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Date 11/15/71 — 2/9/78 - Sally Lee

APOLLO 13 TECHNICAL CREW DEBRIEFING

(U)

APRIL 24, 1970

PREPARED BY:

MISSION OPERATIONS BRANCH
FLIGHT CREW SUPPORT DIVISION

GROUP 4
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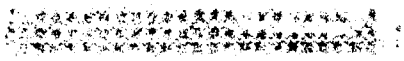
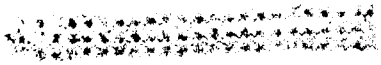
1.0 SUITING AND INGRESS

LOVELL I thought the time was adequate. I had no particular problems with the suiting or the ingress procedures. The only thing I did notice was that we had our protective visors on a lot longer than I expected.

SWIGERT We did not get the protective visors off until after we had ingressed and were all strapped down. The fact that we were strapped down made removing the visors difficult. Everything after that went according to the checklist, and we had adequate time.





2.0 STATUS CHECKS AND COUNTDOWN

LOVELL Ground communications were very good, and the countdown proceeded smoothly. The controls and displays were as shown to us and as we had experienced in the countdown demonstration. I experienced no particular unusual sounds in the launch vehicle sequence before the nominal engine ignition.

2.5 LAUNCH VEHICLE SEQUENCE

SWIGERT The only thing that both Fred and I noticed was a fluctuation in fuel cell flows. When I switched fuel cells, the flows would be stable for 2 or 3 seconds and then would begin fluctuating. This occurred in all three fuel cells; because it occurred in all three, we attributed it to some sort of signal-conditioning problem. The fluctuations were 1 cycle/sec, wouldn't you say, Fred?

HAISE I'm not sure they were even that regular. When you switched from one to the other, the reading would first be very stable; then, after a few seconds it would start drifting up a couple of Machs on the scale above, and then drift back down to the normal reading. Every now and then, it would repeat this sort of cycle. I'm not sure it had an exact frequency tied to it. As Jack said, it was the same in all three, so we actually

HAISE (CONT'D) assumed that it was in the signal conditioning. I had one other thing to add on the launch vehicle. It's very subtle, but I thought when they said they'd put the hydraulics to the S-IVB, I could feel a little tremble below us at that time; but, other than that, there were no booster actions that I could ever detect.

LOVELL In comparing this part of the flight preparation with Apollo 8, I can say that it was a lot more comfortable on Apollo 13. On Apollo 8, I was very cold during this period, and I suspect they've changed the environmental control system. It was very comfortable this time.

HAISE I have one other thing to add on the crew station controls. We spend so much time in the simulators that we forget the contrast between the simulator hardware and the real hardware, which isn't used to any degree. It was very apparent that all the switches move very hard in the spacecraft compared to the simulator. In fact, the three position switches went to the intermediate position and then I actually had to force them down into position. The same was true for the rotary knob.

3.0 POWERED FLIGHT

SWIGERT I have just one comment. I think all of us felt the PU shifts.

LOVELL I want to emphasize that communications were a lot better than I expected. They were a lot better than they were on Apollo 8. The simulation of the powered flight matched very closely to the actual case. I was much more aware of what was going on on Apollo 13 than I was on Apollo 8, but maybe it was the different seat. The PU shift, as Jack mentioned, was quite evident; certainly the change in acceleration was apparent.

SWIGERT All of us immediately looked over at the engine light. It was quite apparent.

LOVELL I think we discussed the early engine out on the second stage during the inflight debriefing quite adequately.

HAISE On the first-stage separation, I saw a flash out to my left. It didn't appear to extend ahead of us. After the second-stage staging, there was a lot of debris that went out in front of us that we subsequently flew right on through. It looked like frozen particles or something in that state, but I didn't notice any of this attaching itself to the windows.

SWIGERT Our windows came through in good order. I was expecting frozen particles from the water under the BPC, but we didn't have any of that.

4.0 EARTH ORBIT AND SYSTEMS CHECKOUT

4.1 EVALUATION OF INSERTION PARAMETERS

SWIGERT I hit a VERB on ECO and copied down the parameters, which were nominal. We were right on the trajectory until we lost the center engine. We regained most of the velocity, but our time was longer.

LOVELL Our insertion time was about 1 minute longer at that point than nominal.

4.3 ORDEAL

LOVELL I had no problems with the ORDEAL. I was able to unstow that by myself. This is something you can't do in a simulator. I actually improved our insertion schedule.

SWIGERT When I got out of the couch, Jim told me to move slowly and take it easy. I had no problems at any time. I adapted myself and proceeded just as we had done in the simulator, at full speed through the thing and never had any problems — no dizziness, no uneasy feelings at all.

4.4 OPTICS COVER JETTISON (DEBRIS)

LOVELL Jack, how about this optics coverage?

SWIGERT We had a problem with that. I read off the procedure and then did it. I told you I wasn't seeing stars; so, I entered P52 and didn't feel the optics cover jettison until the optics drove in P52 to the first star. Well, I did the optics-jettison procedure twice, reading down the checklist item by item, and I didn't feel they jettisoned either time until I entered P52. I felt they jettisoned all at once in the P52.

LOVELL Were you looking through the telescope at the time? You can usually see debris go off in that thing.

SWIGERT You know, it's just completely black and then all of a sudden there are beautiful stars. And it's just like night and day.

LOVELL It might have been a hangup of some sort.

4.5 COAS AND HORIZON CHECK

LOVELL I have no comments there. The check was nominal. The S-IVB held the local horizontal.

SWIGERT I think that the checklist was adequate. We had adequate time to do everything. I think we were well ahead of the time line.

HAISE Yes. We were sitting around waiting there for one period for approximately 30 minutes for the next event to take place.

4.7 COMMUNICATIONS

LOVELL I noticed no communications problems. Did you?

SWIGERT None.

HAISE Under that heading, I guess, our proposed TV show was a complete bust. The whole Gulf Coast was cloudy and what we had hoped to show was the nice coastline and there wasn't any to be seen.

4.8 TLI PREPARATION

LOVELL We used the nominal TLI procedure. We had adequate time. There were no hangups. The ground gave us a change in data to use based on the insertion of the booster, which was riding high all the time. The change worked out quite well and was covered briefly in the inflight briefing regarding powered flight. They gave us a new angle of 20 degrees for 57 minutes. And at T_o, the ball was zero. So it worked out.

4.9 SUBJECTIVE REACTIONS TO WEIGHTLESSNESS

LOVELL My feelings were as I've had previously. When we first get subjected to zero g, I feel I'm upside down, my head is full, and blood is rushing to my head; this lasts several hours. I think this sensation lasted approximately 6 hours. But

LOVELL (CONT'D) basically, that's the only sensation I felt in zero g. After that, it went away.

SWIGERT I think Fred and I felt the same fullness of the head.

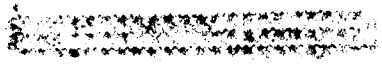
HAISE We both mentioned it about the same time. I don't know who mentioned it first. We both had it go away about the same time. Offhand, I don't remember how many hours had elapsed.

SWIGERT It was around 8 hours; we both mentioned that the fullness of the head was gone.

HAISE I had one other different reaction. On the morning of the second day, I woke up with a pretty severe headache. I drank some juice and ate some bacon cubes. That didn't sit right and I upchucked about 2 ounces of my juice. I sat still for about half a day pretty much; I never had any symptoms again after that.

LOVELL I think a general comment concerning space flight is in order. The fact that when you first get inserted, what you do for the first day (especially if we go into Skylab or something like that) should be held down. We should not try to do too many different things per day. No matter who you are, it's going to take a while to get used to zero gravity. Towards the end

LOVELL (CONT'D) of our flight, we didn't know we were in zero or one g. You get so used to it. But, in the beginning, zero gravity is different. You do feel different; so, you've got to just take it easy until you get accustomed to it.



5.0 TLI THROUGH S-IVB CLOSEOUT

5.1 TLI BURN

LOVELL From the left seat, the TLI burn was completely nominal. Attitudes held. The psi progressed according to the chart. We had about a 3-second overburn, if I recall.

HAISE Three and three-fourths.

LOVELL The overburn of 3-3/4 seconds was based on our clocks on board. We had no anomalies concerning the TLI burn.

5.2 S-IVB PERFORMANCE AND ECO

LOVELL S-IVB performance and ECO were nominal.

