, because MCC always gave us a warning when they were going to break lock and switch antennas. Also, it is a very accurate indication that you are locked on. When you hear the noise, you know that you have broken lock, and it gives you a clue to start looking for the reasons. I don't believe that we need to put an S-band squelch on the spacecraft. I don't feel that the tape recorder situation where we are putting voice comments from crew log-type data on the tape recorder and then dumping it is really an acceptable mode. We should have a onboard tape capability that remains with the spacecraft, similar to the one we had in Gemini but with a better tape recorder than we had in Gemini.

5.7.11 Voice Recorder Indicator

There is undue concern and undue comment back and forth about who has the tape recorder and whether it's been rewound and the position of the tape recorder and so on. I firmly recommend that future spacecraft have onboard tape recorders where the crew can record the items that they want to much the same as they would log them in a log.

5.8 Miscellaneous Systems, GFO's and GFE

5.8.1 Cabin Lighting

Minority opinion on the cabin lighting is that during phases of the mission when the spacecraft should be darkened to assist other crewmen in their functions, the LMP or checklist reader needs some kind of a small maplight, possibly one that could plug into the power switch and be fastened to one of the mirror mounts. Also, it's difficult for the LMP to use a checklist that is orientated to elapsed time, since he has no elapse timer that he can see.

5.8.2 Clocks

5.8.3 Event Timers and Controls

The event timers and control worked fine. The accelerometer worked great.

5.8.5 Electrical Cables and Adapters

The umbilical cables are really massive and they tend to horse you around. The Y adapter failed with an open COMM circuitry for the CMP. I realize that there is nothing that we can do about this for the rest of Apollo, but there certainly should be some effort to avoid this type of situation on future spacecraft. That umbilical must be at least a 1/2 inch in diameter. The Y adapter is a grotesque thing that could be used better as a blackjack, it's so heavy.

LOVELL — The line that went down to the Y adapter from the helmet was overly long. It bunched up and just got in the way of everything during movements in the spacecraft.

5.8.6 Crew Compartment Configuration

BORMAN — We thought there was ample storage provisions and that the spacecraft was well suited to the storage required for a lunar mission.

5.8.7 Mirrors

ANDERS The small chute observation mirror on the LMP side of the spacecraft were essentially worthless. Weight there might well be invested in a maplight.

5.8.8 COAS

BORMAN The COAS worked properly. Of course in this flight it had little function other than ground tracking around the moon but it was a very acceptable position. It stowed well at launch. The lamp successfully survived the launch vibration.

5.8.9 Clothing

I believe all of us thought the PGA was acceptable as is for missions involving EVA. I recommend that on missions in which no EVA is planned and the spacecraft has successfully completed an altitude chamber, that PGA's not be worn. One problem that's been a continual one in the constant wear garments is that in measuring them it seems that they never take into account the bulk added by the biomed harness. Consequently, the waist measurements are always small. I noticed this on my flight one even though we had mentioned this to the people when they were measuring us for them.

ANDERS With respect to the biomed harness, the amplifier assembly leads coming out of the bottom of the pack fit right over the crotch area and are most inconvenient when you urinate.

BORMAN The constant wear garment and long underwear fit fine. They were functional except for the fact that the trap door for bowel movements was not large enough. In order to make a large enough area, I had to rip mine considerably in order to get the fecal collection device on. One other item that I noticed was a considerable fraying on my left bootie. The fraying was so bad that I removed both my boots and placed them in the temporary stowage bag to keep frayed material from filling the spacecraft. Lovell's shoulder on his flight coveralls was quite badly frayed. The lightweight headsets were completely unsatisfactory. Due to problems with the new lightweight headsets, we had to fly the older lightweight headsets. They were so unsatisfactory that after one short trial they were never worn during the flight. We wore the Snoopy helmets. A problem with the Snoopy helmet is that the sweat bands on the forehead are sewn so there is a seam on each side of the forehead. It resulted in lacerations and very uncomfortable fitting after 3 or 4 days. This needs to be corrected before the next flight. The lightweight headset did not fit our heads very well. The weight and the stiffness of the Y adapter made it very difficult to keep the lightweight headset on your head.

ANDERS Also, with the weight of the amplifier assemblies on the lightweight headsets, there was sufficient inertia that any reasonably quick head movement would leave the headset in one place and the head in another. The positioning of the ear tube and the mouth piece was more difficult than it ought to have been.

BORMAN The urine collection device worked adequately for this mission and I don't recommend that you change it for operational Apollo flights. It's obvious to me that it's completely unacceptable for long duration flights. The cundrums become extremely messy and dirty and it's difficult to clean them. A terrible odor permiates the entire device, and I certainly recommend that we devise some better method of collecting urine. I was talking there about the urine collection device in the spacecraft rather than the UCD which is worn under this pressure suit. However, with the UCD I had the same problem that was mentioned earlier where on the morning of launch, the cundrum on my UCD was too large, although I was assured that it was the same size I had been wearing. We changed it, and it remained too large, and as a result, I urinated all over my suit. Now another item on the UCD. If you are lucky enough to fill the UCD, and then, in the normal sequence of events you get out of the suit prior to being able to dump the UCD, you have no method on board for dumping it, unless you unstow the suit, plug it back in through the adapter, and the suit leg, and then dump overboard. This is exactly what we had to do. It's recommended that the crews in the future carry a fitting that will connect to the UCD hose and then mate with the overboard dump system of the spacecraft so that the UCD's can be dumped without using the suits. Also, the cundrums on board were old; they stuck together; they were difficult to unpeel; and most of the ones that I looked at were extra large and were not usable.

5.8.10 PGA Donning and Doffing

The PGA's were never donned and doffing was accomplished with no problem. We have already covered the L-shaped bag and it was an effective means for storing the PGA.

5.8.12 Crew Couches

I thought they were very functional. They operated without difficulty. They moved easily in zero g. They were adequate, very good for the G forces, both in launch and entry.

LOVELL — There were cases though of the armalon on the couches beginning to rip after a 7-day flight, and this again is a continuing problem. All three couches had evidence of armalon tearing.

5.8.13 Restraints

The rubber restraints for the heads that were provided worked fine with the exception that the CMP's restraint ripped and had to be taped in place.

BORMAN — Crewman restraining harness worked fine; its rather stiff, but it seemed to work properly without any great difficulty. The hand straps in the spacecraft are fine even though there had been some discussion about deleting them. I recommend that all the straps be left as is in the spacecraft. The heel restraints were very satisfactory, and held the feet in place very well for entry. The booties with the Velcro on the bottom of them for use during the flight were really not a great deal of help. We already mentioned this, one of them frayed, and the Velcro was really not effective in maintaining position.

LOVELL The best method to work with the optics in the LEB is to lower the center couch to a horizontal position, then strap yourself loosely into the seat in a sitting position. Then you can work the entire optics with no problem and also all of the food preparation because you are right next to the water supply system.

5.8.14 Flight Data File

Flight data file for our mission worked well. One of the items that we thought was particularly important for the entry was that each crewmember have an entry checklist; although we had not planned to do this, we did have it and it was very effective in speeding up the entry timeline. Another thing that all crewmembers agree on is that launch through TLI checklist that was flight plan oriented seemed to work quite well and did not require a breaking of the flight plan, but took us all the way through S-IVB evasive maneuver without a problem.

LOVELL My only comments concerning the flight plan is the fact that when we finally got our onboard flight plan together, they were of sufficient size where I thought that we could combine both lunar orbit operations and translunar and transearth into one flight plan. In future work, I think that this will probably become more important. Minority report — some comments about the star charts: I felt that the charts that we had developed the moon and the earth positioning on worked out quite well. I compared them with the flight plan as far as what stars to use for nav sightings. We used Aldrin's chart a little bit, concerning the 90-degree sunline for PTC, but mainly we used it only as a comparison of what the ground gave us for PTC attitudes, but it turned out to coincide with what the ground gave us. I used, basically, for star chart - for lighting down in the LEB, lighting control, the two black star charts, but they are nominal ones, the ones we've had before, but they turned out to be harder to put on the lights than we did in the simulator and, consequently, they ended up floating up in the tunnel most of the time and this particular procedure didn't work out too well. I used, just briefly, the lunar orbit star chart that had been developed with the lunar equator and it, again, was very adequate for the need.

ANDERS The systems book and malfunction book were excellently prepared by many people. Fortunately, we didn't have to use them.

5.8.15 In-Flight Tool Set

BORMAN The inflight tool set functioned properly and seemed adequate for our flight.