5.3 S-IVB MANEUVER TO SEPARATION ATTITUDE

LOVELL Jack, why don't you discuss the S-IVB maneuver to separation attitude? You were over there about that time.

SWIGERT The S-IVB began its maneuver on time; it maneuvered similar to what we have observed in the simulator; and held T&D attitude well.

5.4 S-IVB MANEUVER TO T&D ATTITUDE

SWIGERT We proceeded to use the normal procedure for T&D, and this worked out well. Pitchover was very favorable compared to what I've observed in the simulator, with the exception of translation control movements which I felt were somewhat different from the simulator in that, in the simulator, you can just tweak the translation controller a small amount and you get a small amount of translation. Here, it seemed to work in jerks. A small tweak didn't produce anything, and I actually had to hold it in. Then my Y and Z translation appeared to be made in a jerky fashion rather than a smooth translation like I had experienced in the simulator; but we had no problem docking. I would expect that the S-IVB pitcharound was about 80 or 90 feet out. Does that seem like a good number to you, Fred?

HAISE Yes. About 80.

SWIGERT About 80 feet out, which was about what I was observing in the simulator on my pitcharound. I felt that the closure rate was slow, maybe 0.2 fps on the contact; and we didn't try to hurry. We had adequate time, and I think the majority of the fuel I expended was trying to get stable. We had drifted around quite a bit after we got contact, and I was trying to get things stabilized.

5.9 DOCKING

SWIGERT When we went into hard dock, the latches ripple fired; they didn't all go at one time. I think that's because we had a slight yaw rate about the time the latches fired. There was no problem with sunlight.

5.11 SUNLIGHT AND CSM DOCKING LIGHTS

SWIGERT The S-IVB was immediately visible. The sunlight on the docking target did wash out the COAS. I had the COAS full bright, and it made sighting the target a little bit difficult. Right in the final phases of docking, we did get into the shadow where the shadow of the CM blocked out the Sun and the docking target was fully visible. I guess that occurred at about 5 feet on in.

LOVELL The hatch removal was nominal. The usual odor was up in the hatch. The odor had been reported before, and I had forgotten about it; but, when I got up there, I could smell it. There is a burnt odor in the docking area after the hatch is removed. I don't know what it's caused from — probably the docking sequences or something like that. There were two latches that were not engaged completely.

SWIGERT I had to recock them.

LOVELL You recocked them and got them back in position. Other than that, there was nothing unusual about the tunnel area.

SWIGERT I think they were latches 1 and 4.

LOVELL We connected the LM power cables, which was no problem.

5.13 EMS BEHAVIOR DURING TD&E

SWIGERT The EMS was just about what we had experienced in previous flights. Our bias test got continuously worse, and we did have a bias in there. I didn't particularly use the EMS except merely as a rough guide. I used my translation predominantly on time, and it decreased very rapidly during the pitcharound; but that has been observed on previous flights, so it didn't bother me.

5.12 EXTRACTION (SPRING EJECTION)

SWIGERT The extraction was performed according to the checklist, and we had no problems at all. It went just exactly as we had experienced in the simulator.

LOVELL I might mention that the procedure that Jack used was different from the one Ken used. However, the procedures worked out perfectly as far as our crew coordination was concerned. We had no problems that way and we were in good shape through

LOVELL (CONT'D) transposition and docking. I saw really nothing unusual during the whole procedure. This is one procedure that I thought required a lot of close coordination, a lot of working, because there were many things happening here. Everything worked out perfectly. One thing that we did do — we had the TV up, and that took a lot of Fred's time. ... to hold that TV to get the pictures of the docking. You might want to comment on that, Fred, and also on the high-gain antenna.

5.15 PHOTOGRAPHY OF TD&E

HAISE It's probably not as appropriate here as it was during the next TV session where we were trying to do the midcourse, but if you are going to play with it in the opposite focus and worry about the lighting and contrast and that sort of thing, it does take about three quarters of your time fiddling with it. I guess my only other job during this period was to make Jack feel that his estimates were right, when he would ask me about how far out it was, and to take some pictures. For this particular sequence of events, I didn't feel I was shortening myself too much in what I was supposed to be doing, which wasn't that much. About the only picture I missed was halfway through the turn-around. I was still worrying about getting the TV set up, and I missed the same picture that 12 had already shot, which was

HAISE (CONT'D) one SLA panel drifting off with the Earth for a background; but I didn't have the camera handy right then. Other than that, I felt that I got the number of pictures they wanted with the LM coming in at varying distances. Lighting was surprisingly good to me. I don't know if it was a different attitude, different Sun angle, or what, but at least from an eyeballing standpoint I thought the lighting on the LM, on the S-IVB, and in the IU was very good.

LOVELL We've probably got some pretty good pictures of the S-IVB. One general comment concerning that: unless there's a definite engineering requirement, I would suggest that we review using the TV during docking and the midcourse burn because I think that we've overdone that.

5.18 S-BAND PERFORMANCE

HAISE On the S-band performance, I had one goof-up there. I thought I had the angle set for docking attitude, but I had left a switch in MANUAL. I thought I had it in REACQ. We came around and locked up beautifully and had good gain; but, when Jack went to the next set of attitudes, we started losing signal strength. That's when I found out that I didn't have it where I thought I had it; so I put it down to REACQ, and it immediately

HAISE (CONT'D) AUTO TRACKed, got its gain back, and worked beautifully thereafter. The only S-band problem was an operator error.

SWIGERT As far as sounds go, I think the RCS sounds were much like they've been reported previously — that you can hear the sound of the valves opening — and I didn't notice any difference from the simulator.

HAISE The closest I could reproduce the sounds of the thruster was by sticking the pad of Velcro on my foot to the lower bulkhead and then snapping in and out the bulkhead. That kind of made a sound like the thrusters, which upset Jack now and then, too.

SWIGERT Because I would have the switches off, and I'd say we're not supposed to be firing. What's firing?

HAISE That was my foot firing.

LOVELL There was nothing unusual. I thought that the contact had more of a jolt to it than I thought it was going to have. That's why I asked you what our closing rate was.

SWIGERT It was slow; it was very, very slow.

LOVELL The man in the middle seat is really blind. He's worse off than the people back on the ground who can see the television

LOVELL (CONT'D) because you can't see anything from the middle seat, and Fred and Jack could see everything from their rendezvous windows.

5.21 WORKLOAD AND TIME LINES

LOVELL The workloads and time lines, I thought, were nominal. I don't think we have to have any changes there. I think that the crew can handle those with no problem.

SLAYTON Any comments on photography other than the TV?

HAISE I shot whatever the flight plan called for. I think it was either five or 10 pictures of the LM during both docking and extraction, and then we shot some of the S-IVB after we did our maneuvering. We had the camera in the center hatch.

SWIGERT We also had the sequence camera going, as the flight plan called for. We followed the flight plan completely.

HAISE That's why I made the comment about the lighting a while ago. It looked pretty good for the settings we had, so I expect the pictures to be all right.

6.0 TRANSLUNAR COAST

6.1 IMU REALINEMENT AND OPTICS CALIBRATION

SWIGERT The first P52 was done with PICAPAR. We put the star right in there; we had no problem. The optics calibrations for the first P23s were nominal. I think I only did four of them and three of them were the same value, so I used that value —

LOVELL About 300ths or something like that.

SWIGERT Minus 300ths — 89997. I guess while I'm on this thing I could talk about that first set of cislunar navigation sightings. All the stars were completely visible. You and I had a coordination exercise there that worked out well.

LOVELL Yes.

SWIGERT We got those done within the time allotted.

LOVELL That was one thing that I didn't think we were going to do, really. I gave cislunar navigation a secondary priority. I thought that, if we didn't get finished in the time line, I was just going to drop it because it really wasn't required on the way out. It was merely training. I thought we would try

LOVELL (CONT'D) to get the DELTA-H for Jack's calibration, but we got through all the stars. In fact, we repeated one.

SWIGERT I'll tell you also that I had done an awful lot of P23s and I became very proficient. I knew I had a good hack on fuel. During the simulator sessions, it had taken me 15 pounds to do that first set of P23s, and it took exactly 15 pounds in the flight. They called up the fuel used, and it was exactly 15 pounds; so it compared very well. They relayed back that the DELTA-H was very constant — within 2 kilometers, I think, which was 17 kilometers plus or minus 2, I think. They were very happy with it.

6.3 PASSIVE THERMAL CONTROL

LOVELL We had a small problem with the first attempt at passive thermal control. I'm not too sure what our reason was for that. We didn't null out the rates, though.