5.8.16 Food

The food: I think by and large, although we agree that the food is acceptable for the rest of the operational Apollo flights, we feel that there has to be a definite improvement in the food for the long-duration missions. By and large, the bite size items were not eaten, the rehydratables take too much time to rehydrate, all of them taste the same except for the stronger items like the fish meal. They seemed to all adopt the taste of the wrapping they are in. They were, in my opinion, very unappetitizing. The one item that I thought was particularly good was the turkey that we had on board for Christmas that was evidently an Air Force function - that was chunk turkey chunks that were eaten with a spoon. This was very good; there was no problem as far as rehydrating and it tasted great. It's probably a good idea to include a spare package of fruit juices and drinks. The grape punch was good and some other drinks that are little different so that - the grapefruit drink was good - so that you end up with a more consumable drinks that could be used at any time during the day rather than just at a mealtime. We did that by raiding the extra food we had onboard and taking the drinks out of it.

5.8.17 Personal Hygiene Equipment

The personal hygiene equipment: we already discussed the fact that the urine collection device really is unacceptable for long duration flights, and although it will be, of course, it's operationally feasible for the Apollo flight. The fecal collection system, again, is unacceptable for the long duration flights. I think, probably other than worrying about analyzing the hormones in a 25-hour postflight urine sample, the people involved with the urine ought to be figuring out a better way to get rid of it in flight.

LOVELL One more item on the personal hygiene equipment: the little wipes that we get in the food packages to clean up with has the lousiest odor, and it seems to me that we could put a little pleasant odor in with them to make it more palatable when cleansing ourselves.

ANDERS The valve nomenclature on the UCTA also is rather poor and is sort of a 50-50 operation as to which way the valve ought to be, and at one time the valve was malpositioned and the condrum was sucked in and a slight hole was punched in the side of the condrum with the little pointed head of the yellow valve inside the UCTA and this created some confusion and disconsternation in the cockpit.

BORMAN All in all, the personal hygiene equipment, in my opinion, is substandard and unsatisfactory.

5.8.18 In-Flight Exerciser

LOVELL In general, the inflight exerciser worked as we expected it to. We did feel that the overall length of the lines was long, such that I ended up grasping the cylinder of the device to shorten the distance between the end of my leg and my arms to get better operation of it. Other than that, though, it worked as we expected it to.

5.8.21 Data Collection

BORMAN — The data collection: It would be good to have an onboard tape recorder that was fed with tapes on board and could be used as a log and would be far better. Even if we had to use a separate microphone to transmit into it rather than putting it into the spacecraft system, it would be very useful to have a small tape recorder on board.

ANDERS — The problem with the DSE is that the voice quality is coupled with the telemetry bit rate required. An individual tape recorder without this coupling would be much easier to use by the crew. There is not really any great requirement for real-time read-out of recorded data, and I think it's felt by all hands that recorded data is important, and it was a real pain in the neck to try to cycle in with telemetry requirements.

5.8.22 Thermal Control of Spacecraft

BORMAN

Thermal control of the spacecraft has already been discussed. I guess we should mention again that the spacecraft remained cool and comfortable during entry even though the cabin fans were not on and there was no extended heat cold soak provided.

5.8.23 Medical Kit

The medical kit seemed to be adequate for this mission. I want to talk about the Seconal. I'm convinced that, even though I tried it out on the ground and I got a not too unacceptable reaction from the Seconal, I'm convinced that this is what made me nauseous earlier in the flight. I tried it again later with a half a dose and got nauseous again. Now, Bill Anders used the Seconal quite effectively for inducing sleep, and it may be that we will want to carry some of this in the future, but it seems to me that we ought to make sure, perhaps with a more extensive evaluation of the pills, before committing the crew to use them.

ANDERS The 100-milligram Seconal was the one that caused the problems.

5.8.24 Camera Equipment

BORMAN Our camera equipment: we will let Bill Anders comment mostly on the camera equipment. I would like to say one thing. The film magazines required some manual manipulation before we could get the cameras to initiate each time we brought them out. Now I've discussed this with the camera people, and they feel that it is a vibration during launch that causes the magazines to back off. I do think that we would be better off exposing one or two shots on the ground prior to loading the thing, so when you grab a camera in the air, you don't have to fool around and manually manipulate the magazine in order to get it to start.

ANDERS I've already commented on the marking of film magazines, but one general comment I think for possible future flights is that the Hasselblad cameras and the data acquisition cameras seem to be most adequate for what we are using them for now. I think that they are too noisy and some work should be done either to make them quieter or to look at a new camera, because there is some inhibiting of photographs during crew rest periods in order to avoid awakening other crewmen.

BORMAN Another item along the camera: in reality, it's almost ridiculous - ludricrous that we're using a camera without a light compensation on it. The fact that we have to use a spotmeter to determine a light setting, and then go to a camera - you have missed the photograph most of the time. It seems to me that with all the other things that we can develop, such as a communications system that operated a lunar distances and a TV that can transmit from there, we ought to have a hand-held camera that doesn't require manual manipulation of the light settings. I think that it is absolutely ridiculous that we are stuck with this type of situation, and I strongly urge that NASA go out on a contract or something and get it out of the personal knowledge business. Everybody that has ever taken a picture seems to be a camera expert, and I think we ought go out with some knowledgeable people and develop a camera that all you have to do is point and click.

ANDERS Also, with reference to filters for the camera, the polarizing filter, if it's going to be used again, it ought to have detents and much better marking in order to be able to tell exactly what position it's in. Also, the red and blue filters tended to fall off the camera at regular intervals. The following will be some general comments on photography from the photo log. I feel very strongly that the film magazines should have super obvious coating to preclude even the slightest possibility of becoming confused as to which magazine is on and which f stop to use. I suggest something like having all color film magazines of some particular ASA, all one color on the outside and black and white, possibly black and white striped, something even more obvious than the tags presently on the magazines. Mistakes were made at least two or three times on this flight at the expense of a good number of nice targets, and probably the same mistake will be made again, so it might be worth the trouble. Also, the film codes on the magazines were not completely standardized with the data carried in the LMP log. Inventory coding, et cetera, was slightly different, and it's suggested that a simplified code be established for all films and used throughout the flight for onboard data and magazine marking. Another area of concern is the use of calibration strips at the end of the available film in a magazine. The magazines without the cal strips have an automatic stop feature that will alert the crew that the magazine is empty or depleted. With the cal strip on, there were some 30 exposures at the end of two magazines which had the net effect of (1) decreasing number of exposures available and (2) ruining the cal strips when the intervelometer actuated the camera right over the top of them. I think that a much better method could be thought of in this area. Also, the Velcro available at the LMP's side of the spacecraft is inadequate to adequately handle the photographic tasks of this nature. More Velcro should be added in the area where the gas analyzer used to be located, and the camera should be inspected to see if the Velcro patches that are in existence now are actually usable. For instance, camera number 1 has Velcro near the automatic actuation plug which makes the Velcro patch unusable since the plug will not allow the camera to be put flush on any mating Velcro surface. I would also like to reiterate that, in my opinion, it is impossible to make handwritten logs of targets taken at the rate which they become available on the moon. Therefore, a great effort should be made to insure that the ground can play back and evaluate the onboard recorded data as soon as possible in order to advise the crew if the quality is satisfactory for data recording. It is my understanding on this flight that the data actually was available but a NO-GO was given on the DSE due to some ground confusion, and therefore, some amount of photographic data and possible geologic commentary was not attempted. With respect to other targets suggested in the photo plan, no dim light phenomena was observed or photographed, except a possible cloud noted during

Rev 10 just prior to TLI. A star map was made from memory and this cloud noted for possible correlation. Cameras were stowed; therefore, photography was not possible. Aurora: earth was studied through the binoculars at various ranges in an attempt to see if any aurora was visible. The brightness of the spacecraft atmosphere, coupled with the earth's brightness, made this phenomena virtually, in my opinion, impossible to see. Camera calibration: due to the use of all the high-speed film in lunar orbit, there was no film for the camera calibration. It could be said that there were considerable ice particles breaking off the vent lines continuously from the spacecraft, in that during water and urine water dumps the stars are obscured by the reflected light from the frozen fluid. I would like to state that the photo targets indicated on the map were ambitious, but I don't think necessary overly so, had the crew been sufficiently rested prior to lunar orbit insertion. The map information was well done, and I would like to congratulate those people who prepared the data and codified it and the way that they did. As a matter of fact, the targets were actually accomplished in about half the time that was originally anticipated south of the track and unfortunately the opportunity north of the track did not exist due to crew rest considerations. The method of using the prime meridian, so-called, plus delta time from that meridian to determine positions wasn't quite satisfactory for the photographic task and made piloting much easier than it might have been from landmark recognition.