SWIGERT We nulled out the rates okay, but remember Ken's checklist had a red mark in there that says, "Enable opposite pairs." In the checklist, where it is headed, "Enable all jets," it had that crossed out and had "Enable opposite or couples" — "Opposite of opposing couples." We followed that and we didn't turn on all the quads. We just turned on the couples on those

SWIGERT (CONT'D) particular quads. As a result, we were off on that, and Houston called back up and said, "Have you enabled all the jets?" We discarded that part of the checklist and went back enabling all our jets. The second time, we used Houston to tell us when our rates were null, so we knew our rates were stable when we started. The second one worked out very well. I think we went some 20 hours without firing the jets at all.

6.5 MIDCOURSE CORRECTIONS

LOVELL The MCC that we did was nominal in every respect. I saw nothing wrong with the procedures. We used the card that we had rather than the checklist.

6.6 PHOTOGRAPHY AND TELEVISION

LOVELL My only comment concerns the next line which, if I had it to do over again, I would request not to have it televised because it cuts into our normal crew flow of activities. I didn't think that Fred was going to spend that much time on the television camera trying to get things done. This was the first time that engine was ever burned, and I thought it was kind of important. I would have probably just eliminated it. So I would eliminate that the next time unless they want it for engineering purposes and then we'd just put the camera up somewhere.

6.7 HIGH GAIN ANTENNA PERFORMANCE

HAISE Actually, on the translunar coast, we didn't use it except during the periods of TV. For the most part, Houston just had us select OMNI B; and, as we went around through the pole switching, they would just cycle back to D or not D. The ground really handled all the switching on the OMNIs. We didn't have any COMM problems at all.

There are a couple of things I ought to say. One of the things the simulator guys wanted me to notice in particular was the effect of turning on the gimbal motors on the O_2 flow. In the simulator, you get an enormous jump in the flows in the fuel cells when you turn on the gimbal motors; and, in the vehicle, you don't. The fuel cell flows barely moved. You do get a very rapid jump on the ammeter. If you're looking at the appropriate fuel cell for the bus of the gimbal motors, you're turning on - about 8 to 10 amps.

LOVELL Did we get a light?

HAISE We never got an UNDERVOLT light, which is normally true in the simulator. The other distinction I noticed was, when the burn started, that the ball valves opened very, very slowly. In the simulator, they snap open. In the real vehicle, it's almost

HAISE (CONT'D) like you can see the worm gear turning, and they're slowly grinding open. I would guess it's probably a 0.25 second or so, but it was quite a bit slower than in the simulator.

6.8 DAYLIGHT IMU REALINE AND STAR CHECK

LOVELL The star check for the burn was nominal.

6.9 CM/LM DELTA-P

SWIGERT The DELTA-P between the LM and the CM — remember we started out, and by the time we went to open the hatch, we had 1.1. Remember it was part of our procedure; we had to vent the tunnel down to 1.7 or greater. We had a pretty good tight tunnel connection.

LOVELL There was one question I asked Houston. The answer was to get a better purge in the LM before we went into it. I guess that was missed in the training someplace along the line. I didn't see it in the flight plan when I went through it. Okay, that was no problem.

6.10 LM AND TUNNEL PRESSURE

LOVELL LM and tunnel pressures were nominal.

6.11 REMOVAL OF PROBE AND DROGUE

SWIGERT On that, I followed the decals printed on the tunnel wall. I think this was our first time through it, and I think it took us slightly under 15 minutes to do it.

HAISE About 12 minutes.

SWIGERT I thought that was pretty good for the first time. We never reinstalled them, but I'm sure the second time would have been significantly less because we were purposely going very slowly, trying to do it right the first time.

LOVELL When we took that drogue and probe out, we slowly realized we were going to be living with it for the next 5 days.

SWIGERT Right. We had three bodies on the couch. We had one hatch, one probe, and one drogue strapped down to the couch for all the rest of the flight in the CM.

6.12 ODORS

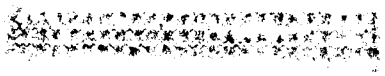
LOVELL When I removed the hatch, all of a sudden I smelled this burnt smell. I guess it must have been caused by the docking with the connecting of things and the rubbing and friction.

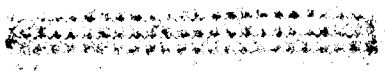
SWIGERT But you know, I carefully looked there when I took out the probe and the drogue. I looked for scratches, and there were none. We hit it pretty much dead center.

LOVELL You mean in the drogue?

SWIGERT Yes, in the drogue. I looked at the probe, the head of the probe also. There weren't any scratches at all.

LOVELL I do recall, though, putting my hand up against the probe when I first removed the hatch, and it was still pretty warm because it had been sitting out there in the sunlight.





7.0 LUNAR MODULE FAMILIARIZATION

LOVELL You might want to start this, Fred. You went in there first. We had one thing to do in this thing that wasn't on the flight plan and that was the SHe tank.

HAISE Our communications were yelling back and forth through the tunnel and we lived with that the next 4 days. It was really entirely adequate; particularly this time, because we didn't have all the pumps going in the LM. I didn't find any real problem in going into the LM. The shift in orientation did seem sort of strange. Although I had done it in the water tank, I found myself standing on the ceiling in the LM; when I got down in there, I had to do a 180 turn around. The LM itself was very clean. I found two washers floating around and I found the plastic cap from the sequence camera. It had drifted off and was lodged behind one of the ED switches, over on Jim's side of panel 8. That was the only thing out of place in the whole vehicle. We went through the regular checklist of housekeeping items. Then we threw in the extra addendum page that Houston had read up to us. They wanted a reading on a SHe tank, which, for the record, turned out to be exactly what Houston predicted. We didn't have much of a SHe tank problem.

LOVELL At that time it was between 7:10 and 7:20.

HAISE We had no COMM checks during this LM visit. I think the only transfer of equipment we made was the G&N Dictionary. I took the LM Time-Line and the LM Activation books back with me because we were going to discuss our powerup and descent operations with Jack and coordinate those with respect to the CSM solo book. I did all the housekeeping items with the exception of the 16-mm camera items. They had been deleted back to PDI day because it would have interfered with getting the hatch down and tucked away.

LOVELL Did we carry the film in?

HAISE Not the 16-mm film.

SPEAKER How about the 70-mm film?

HAISE We carried all the 70-mm film, but no 16-mm film. Other than that, I added a little tape to the right side of the crash bar and that was about it on the housekeeping side. We spent the rest of that visit in the LM putting on the TV show.

LOVELL I'd like to make one important point. We received a GO to enter the LM 3 hours early because we were ahead of the time line.

LOVELL (CONT'D) I think that was fortunate in several ways. Aside from the incident that occurred right after this, we could have gotten the nominal things finished and not have had the TV interfere with us. One man could operate the camera and do all that work. That is a lot more effective than if he had had to do the TV at the same time he was looking at the SHe tank pressure. People wouldn't understand what was going on.

We had the TV concurrent with going into the LM. That is not the way to do it. After normal LM housekeeping, we should have set aside a time for nothing but TV. We had the time.

HAISE Neither do justice to the other — they detract from each other. One should do one or the other. One should plan a TV show and put it on; then run the spacecraft when needed.

SLAYTON Explain the SHe tank use.

LOVELL We never did it. I did an IVT to the CM for about 8 minutes. I wasn't up there very long. This is where the PRESS vent went. I guess it was about 8:40 when we finished the TV show and the next time I looked at a watch, it was 3:00 in the morning.

The time went pretty fast after the emergency. I might mention the TV show was just over and the scene was set for the incident.

LOVELL (CONT'D) We were geared to bangs because Fred had actuated the REPRESS valve a couple of times. These caused a bang in the spacecraft. The first time he forgot to tell us about it, so Jack and I were springloaded to loud bangs. When the actual bang came, I didn't know exactly what the situation was. I thought maybe Fred had actuated the valve again.

HAISE I was sitting down in the LM.

SLAYTON Is this the LM REPRESS valve you're talking about?

LOVELL Yes, it's the LM REPRESS valve.

8.0 SPACECRAFT EMERGENCY

LOVELL To the best of my knowledge, Jack, you were in the left-hand seat.

SWIGERT I was in the left-hand seat.

LOVELL I was in the LEB, and Fred was somewhere up in the LM. We all heard the explosion together. I said to Fred, "Do you know what that noise was?" Fred said he didn't. Then, Jack said, "Remember the 80-amp glitch we had in training?"

SWIGERT You explained the 90 amps short on MAIN B.

LOVELL Then you said, "The MAIN B LIGHT is on."

SWIGERT That was my concern.

LOVELL That's right. Then I went over to look at the instruments. I don't think you even closed the hatch on the LM side, did you?

HAISE I left the LM hatch open and came down to look at the systems.

LOVELL When I heard the explosion, I thought I saw a light someplace along the side. It might have been just a reflection off the hatch door when you were closing it. That's what made me believe you had your hand on the hatch. At that time, Fred came back

LOVELL (CONT'D) to the right seat to look at the systems. I moved over to the center. Jack was in the left-hand seat.

SWIGERT Then you called Houston about our problem.

HAISE Yes, that was our first transmission.

LOVELL Then I called again and said we had a serious problem. The MAIN B BUS UNDERVOLT light was on, and we had a FUEL CELL light on. Jack, tell them what you saw.

SWIGERT I heard the explosion. It was about 1 or 2 seconds until we had a MASTER ALARM and a MAIN B UNDERVOLT light. I immediately left the left-hand couch and floated over to the right-hand side and looked at MAIN BUS B. We had normal voltage, normal current, and normal fuel cell flows. At this time, I came to the conclusion that whatever had occurred was a transient on main bus B because the performance of main bus B had returned to normal. At that time, I figured something had happened to the LM. My concern was the open hatch. I wanted to get the hatch installed and then take stock of what was happening. I went to get the hatch. I transmitted to Houston that, "We have a problem here." At that time, I went back to get the hatch.

LOVELL The LM hatch was still open. We were going to put the CM hatch back on.

SWIGERT While Jim and I were trying to do this, I misalined it in the tunnel and didn't get it in the first time. While Jim and I were doing this, Fred slithered down and started to look at the systems.

HAISE I'm not sure how many seconds I was behind Jack. When I looked at main B, the volt meter was pegged full-scale low. About that time an AC 2 light came on. Shortly thereafter, an AC overload light came on. I turned off inverter 2, but that didn't change anything. The meter only reads down to 23 volts. It could have been 22 or less, but as far as I knew it was zero. I looked at fuel cell 3, and its flows were showing full-scale low. This meant that this fuel cell wasn't carrying any load. That meant the whole bus was gone. I admitted that LOI was going to be NO GO about now. I didn't even think to look at the other two fuel cells at this time. I started switching AC loads to get all those things that were on AC 2 over to AC 1. The first couple of items I cycled I had a MAIN A UNDER-VOLT. Then I looked at main A and it was down around 25 volts. I cycled through the other two fuel cells. Fuel cell 1 was showing no flow. It was not producing anything so we had only one fuel cell on the line at that time. About that time, Houston wanted all the regulated pressures of O_2, and N_2, and H_2. Jack read them down to Houston.

HAISE (CONT'D) It turned out that N_2 was pretty sick on fuel cell 3; and O_2 was the one that was off nominal on fuel cell 1. Those were the two readings that were not looking very good.

LOVELL Before the incident, we did have a transducer failure in O_2 tank 2 quantity. Then we started looking through our systems again. We saw the pressure on the O_2 tank 2 was zero. I never saw any transients at all — just zero. Number 1 tank was down to 500 psi.

SLAYTON The O_2 tank 2 quantity failed prior to this.

LOVELL Yes, it failed off-scale high.

SWIGERT We had been having some stratification problems when we cycled the fans. During our scheduled periods of fan cycling, we would get a CRYO PRESS light which is an indication of stratification in the tanks. During one of these fan cycles, the O_2 tank 2 quantity indicator pegged full-scale high. We did another fan exercise to try to see if we could jar it back the other way. It never did. It stayed full-scale high for the remainder of the flight.

HAISE The next thing that showed up was the surge tank continuing to go down. When it kept going down below the pressure needed

HAISE (CONT'D) for the remaining fuel cell, I knew the remaining fuel cell was going to go the same way as the others. I left the CM about that time.

SWIGERT At this time, I called Houston and suggested that perhaps we should get somebody in the LM and start coarse alining the platform. Then Houston asked us to shut down fuel cell 3.

LOVELL Yes.

SWIGERT I read the procedure to you and you did it item by item.

LOVELL We had questions on the REACS valves. Once we threw the switch on the REACS valves, we couldn't get the fuel cells back again. It wasn't obvious to us at the time, but we should have known we didn't have any fuel cells then because we didn't have any oxygen. Throwing the REACS valves was just merely a formality.

SWIGERT We came back and shut down fuel cell 1. We asked Houston to confirm that decision. They did, and we proceeded with the procedure to shut down fuel cell 1. Then we started activating the LM to get our platform coarse alined.

LOVELL It was none too soon.

SWIGERT It wasn't much later that Houston came back with the advisory that we had about 15 minutes of life left on fuel cell 2 as a result of the decreasing pressure in tank 1. Jim and Fred proceeded into the LM to power it up. They did it expeditiously and we got the platform alined. I did two VERB 06, NOUN 20, ENTERS and read the angles down. This gave Houston some fine torquing angles to give to you and you got the platform fine alined and in good order. We had good coordination here.

LOVELL One of the big turning points in the flight was the fact that we got the LM platform up. We received the coarse aline from Jack and the torquing angles from MSFN. The one VERB 06, NOUN 20 that we got isn't what we normally do. During a normal activation, one gets a better angle out of it. We did get the platform alined enough to do the burn. I think where we made a mistake was going into the normal activation checklist. We should have gone into a quicker activation checklist. There is a lesson to be learned here. To get that LM powered up, one has to get the platform up because it is the heart of the whole thing.

SWIGERT At that time, I had BAT tie AC on to help with the load. About 15 minutes later, the fuel cell flows on fuel cell 2 went to zero. The LM was powered up at that time.

SLAYTON How did COMM work? When did you get the LM COMM and was there a problem there?

HAISE No. The only problem was that we were in the hot-mike mode for a long time without knowing it. We didn't go into the activation checklist on our own. We went under the direction of Houston.

LOVELL Yes, that's right.

HAISE They gave us the sections of the activation checklist to use.

LOVELL That was good. It cut down on the time to get the platform up.

HAISE It really wasn't faster, but there was less chaff in it. We had to use the 2-hour PGNS turn-on in the Contingency book. That is the only one that gets one a good platform. A 30-minute activation doesn't get a platform.

HAISE They would have had less to weed out if they had jumped into the Contingency book. Thereafter, that is all we used.

LOVELL One of the turning points was that we did get that LM platform alined enough before we lost the CM platform.

SWIGERT We failed to mention the venting outside the SM.

LOVELL Yes, a tremendous amount of venting could be seen out the left-hand window.

SLAYTON You called that out almost instantaneously with no alarms.

LOVELL Yes, it was just pouring out. We could see it because the Sun angle was just right. Another thing along with the physical sensations was the debris. The oxygen venting disappeared almost immediately, but the debris around the spacecraft was tremendous. An early discussion we had with Houston was to use the stars to get an alinement. It was very difficult to see anything out the window with all the debris. There were all kinds of debris out there.

8.1 COMMAND AND SERVICE MODULE

LOVELL We went over there and saw the venting; I knew that we were losing something at the time. I really wasn't too sure what it was. I suspected that it was oxygen because I saw the pressures were down.

SWIGERT The pressure was going down. We all came to that conclusion.

LOVELL Yes, right.

SWIGERT I don't think any of us quite realized the extensiveness of it until we shut down the second fuel cell and the pressure was still decreasing.

LOVELL About that time, we realized that there wasn't any sense in putting in the CM hatch, and we put it back down again.

About that time, Fred was going into the LM anyway, and Houston came up and finally said we'd better activate the LM systems. We activated the communications, the power, and the guidance system.

QUERY And didn't you have some trouble with brakes in here, Jack? Controls?

SWIGERT Yes, but I don't feel that that's strictly because of the same problem that you had with pitch that the RHC is no good with the

SWIGERT (CONT'D) stack on. You have to use the THC to get adequate pitch control. Remember that you had the same problem when you were using the THC.

LOVELL I don't think we ever knew, though, whether our SM RCS system was completely working or not.

SWIGERT Yes, I did. I had good thruster control with it. I think I did get some rates. I don't recall now exactly how much.

LOVELL That might be nominal with the hand controller when you have the whole stack on.