6.0 VISUAL SIGHTINGS

6.3 Earth Orbit

BORMAN In earth orbit, the only manmade objects that we saw were the S-IVB and the panels. The panels were jettisoned off the S-IVB and as we mentioned earlier, they went in a retrograde motion. The only time we saw the S-IVB was after TLI. We were able to see it for some time after it had completed its slingshot maneuver. The geographical landmarks, cloud covering, and horizons were no different on the earth orbit of this flight than on any other of the earth orbital missions. One thing I think is very important as far as land marks go is that is probably unrealistic to expect any particular success with star landmark sightings in earth orbit.

LOVELL We did an IMU realinement in earth orbit during local horizontal mode of the S-IVB, and this presented no problems. It was there, though, that we jettisoned the covers for the optics and got quite a bit of debris that floated around and obsured some of the scanning telescope view.

6.4 Translunar Flight

To repeat some comments that were for translunar flight in the navigation phase, the greatest problem we had was the immediate navigation sightings. This was affected by several things: (1) Close aboard the earth, the horizon is indistinct. It requires more observation to get a good definition of where to put the star. (2) We were still in the vicinity of the venting S-IVB, and it puts out a tremendous amount of particles which are all illuminated by the sun and prevent recognizing the stars or the constellations to identify stars. As you get farther on out between earth and moon, the stars become more visible, depending on the attitude of the spacecraft, and the earth becomes more like a moon as far as preventing sightings of stars.

ANDERS The only manmade objects observed translunar and lunar orbit and transearth were the urine dump ice particles.

6.5 Lunar Orbit

LOVELL One comment on using the lunar horizon for cislunar: shortly after departure, the horizon is quite irregular due to the crators and the crests that are on the horizon, and it presents a little problem of exactly where to put the star. In observing landmarks from the lunar surface in lunar orbit, we found no difficulty in the area of the landing site. The onboard charts, maps, and photographs presented clearly the initial points that we were to see; they were very distinct and easy to recognize. The speed across the terrain was such that we could track very easily, and our landing site area that has been designated was easy to spot; that was B1. On the back side of the moon, our charts and our photographs were less accurate mainly because of the height of Lunar Orbiter in getting the photographs. It was a case of having to try to match the photographs with what we were seeing out the window. Also, spacecraft attitude had some affect of which way the terrain was passing below us, and we had a more difficult time determining our actual position. The terminator did help. It is more difficult to spot things on the back side because of the sameness of the back side as compared to the front side. We don't have any very prominent features on the back side that allows us easier tracking.

7.0 PREMISSION PLANNING

7.1 Mission Plan

ANDERS

Premisssion planning the mission plan: one of the beauties of this mission was the fact that most of the mission plan was decided on August 19 in about 3 hours, and it didn't vary greatly from that time. When you plan and fly a mission in 4 months, you don't run across the optimization changes that are inherent in most long drawn-out mission plans.

BORMAN

I thought that the mission plan was a good one and it was not changed. We had a series of meetings, the data priority meetings, and procedures board meetings, which lead to developing the means for flying the mission, and by and large, I thought they were all very successful and, certainly, the mission plan was an entirely feasible and an operational one.

7.2 Flight Plan

The flight plan was again developed, of course, with the normal changes that come in any flight plan; however, basically, the tenets of the flight plan did not vary. However, I would like to point out that in one area I think we were too ambitious, and this was the flight plan involving operations in lunar orbit. We really did not allow enough time for rest; there were too many detailed photo objectives put in requiring too many changes of film, too much recording. By and large, I think that this phase of the flight plan was too ambitious.

LOVELL I think one of the areas in the flight plan that can be utilized for future planning is to reevaluate our work/rest cycles, especially translunar, in regards to the heavy workload that is going to face the crew in lunar orbit to accomplish the nominal Apollo LM landing-type of a flight plan. We ought to look at minimizing workloads, too, to keep up the sleep of the crews, and to make this possible in lunar orbit.

ANDERS One of the difficulties with the plan around the earth, was the complicated and in my opinion, unworkable photo plan we had — I mean, pardon me, around the moon. We got up there and actually, at some times, avoided or did not neglect, but did not take photographs of interesting objects because they were not included in the photo plan. In all reality, when you are exploring or looking at a new area, it seems to me that we should have just taken as many pictures as possible and then brought them back for people to evaluate rather than go after specific items and hence overlook or neglect to take pictures of items that were interesting in real time. The photo plan was complicated; the changes of films required in just taking one picture from the next, the magazine changes, and so on, and then trying to log it with a manual procedure rather than having a good onboard tape setup, in my opinion, were overly ambitious and although there was an awful lot of work done on it, I think that we probably would have been better off just to go up and take as many pictures as possible. In the funnel, another item that bothered us, of course, in conducting the photography around the moon was the frosting on three of the windows. This has already been noted and this hindered greatly, and I'm sure it will degrade from the photos that were taken through those windows.

Bill Anders has already mentioned that he filed a minority report on the photo plan and, certainly, there was a lot of premission planning that went into that and a lot of hard work. I'm sure that the photos we got will be worthwhile.

7.3 Spacecraft Changes

BORMAN The spacecraft changes, again, were a result of flying a mission in relatively short time; I really liked the way this operated. We had about two or three meetings where we decided what we needed to change on the spacecraft. The decisions were made and kept, things like we put a new SPS engine in, we made some changes to provide an alternate means for dumping waste water that we did not need to use; but all the basic decisions to prepare 103 for a lunar mission were made in about three meetings with Mr. Low and Mr. Slayton and then down at the Cape with Mr. Petrone. So, I must say that the management system operated very effectively along those lines. Every significant change that was required for the lunar mission was made, and it was done swiftly. In other words, the normal procedures for soliciting changes were bypassed in this case.

7.4 Mission Rules

Mission rules: I thought that they were evolved very well; we had no haggling nor formal ~~bitches~~ about the mission or complaints about the mission rules, and we didn't even have any heated emotional discussions. The FOD was very easy to work with, and I ended up being completely satisfied with the mission rules. Bill Anders did most of the work as far as the systems GO/NO-GO decisions and, of course, since we didn't have to evoke any of the mission rules, we don't really know whether they are good ones or bad ones, but certainly they did not require a lot of time. I think they were all coordinated and agreed on in 2 daylong sessions. Bill points out they were agreed to in 2 daylong sessions, but they were evolved over a period of 2 months.

~~CONFIDENTIAL~~

8.0 MISSION CONTROL

8.1 GO/NO-GO's

Mission Control, GO/NO-GO's: Everything down there was nominal and just the way we'd planned.

8.3 Consumables

Oxygen, electrical power, RCS fuel and SPS fuel, of course, were no concern in this flight. They plotted out very well. We deviated from the flight plan mainly for crew rest provisions. It was obvious the last three revs in lunar orbit that we were getting behind the power cycle, and so we completely eliminated the activities planned for the last three revs. The real-time scheduling, again, involved mostly the crew rest/work cycle; the burden of keeping one man awake at all times to monitor the PTC mode made us aware of the fact that it's probably better to use shorter sleep cycles than we had evolved and, consequently, what it really amounted to in the real time was that any time a person wasn't needed to perform a duty, he was asleep, and this was the way it worked out, particularly on the transearth portion.

9.0 TRAINING

9.1 CMS

BORMAN The CMS was our primary training device. It was used extensively in this mission, particularly with large doses of it in the last 2 months. We had some departure from normal procedure in that we spent much less time with the spacecraft. We didn't even see the spacecraft in the factory, and the only things that we did at the Cape that interfaced with the spacecraft were the mandatory checks. So our primary training device was the CMS. In general, the CMS worked well, considering the time that they had to get it ready for the flight and the change in the flight. The visual was a problem throughout most of our training cycle but, nevertheless, the CMS was adequate for providing the proper training. The instructors here in Houston and at the Cape were good. I thought that the CMS was the primary training device we had.

ANDERS We should point out that when the visual was working, it was very accurate. Now we were concerned one time in the CMS when, during entry, we saw a moon come through the window, and we didn't understand how that could be. But, lo and behold, further studies showed they were right, and it was confirmed on actual reentry because there came the moon.

LOVELL As was expected, CMS training with regards to cislunar navigation was fair. When the sextant optics were working, we were able to develop techniques that were required in flight. The CMS training for landmark tracking was essentially nonexistent, and we do not have in existence any simulator that will give us adequate landmark tracking at present.

BORMAN Now the launch simulations: the entry simulations and network simulation were all conducted during the last 3 weeks of the training cycle, and they went fairly well. In looking back now with a more unprejudiced eye, I think that the simulations worked very well, and they proved themselves out in the flight. The flight went just the way the simulations went. Now, one of the problems that we did have were some comm

CMS, between CMS and MCC-H. We also had some timing problems with the CMS and MCC-H, but these were, I think, the type of problems you would expect in any operation. Although all they resulted in was loss of training in some instances, the overall effect of the simulations was very beneficial.