HAISE We had just put on the TV show. We were in a stabilized attitude for high-gain angles; the vehicle wasn't moving. All at once, Jack got negative pitch problems. He fired a thruster, and I remember your telling the ground about it as I was coming back through the tunnel. I could hear jets firing. I thought you mentioned you had rates in two axes.

SWIGERT Yes.

LOVELL Okay, but we never did figure that one out completely. That could very well have been due to the venting of the oxygen, because when the SHe tank blew, it changed the motion. Most of the mass is back in the SM, so it wouldn't make that much of a change.

SLAYTON At some point there, quad C malfunctioned. Do you remember anything about quad C specifically?

SWIGERT I didn't. Quad C was one that gave me pitch. I thought that perhaps I didn't have any quad C. I don't really have any absolute proof to substantiate either its loss or its performance, because I didn't try to control pitch to any large degree with the THC. I didn't really try to stabilize it out. We did get the rates down somewhat.

I know I had direct thruster control; I used the DIRECT switches, and that led me to believe that quad C was okay. I do recall calling up channel 31 and looking at the computer to see that the breakout switch was okay.

LOVELL That's right, we were in that malfunction procedure at the time, weren't we?

SWIGERT Yes, but, looking back now, I don't really have any substantiating evidence either to prove or to disprove the operation of the normal switches in quad C.

LOVELL That's an area that we're still a little bit hazy on, mainly because we shut down power in the CM to conserve the batteries; and we really didn't have enough time to psych it out.

SWIGERT I think that's the reason that I had channel 31 called up. I did look at that, and that appeared normal. About that time, we got the emergency powerdown procedure for the CSM; and that was about all the troubleshooting we did on the quad.

The emergency powerdown procedure was a very simple six-step procedure. The CM power was completely killed. We pulled all the circuit breakers on panel 250 except the sequence circuit breaker. The CM was like a tomb.

8.1.2 Noises and Flashes

LOVELL There was a dull but definite bang — not much of a vibration, though. I didn't think there was much vibration — just a noise.

SWIGERT Just a noise.

LOVELL Probably came through the structure.

HAISE I felt just a slight shudder.

LOVELL Maybe I was floating at the time; I didn't feel it.

8.1.3 Debris

LOVELL There was much debris all around outside the spacecraft; we couldn't even see stars.

HAISE The debris particles weren't very large. They were small, like frozen particles, or what maybe look like floating metal. A couple of inches or less.

LOVELL I saw one piece of wrapping float by.

HAISE Yes, but there was nothing that was extraordinarily large.

LOVELL We had no indication from the debris as to the extent of the damage to the back end.

SLAYTON You commented at one point that you saw about a 4-inch chunk floating by.

LOVELL Yes.

SLAYTON Is that about the biggest piece you saw?

LOVELL Yes, it was a piece of wrapping or something.

8.1.4 Physical Sensations (Attitudes, Rates, Vibrations)

LOVELL We think that the venting did impart a velocity to the spacecraft stack.

8.1.5 Communications

LOVELL We had no problems with COMM during the emergency.

8.1.6 Tunnel Operations

LOVELL We had difficulty putting the hatch on, but I think it was due to our rush, because we went back and checked it again before entry and it worked fine. We decided to leave the whole tunnel system open because we determined there was nothing wrong with the LM, finally.

8.1.7 Cabin Atmosphere

LOVELL There was no problem there.

8.1.8 Ground Updates (Procedures)

LOVELL Everybody, including ourselves, was trying to figure out what the story was. We didn't know exactly. The basic thing was to get the LM powered up and get the PGNS on the line.

8.1.9 Emergency CSM Powerdown

LOVELL Emergency CSM powerdown went along according to the checklist.

8.2 LUNAR MODULE

8.2.1 Power Transfer Activation and Checkout

LOVELL We went through the Activation checklist as we mentioned before. If we had gone through the contingency 2-hour checklist, we'd have had a little less to work with.

In any kind of emergency, having the ground tell you what to do as you go along is great. They can look at the checklists and tell what circuit breakers to throw, double check with their various people, and not have to worry about us reading. I thought that communications back and forth were very good. There were no problems with LM ECS, and the suit loop was okay.

Just after the emergency occurred, we did have some problem getting into PTC. The ground had a hard time locking on, and we had a lot of noise in the system. We didn't know whether it was our problem or the ground's at first. It was determined to be a ground lockon problem.

8.2.4 PGNS Activation

LOVELL The PGNS activation went okay. We got only one set of gryo-torquing angles. We could not do a really fine activation like we normally would have done. Because I had made mistakes in the arithmetic several times during SIMs, I wanted to be sure

LOVELL (CONT'D) we got the right arithmetic in. So, before I put it in the computer, I asked the ground to confirm my math. When they said it was okay, we would put it in.

8.2.5 Update Pads, Alinements, and Calibration

LOVELL In general, the update pads were very good. I think the technique of taking the existing checklists and having the ground modify them to fit the particular emergency was fairly good. It eliminated running down a lot of complete checklists. I was a little worried that we would have people on the ground that would be interested only in a certain part of a system and would not see the overall picture. I was interested in keeping everything as short and as simple as possible.

I didn't want to get a lot of stuff up there that really wasn't required. That is why I made some comments on the way, to just make sure we did only the essentials.

SLAYTON We spent so much time on that final activation because we wanted to make sure that we used what you had on board as much as possible and that we did not give you a whole bunch of unnecessary stuff.

LOVELL That technique is good. What we didn't have, and we never thought that we would ever use one, was a CSM Activation

LOVELL (CONT'D) checklist. We should look at some of our contingency books and include some of these items in it. I don't think that we will ever get away from having to modify some checklist. The systems guys are going to have to look at what you have and what you don't have, and how to work around it. I certainly never thought about powering up or charging CSM batteries with LM power. It never occurred to me that it could be done. Jack and Fred thought that they could do that. The ground had the technique, and it worked well. That was a big help.

We have our Contingency checklist; our method of doing a DPS burn; and how to control using the TTCAs for attitude control, pitch, and roll, and ACA for yaw control. This technique did work and was adequate. In fact, that is the way we flew the vehicle all the time. Our only big problem was when we shut down the FDAI to save power and went to the computer flashing 16 20, which gave us yaw, pitch, and roll, actually outer, inner, middle gimbal angles. We wanted to keep the middle gimbal angle out of gimbal lock. The technique that is in the contingency checklist is not valid. You can't use the TTCA and fly the computer the way we fly the 8-ball.

HAISE That's right.

LOVELL As a matter of fact, we spent hours trying to do it. I still don't have the technique. You just have to try to figure out by experimenting which way to hit the thruster. It changes depending on where you are, what quadrant you are in, and what the angles are as to which way to throw that translation controller to stop the angle from going toward gimbal lock. We were trying to keep it at a gimbal angle as close to zero as possible. I wasn't too worried about the other two gimbal angles. It was a continual battle to find it.

Maybe we ought to do some more research into using that technique. In the future in event of such a contingency, we ought to look at keeping the 8-ball powered up and powering down the DSKY, or something like that. I think our PTC mode was finally the AGS ATT HOLD, which held the vehicle once it was in position.

HAISE The problem could be handled the same way that we did it. We taped over each ball top and side and wrote in what the representative TTCA gave in terms of pitchup, pitchdown, roll right, and roll left. This is a nice handy reference. You didn't want to think about the geometry of things if you could just look at this piece of tape and tell you which way to do it.

8.2.7 ORDEAL

HAISE We did not use the ORDEAL in the LM.

8.2.8 DAP Loads

LOVELL DAP loads were sent up by the ground. We didn't use DAP at all; we used AGS almost all of the time.

8.2.9 MSFN Relay

LOVELL We did not use the MSFN relay itself.

8.2.10 DPS Maneuver

LOVELL As soon as we got the LM powered up and got our alinement, the ground, which was quite correct, planned to get us back on our free-return trajectory. We did the first DPS maneuver in AGS ATT HOLD. We had to maneuver manually to the proper attitude, and then PGNS ATT HOLD held us at that attitude. We couldn't do an AUTO maneuver to it. We maneuvered manually to the attitude, nulling out the needles, and PGNS ATT HOLD held us there. We went through the DPS throttle check.

HAISE Pericynthion plus 2? About 25 ft/sec.

LOVELL Is it in the LM contingency checklist?

HAISE The 38 DELTA-V_R. Okay.