9.2 DCPS

The DCPS was particularly effective for launch and abort trainings, and I think it represents an accurate simulation of the Saturn I-C or the Saturn V launch with the exception that the noise level in the first 20 seconds of the flight is not loud enough. Also, there were some more chances - perhaps more transverse oscillations noticed in flight than are apparently scheduled in the DCPS. Going back to integrated SIMS, I thought that the number of SIMS was just about adequate for this mission. Now it is obvious that when we have a rendezvous mission you are going to require more, but for this mission, I thought we had done about right.

9.3 CMPS

The CMPS was very valuable in the entry training. I thought the best part of the entry training came on the CMPS, not only because of the experience, but in talking with the people like Will Hinton who had helped develop the entry procedures. Now, one of the problems with entry training on the EMS: the cathode ray tube is a kind of a marginal display and we had a lot of difficulty in the initial stages of getting the EMS up to snuff. However, in the last 2 weeks of training, the EMS and the CMS worked well with the handicaps that I have already mentioned, of having to use the cathode ray tube. The best actual training with an EMS was in the centrifuge where we had a regular prototype unit and we were able to train with a regular scroll.

9.4 NR Evaluator

The North American evaluator was only used for this mission for entry simulations and, by and large, from a training standpoint, it was probably not worth the time going out there to use it.

9.5 Egress Training

The egress training went well — the Gulf exercises one on time mockup egress. One comment on the egress training at the Cape: it occurs early in the time we got to the Cape and, actually, by the time we launched, the training that we had had during the initial phase was almost outdated. I think that perhaps on future flights the egress training should be included closer to the actual launch date. There is really no need for the egress training unless you are going to enter the spacecraft in a suit. Part of the reason they had for having us do this training so early - on our time at the Cape - is that we would be in the spacecraft, and we needed to know how to get out of it. But I really think that we were a little bit too early on that. On this egress training, I wasn't talking about the mockup exercise; I was talking about the emergency egress test that was run out at the launch umbilical tower.

9.6 Centrifuge

The centrifuge was used in this flight for entry simulations. I thought it was a worthwhile training device. As I mentioned, it had a prototype EMS on it, and it was the best time we had to use the scroll. I recommend that anybody who is going to be involved with supercircular entries run some profiles on the centrifuge. Now this doesn't mean you have go over and run 50 12g profiles, but you ought to look at both ends of the corridor, and since it is a closed loop simulation, you can manually control-fly the EMS to the splashdown point.

9.7 Planetarium

We did not use the planetarium for this particular flight and, provided the crews have an adequate background of knowledge in the stars, I don't think that you need to use it. However, in my opinion, the single best return per hour invested is in a planetarium if you don't have a basic knowledge of where the stars are. However, we have been studying them for several years now, and the star simulations in the CMS were adequate.

9.8 MIT

MIT was very cooperative and very effective in providing training and sending people down to help us in systems training at the last. Now there is some question about whether the LMP in this case needed to participate in the training, since he didn't have a G&N system to work with. However, when we went to MIT the first time, we still had an LM, Bill, and then you would have needed to participate in the G&N training. But for the one-vehicle-type operation, we did specialize considerably and it probably would have been better if we didn't even bother taking the LMP to MIT. What I meant to say is we probably should not have required the LMP to sit in on G&N briefings that were conducted here.

LOVELL Brief comment concerning the two MIT trainers which were utilized for this flight: the roof trainer for tracking was okay for some basic look-see's at stars, but the area being problems with Boston - the center of Boston - made sight observations, at best, haphazard. I think that we can simulate the same thing back here in Texas. As a matter of fact, I suggest strongly that we get an optics system in some clear area where we can train people to actually view the stars through the optics as they will see it in the spacecraft. This is one area that has been sort of lacking in overall training. The hybrid trainer up there was utilized to do the last particle of manual maneuvering for system navigation, and it appeared and turned out to be adequate to give the navigator some idea of spacecraft motions, spacecraft-to-control and star motion for determining the substellar points for navigation.

9.9 Systems Briefings

BORMAN Systems briefing were conducted adequately on both launch vehicles, the S-IVB, and the spacecraft. We found that the system utilized to set up these briefings was adequate and prompt. The people were competent and were willing to travel and do it at the spacecraft crew's convenience. Nothing but praise for the way all these briefings were conducted.

ANDERS As far as the LMP in this flight was concerned, the North American briefings were good but a little too black-box oriented, and the FOD briefings and study sessions were very superior. I would urge all further crews to participate as much as they could with the FOD Systems' people in their briefings and also to try to bring these people in, if they have time, into CMS systems training prior to simulations.