LOVELL After the 31-second burn, we reinitialized the gimbal angles; we put new gimbal angles in based on the stack. The whole burn worked out okay.

SWIGERT Was that the one where I called out the times — 5 seconds at the 10 percent?

LOVELL Yes.

HAISE It was right on the money on the time. The residuals slipped to 0.2.

LOVELL Yes. That was a very good burn, as far as the DPS goes.

SWIGERT It was beautiful. The attitude excursions were nil.

LOVELL Yes.

8.2.11 LM Powerdown

HAISE We didn't do a lot of LM powering down. We kept the PGNS up.

LOVELL We got rid of the FDAIs; we kept the PGNS activated until the pericynthion-plus-2 burn.

HAISE We never powered up the AGS.

LOVELL The powered-down configuration is probably listed in the contingency checklist. We can decipher it from the other powerdowns

LOVELL (CONT'D) that we had. However, basically, we kept up the PGNS. We wanted to keep the alinement that we had obtained from the CM.

8.2.12 AOT Checks

LOVELL An AOT check was made. I don't recall the time to verify the alinement prior to the pericynthion burn, in which case we were using the Sun to see how valid the alinement was. That was some time, I think, prior to LOS. The ground gave us a 2-degree excursion on that. We double checked it quite a bit. We were in PGNS ATT HOLD after we got there by maneuvering manually. The Sun checked out just about where it was supposed to be. It was off just a little bit, perhaps half a diameter. So, that again was very fortunate for us. Getting a better alinement would have been rather difficult for pericynthion plus 2.

The Sun filter worked; however, there's one problem inherent in its design. One can hardly see the reticle with the Sun filters on. It's difficult to do alinements until the Sun is very close to the center of the reticle where the lines cross. It's hard to tell exactly where the Sun is with the filter on. The Sun check worked, and we did not do another alinement. We kept the PGNS powered up.

8.2.14 Procedures (Onboard and Ground)

LOVELL The procedures were completely changed as we went along. It was a case of never going back and doing exactly what we planned to do but looking for the ground to do what was required and passing those modified procedures up to us so we could do the job. The best indication that they were adaquate is the fact that we're back here.

SWIGERT The ground passed me up a basic switch configuration for the CM, which I set up. We just went on down the launch checklist and set every switch per the ground instructions. We started out with the basic CM switch list.

HAISE The powerdown we did was the one that we ad-libbed. We went down the rows and gave up what we thought we could give up, lights and things that were very obvious. We didn't do too much on the powerdown. I think the crew and the ground were both hoping to keep the platform going to get the next PC-plus-2 burn done.

LOVELL We powered down everything that we knew we wouldn't need, and we just pulled the circuit breakers on it. We almost had a problem, though, because we almost pulled the PGNS circuit breaker, which we did not do, fortunately.

8.2.15 Passive Thermal Control

LOVELL PTC was done primarly on the computer, and it was difficult to fly the gimbal angles on the computer in this configuration. In the future, we should prepare for that type of flying.

HAISE The PTC you're talking about here is where, you were turning approximately 90 degrees.

SWIGERT We would turn 90 degrees, then sit an hour, then go on 90 degrees, stopping for an hour, et cetera, rather than in a normal, continuous PTC motion.

8.2.16 Spacecraft Stability

LOVELL There was no trouble controlling the spacecraft motions. That was one thing I was worried about. If we'd ever got uncontrolled, we'd have been in deep trouble. You can control the motion a lot better if you have a body to orient on, like the Moon or the Earth.

8.2.17 Cabin Environment

HAISE The CM was dark and unpowered and was just going to go down slowly in temperature. At this time, I thought the LM was fairly comfortable. I don't recall any cabin temperature readings, but I don't remember being really uncomfortable in the LM or in the CM during that first period of activity; they were both quite reasonable.

SWIGERT Down to that first PC plus 2, both spacecraft were comfortable. That first night we did like before and put the window shades up.

LOVELL That was a mistake.

SWIGERT That cooled the CM down, and we decided from then on that we'd leave the window shades off.

LOVELL We'd put the window shades up, and it would really cool it down faster than we wanted it to just in the CM. We used that as a bedroom and so we had the window shades down to keep it dark in there.

SWIGERT It was still pretty reasonable though. One could sleep up there.

Prior to this — when we were on the normal flight plan, we had kept accurate records as to exactly what we had eaten and we had transmitted to the ground our sleep, and the quality of the sleep. Urination was no problem; we had been very regular. After the mishap, it was a problem in that we couldn't get our water. We were told not to use the LM water, and about this time they passed a procedure for activating the CM to obtain water. I did this several times and filled a number of the juice bags to try to get ahead. I figured that we needed at

SWIGERT (CONT'D) least one 8-ounce bag of juice per meal, so at one time I filled 13, and at another time about a dozen. At one time, we filled 20 or 22 bags.

LOVELL The procedure gave us a lot of water at one time, but if you didn't use it the pressure would bleed off.

SWIGERT I kept filling juice bags until the pressure had bled off and I couldn't get any more water out of it. However, the only problem there was that I had no idea how much oxygen I was using out of the surge tank every time I did this. I didn't think it was extreme, but I just didn't know when I was going to limit our CM. At that time, we didn't know how long the LM would last, and I wanted to have lot of CM O_2 left.

HAISE You might think that you have to stop overboard dump because of the loss of the electric power and the heaters on the urine dump, but Jack actually rigged up the AUX urine dump through the forward hatch and I think he tried it.

SWIGERT Jim did it once.

LOVELL You should tell Houston, too, that dumping overboard was a bad thing to do.

HAISE The point I was making was, other than the problems of tracking — I don't think you need a heater for that overboard dump, and I think you can use it forever and ever without having a heater. With the tracking, though, that made the picture entirely different. When we couldn't dump it anymore, I think we improvised some place to store all this good fluid.

SWIGERT One comment on using that auxiliary dump for urine is that it does completely cloud up the hatch window. If you ever use that, you might as well forget about photography. We used it for one urine dump, and there were particles on the window from then on.

LOVELL That is a good point. Using that auxiliary dump either for waste water or urine is strictly for backup. We kept the urine on board, and we had to figure out ways of keeping it.

HAISE We used both bags. We filled both of those bags we showed on TV, which were the bags we were going to fill with water from the PLSS, and we used all the Gemini bags out of the CM. We used all the urine bags in the LM; I think there were six. We were down to where we were contemplating next using our old drink bags.

LOVELL We had urine all over the place, stacked in places we never even thought about. The nice thing about it, though, is that we found enough quick disconnects and rigged up lines to get urine into things that normally we were putting other stuff into or taking stuff out of. So, it worked out that we could store a lot more urine than we thought we could.

HAISE In fact, while we were thinking about the water, and talking about feeding PLSS water into the sublimator, I had a way figured out to get the urine through the sublimator.

LOVELL Of course, at this time, we were also thinking about the PLSSs, about using the water for the sublimator and then using the fans and the batteries and the oxygen in case the LM system failed.

SWIGERT It's really surprising that a lot of the things the ground sent up, we had discussed. Fred had immediately done some calculating and figuring on the life of the batteries which proved to be very accurate,compared to what the ground had. Of course, at this time, we hadn't figured on the powerdown.

HAISE Both of us missed it; both the ground and I were initially conservative. The LM did its emergency powerdown better than either I or the ground figured. In fact, I think we even got

HAISE (CONT'D) down to 10.3 amps there. On the water, I missed. I had figured about an average of 3-1/2 or 4 pounds an hour on water for the whole time and ended up having 1 hour to spare. Of course, we came out a lot better.

LOVELL It was very uncomfortable. Basically, the cold made it uncomfortable.

SWIGERT First of all, even though the temperatures were comfortable, the humidity started to climb. The LM, obviously, couldn't extract the water out of both spacecraft. We began getting condensation on the CM windows right away, even though we still had comfortable temperatures in both vehicles. And then the temperature in the CM and LM started to lower.

LOVELL So it was a case of having a cold, high-humidity environment. The cabin pressure was no problem. The CO_2 buildup — that's a story in itself. Houston came through with a technique for using CM LiOH canisters in the LM, which worked probably as well as the basic system. We ended up with a complete primary LiOH canister that we didn't use. And that was 40 hours worth of running.

SWIGERT We had more canisters in the CM which we could have just added onto this thing. I felt we had an unlimited supply of LiOH canisters.

LOVELL So even though we probably didn't even have to go through that other mode, it kept us busy. It's like putting up the antenna in a liferaft. Does it work? Maybe it'll keep you busy for a while.

SWIGERT It's worthwhile mentioning that on the first canister, they did allow us to go up to 15 millimeters and, qualitatively, I didn't notice any change in the environment at all.

LOVELL I was worried that when we started the sleep-rest-work cycle we would forget about these CO_2 buildups. We had adequate ventilation in the CM, too, by putting the hose through the tunnel.

SWIGERT We put that vacuum hose on the CDR's hoses. That reached up into the tunnel and was one thing that contributed to the CM getting cold.

LOVELL Yes. We had one hose in the LM and one hose as far up the tunnel as possible to ventilate the CM. That kept it going.

SWIGERT Like a snorkle sticking up there. The sleep-rest cycle, the first couple of cycles, seemed regular; but, after that, I really kind of lost track of who was on watch.

LOVELL They tried to set up something, but I couldn't go to sleep after the accident. I don't know how many hours after that it

LOVELL (CONT'D) was when I just quit working. You know, I just had to see if things were going right or not. It was a little later I realized we couldn't do it for long, and so then we tried to get something going on the work-rest cycle. However, I don't think we really did accomplish that objective.

SLAYTON No. The flight-planning guys were trying to work out one, but we finally decided it was better to block out periods and somebody could be sleeping; that is, let you men figure out who should be sleeping.

LOVELL Yes. That's the only way we could do it. When a guy felt tired, he tried to get some sleep and another guy would take over. But we just couldn't look in advance. We knew that we had to get some sleep; we couldn't last forever. So, we didn't get much sleep at all, maybe an hour at a time, I think. Actually, Fred, you got some good sleep?

HAISE Yes, I did.

SWIGERT Yes. You slept that one time in the tunnel very well.

LOVELL And one time in the CM, I think you got about 4 or 5 hour's good sleep.

SWIGERT My sleep was very sporadic.

HAISE I would sleep in the tunnel right next to the ECS unit. This was the warmest place. And I got in the sleep restraint and slept upside down in the tunnel with my face back toward the hatch. I zipped up the sleep restraint and used a string on it to hook myself to the latch handle on the LM hatch so I wouldn't drift away. It must have looked very strange. And the food business was another thing. We may have cut ourselves, without thinking about it, a little short on the liquids. With the water problem, we stopped reconstituting. So, the only food we ate after the incident was cubes, the wet packs, and the sandwich spread. We didn't reconstitute another bit of food after that.

LOVELL Well, I wanted to save the water.

HAISE We also didn't have any hot water. Some of the reconstituted food was not too good without hot water.

LOVELL I might be wrong, but I thought that using all the water we had for juices, and then using that other food, was better than trying to reconstitute some of that food.

HAISE I meant for regular water. You'd drank all the juice we drank and you'd still eaten reconstituted food also.

LOVELL Oh, yes.

HAISE We didn't have much water, so, we were short.

LOVELL Anything else on the comfort and eating?

SWIGERT I think the only thing as far as eating was that we filled about 35 juice bags when we ran out of CM water. We had gotten about that quantity out when we ran out of water.

SLAYTON Were you consciously thirsty at any point?

LOVELL We were, right after the accident. My mouth was dry.

SWIGERT I don't think we were really thirsty. I think the last day I was thirsty.

LOVELL Yes. That was all.

SWIGERT And then, at that time (about 12 hours after) we ran out of CM water and we had used all the juice bags.

HAISE Then we knew we were kind of bad on water, I was thirsty. But when I started having my urine-burning problem, I drank excessively. That was the old school medicine I remember, which says you ought to flush the system. So, I started drinking to do just that.

SWIGERT Something that we didn't mention was a leak in the LM water gun at one time, which deposited a considerable amount of water in the LM.

LOVELL That's right.

SWIGERT We disconnected the LM water gun and then used the CM water gun.

HAISE Would you guess about a quart of water, maybe?

SWIGERT Yes. I think so. It had quite a bit of adhesion and it stuck all the way around the ascent-engine bell cover and then around the part where the LM water gun attaches. It took six towels to sop it up.

SLAYTON You replaced that with the CM water gun?

SWIGERT We replaced it with the CM water gun.

SLAYTON Was it leaking constantly?

SWIGERT I'll tell you how I noticed it. All of a sudden my feet were wet. My feet were so damn cold. It took me 2 days to get my feet dry. It had completely soaked through my bootees and my CWGs and that was my first indication.

HAISE Jack was in his usual LM crew position, straddling the ascent-engine can with his feet draped in the water pool.

SWIGERT But, anyway I went back up in the CM. You disconnected the water gun.

HAISE I shut off the descent O_2 valve and no more water could get down the tube; then we just disconnected the gun. Some time later it was brought down.

9.0 LUNAR FLYBY THROUGH 2-HOUR MANEUVER

LOVELL The next thing we should talk about is the PC-plus-2-hour burn. That was the PGNS DPS stack burn. We got two updates and an update to the original burn. We updated a whole change in the DPS profile. We maneuvered manually and went into PGNS ATT HOLD. We powered up early. It was a mistake, but I wanted to make sure. I was a little worried about getting into the proper attitude. So I asked if we could power up and we went through the contingency DPS burn faster in the checklist than we thought we were going to be able to. We were sitting there for almost an hour powered up. I kicked myself, I don't know how many times, for powering up early and using that power when we didn't have to.

SWIGERT We were so concerned about getting this burn off.

LOVELL We wanted to get the burn off and wanted to make sure of the proper attitude to do it. We powered up early. The ground didn't say anything, so I was thinking seriously of shutting down and starting up again; but I thought, we're already here and everything is all squared away, why don't we just do it?

SWIGERT All our consumables and everything else were based on the fact we were going to be powered up through that point.

LOVELL So, I guess those were okay. Jack tried to keep track of time for us when the engine started. We were 5 seconds at idle, 21 seconds at 40-percent throttle, and the remainder of the burn at full throttle. But the way it was configured, at 26 seconds, it goes to full throttle. So, it actually beat me going to full throttle at that time. When the DPS burned, it was exactly like flying the simulator. The attitudes were very stable — no oscillations — and the engine was very quiet, very smooth. At the time, I wished I was doing the landing with it. It was a beautiful burn.

HAISE The only way I could tell that engine was lit was to watch the ENGINE THRUST gage. It was extremely quiet.

LOVELL I don't have any more information on the PC plus 2. Does anybody else have anything on that burn?

HAISE No, except during the first one, apparently the gimbals had settled down pretty well and the attitude was extremely good.

LOVELL We did not change gimbal angle this time on the engine. We went with what was left over from the last burn. We used a VERB 49 to get the needles to fly by and to which we had to nudge manually. PGNS would hold the stack at this position. It wouldn't get it there. It would hold the stack at that

LOVELL (CONT'D) position. We also did something else. Didn't we power down — Rather, didn't we shut off some thrusters so we wouldn't impinge on the CM?

HAISE Oh, yes. We did NORMAL, VERB 65 before the burn. I had AGS up to this time and its DELTA-V readout was within the COMP cycle. It was right with the PGNS all the way.

SLAYTON That was the other factor in this thing; if you had burned the DPS engine for that period of time without the CM. They were afraid to fire it up again because they had no data to indicate it was a safe thing to do, because of the soakback.

SWIGERT About the SM, you mean?

SLAYTON No. Just the performance on the DPS itself. On the DPS engine with the shorter burn, nobody was concerned about cranking that up.

SWIGERT Oh, I see. For the long burn, they were concerned about it burning up.

SLAYTON It was almost to fuel depletion, although we figured you had approximately a 7-percent margin on it. They would have been afraid to fire using it again.

LOVELL We were looking at that for maybe the last time.

SLAYTON The next area we should talk about is what occurred in lunar sphere of influence. That is, in terms of observation, photography, and anything like that.

LOVELL Well, we got photography. Jack and Fred took the cameras on our pass around behind the Moon and took pictures and confirmed that at this stage, the Moon was really gray. They're free to discuss it themselves.

HAISE Jack and I were crying all the way around and shooting pictures like crazy. I guess we were up in the CM, first shooting out of window 1 as we came upon the back-side terminator and subsequently ended up at the right window of the LM as we came around the corner. Then we were also shooting out of the overhead (docking) windows.

LOVELL I'll be perfectly frank. I wasn't interested in photography at the time.