BORMAN The final systems briefing conducted with personnel from the Cape was very good. We pointed out the little anomalies and characteristics in the simulator or actual spacecraft. One of the ones I wasn't aware of which showed up which we were worrying about ahead of time was the motion of the GPI when the hand controller was actuated with the TVC servo power switches off. Just little items and characteristics of individual systems that we had talked about, such as which transponder was the most powerful and little items like that, were very, very valuable.

9.13 Spacecraft Systems Tests

Now manned spacecraft systems test: as I pointed out before, we probably spent less time in this spacecraft prior to launch than any other crew in the space program. I see nothing wrong with continuing this type of approach in the future. The support crew did yeoman work and covered most of the tasks; the prime crew participated only in those tests considered mandatory such as CDDT, FRT, and then, of course, the launch and the altitude chamber. The backup crew, of course, participated in the same series of tests.

9.14 Mockups and Stowage Training Equipment

The mockup and stowage training equipment were adequate. They were provided when we wanted them. By and large, the training equipment, although it was crude at times, sufficed, and the mockup back here in Houston was well up to date for our purposes. The people that helped us did an excellent job. Now we did not miss not having a mockup at the Cape. As a matter of fact, with the DCPS being back here in Houston and the requirements to come back periodically for data priority meetings, the mockup here worked in very well.

9.15 Photo Training

ANDERS — Photography and camera training was adequate. Personnel involved were most helpful, although the one thing I noted was that the photo ops plan seemed to be generally outdated with the whatever plan was currently in vogue for photography.

9.16 Sextant Training Equipment

BORMAN — Okay. Sextant training equipment:

LOVELL — Well, I think sextant training equipment has already been discussed as equipment that we had set up at MIT, and their space navigator and the equipment in the CMS, and at the state of the art we have in the CMS right now; it was adequate. There are improvements that could be made.

9.17 General Support

BORMAN One thing on the general support procedure, data priority meetings, and so on: I think that the data priority meetings, the procedure board meetings, were very important. They helped formulate the procedures to fly this flight and hopefully to fly the rest of the lunar flights. I do think it is important, though, not to drag the whole six people on both crews into these meetings. It seems to be accomplished with representation of one person or one person from each crew. We did this generally, and I think it worked out very well. If you try to bring six people into these formative meetings, you just waste an awful lot of time. It's far better to send one representative in and then distribute the procedures and have the whole crew study the procedures that they have evolved. Now, the publications that come out of data priority meetings, I thought, were very helpful and formed the background for flying the flight.

9.18 Planning of Training and Training Program

The planning of the training and the training program, I felt, went real well. We used John Van Bockley extensively on that, and he did an excellent job. And as a matter of fact, from the CDR stantpoint, I didn't even get involved in most of the planning. We discussed with him when and what we wanted, and he set it up and then carried it through and did a fine job of planning and coordinating the training program. This again is something that future crews are going to have to get used to, that they don't do all the business themselves, but use the help that is available.

10.0 CONCLUDING COMMENTS

BORMAN I believe we met all the mission objectives. The crew did no negotiating on the medical requirements. We just accepted the medical requirements from the protocol listed and signed off by the directorate, and I believe that it is acceptable for the future flights. Certainly, we would like to see any of the medical requirements that don't stand up be eliminated, but in the real world, I have some doubt about whether this will ever happen. I hope that as the flights progress the medical requirements will be eliminated. Okay. The PAO requirements, again, were only met through the ones that determined by the directorate, and I thought, by and large, they were acceptable. I didn't feel they detracted from the crew training at all. The participation by John Stonesifer and Ben James aboard the carrier was excellent. They were there; they obviously had a good rapport with the crew of the ship, and we were not subjected to any sort of undue demands. Most of the time was our own to sleep or do what we wanted to do. As far as the participation with the crew, I thought it was done real well. Okay. Just picking up odds and ends here, during the initial part of the flight, the CMP was maneuvering underneath the seats with his suit on and inadvertently snagged a lifevest inflation device and one side of the lifevest inflated. We didn't do anything about it at the time, but later on in the flight, we bled the CO_2 out through the urine dump system.

LOVELL One change in the checklist in that portion of the flight: the first thing the CMP should do, since he is the first one out and has to move around, is to take off those lifevests which we forgot voluntarily. It wasn't until the CMP popped his lifevest that it dawned on him that that was the first thing he should have done.