HAISE In fact, we keep getting comments from our Commander, "Hurry up, we have a burn to do. Hurry up." And we said, "Relax, Jim, you've already been here before, but we haven't." We were just taking pictures like crazy. But we had LOS at the

HAISE (CONT'D) proper time and we had sunrise at the proper time and we had AOS at the proper time, so we had a fairly good idea that the ground had good tracking on us.

LOVELL I might mention the one thing I was worried about in controlling the spacecraft before we did the midcourse. It was back on the free return and that was when using the TTCAs. I didn't know what kind of trajectory changes it would give me. After we did our very first midcourse, tracking indicated that we had a 60-mile pericynthion, and I wasn't too sure whether control of the stack with the TTCA was going to reduce that or increase it. I didn't know what it was going to do. I made that comment to Houston. I guess it didn't make that much difference.

HAISE Well, after our free return, we now had 137.

LOVELL Well, I wasn't worried then.

HAISE We went around it and we had lots of fat.

LOVELL Okay. After PC plus 2, we did a PTC maneuver using PGNS. The procedure was called up by Houston and I can't really recall what it was. I don't have the checklist with me. After the burn, they gave us a method of using the PGNS to do a PTC maneuver. So, then they were going to shut down the PGNS.

LOVELL (CONT'D) I'll have to renege on making any exact comment on that; I don't remember what it was exactly.

SLAYTON That's the one he had trouble getting into, though. That is when we were really sweating your fuel consumables.

LOVELL Yes. I was anxious to get the power turned off, too, and to get it cut down again. Right now, I don't recall exactly the type of procedure I actually had to do.

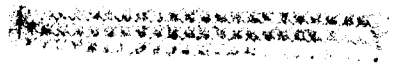
LOVELL Anyway, I think the procedure worked very well. Two things about this time, we also powered up the PGNS and we went to MANUAL on the antenna. That was basically the procedure we used throughout the entire transearth coast.

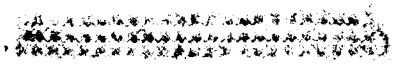
HAISE We did go into the powerdown on page 5 in the Contingency book. That's the first real powerdown we had; that's after you got that PTC down.

LOVELL Yes, we went through it to where we had gone down to minimum power.

HAISE I thought it was pretty nice the way they went to a section and page in this book — which was clearly appropriate for it — and made the deviations from that according to the situation they

HAISE (CONT'D) wanted and had us update that. It really wasn't very extensive. We just followed the script and powered it down; it was very simple.





10.0 TRANSEARTH COAST

LOVELL Basically, the transearth coast consisted of the spacecraft in a powered-down situation; it was in somewhat of a PTC attitude with a rate that would keep the thermal conditions consistently even. We performed one manual midcourse maneuver at 105 hours and then went to a powerup situation and entry.

10.1 SYSTEMS

LOVELL During the transearth coast, all systems were powered down, except for the communications system, and the ECS in the LM that was necessary to keep us alive.

10.2 NAVIGATION

LOVELL Navigation was performed by ground tracking, and by the midcourse correction maneuvers. The midcourse corrections used a procedure that had been generated earlier and, from the crew point of view, was very simple to perform. The procedure is to use the terminator of the Earth to aline the spacecraft to either retrograde or posigrade position and then to perform either a retrograde or a posigrade burn to change the entry angle. It was very simple to perform this procedure in the configuration we were in. We accomplished midcourse correction 5 on the AGS, using the TTCA to control roll and pitch.

LOVELL (CONT'D) It was almost a three-man operation. Fred did the ullage; I started it on time; and Jack called the time for stop. We also set up a timer. The correction was performed with 10-percent throttle. I controlled roll with my TTCA, and Fred controlled the pitch. Jack yelled "Shutdown," and I stopped the engine.

Jack brought up a good point to mention while we are discussing this particular burn — an attitude check using the position of the Sun. If we had been in the proper attitude with respect to the position of the Earth, a pitch would have been valid because of the position of the Sun at that time. So, the idea was to position the Sun at the top of the reticle in the AOT. This procedure worked well, and that's how we got our pitch alinement with roll and yaw — using the terminator.

HAISE I checked both the COAS and the AOT, and both were right where they should have been. It was a beautiful job.

LOVELL That technique — a manual burn using the AGS — does work. We ought to think about that kind of burn for the future.

10.4 PASSIVE THERMAL CONTROL

SWIGERT According to Houston, the earliest possible time for the SHe tank to blow was 107 hours, shortly after the burn

LOVELL (CONT'D) but no pitch. There was also some coupling when we got started. There was some debate with Houston about whether we should start or not. I think the decision was that we could go. This gave us a pretty good reference, because the Earth and Moon would appear in our windows. After a while, Houston came up with angles.

This PTC attitude was very good until the SHe tank vented. At the time of venting, I think Jack Lousma asked if we saw anything. We did see it out the right window, the LMP's window. It reversed yaw completely and gave us a coupling in pitch and roll. That was the attitude in which we remained for the PTC.

HAISE Also, the venting about doubled the rates.

LOVELL Yes, it really spun us up.

HAISE It not only stopped our rate in one direction, but it doubled our rates in the other direction.

LOVELL That was supposed to be a nonpropulsive vent.

SWIGERT We were really switching antennas quite rapidly for a while.

LOVELL But there was one interesting thing. From the time we started it, we didn't touch the thrusters at all; attitude control was

SWIGERT (CONT'D) and after we had gone to PTC. The latest time they expected it to blow was 110 hours. So, we began to watch the tank after this burn, and we discussed it among ourselves — whether we would hear it blow, how we would notice it. I don't think we came to any conclusion, though.

We never did hear it blow. I think Fred was sleeping at the time it went.

HAISE It didn't bother me.

LOVELL Another thing that was particularly good about this manual burn was that by using AGS, we got a good ball alinement after we got into position. So, we actually did not use an outside reference for the burn. We got in position using the position of the Earth, but then we got the ball alined with the AGS, and we used the AGS ball for attitude control during the burn. We also used the attitude deviation needles; then, we went back to PULSE. They told us to roll 90 degrees to get us back in the proper attitude for PTC, which we did.

They said to null rates within 0.05 deg/sec. I didn't see how this was possible, but we nulled them as much as we could. We got the attitude down, and then we put in 21 clicks, either 21 or 12 clicks, of yaw. There was a little roll and yaw,

LOVELL So, we had SM venting of some sort, which we thought was hydrogen.

SWIGERT It was just before or just after this midcourse correction that Houston passed up some procedures for powering up the CM with the CM batteries, so that they could get some telemetry and read some instruments. I did this, and I also read some voltages. They read the telemetry, and then we shut off the TM. So there was a period of about 5 minutes that we had the CM powered up.

LOVELL When did we start doing the battery charge?

SWIGERT After the midcourse correction. Houston passed up a procedure to power up the CM using LM power. We powered up main bus B, and that procedure worked like a charm. Shortly after that, we began charging battery A, and Houston estimated that charging would take 15 hours. We checked out differential current, and, sure enough, there was an 8-amp difference. Then, we finally had a little confidence that Houston knew what they were doing. Actually, we had confidence all along, but it was very comforting to know that they were that accurate on the amount of amp-hours consumed.

LOVELL (CONT'D) strictly on its own, except that the rates slowed down. By 5 hours before entry, it had slowed down to where the Earth would come by the window only once every 12 minutes or so.

SWIGERT I attributed that to the sublimator.

LOVELL There was something else venting, too.

SWIGERT Yes, we had some venting from the CM periodically.

LOVELL We forgot to mention that. There was something all during this period, while we were checking through the AOT, that was venting out the SM. We attributed the venting at that time to the hydrogen tank.

SWIGERT What I thought was happening was that the hydrogen tanks would go up, pop the relief valves, vent for a period of time, and then, the venting would stop. Jim and I were trying to see whether we could see stars as we went around. We found that during periods of no venting, there were attitudes from which we could pick out whole constellations. Jim picked out Scorpio and Nunki. I picked out Acrux, the Alpha and Beta Centauri, and the Southern Cross. We could see whole constellations, but, when the venting started, it was immediately apparent that the stars were gone.

LOVELL At the same time on the transearth coast, we were passed a procedure to configure the CM canisters to scrub CO_2 out of the LM ECS system. That procedure worked very well, and we had no problems. We powered up the LM just before entry. We got it powered up 2-1/2 hours early. One reason for early powerup was heating. Again, we were very cold. We thought of using the window heaters, but I was very reluctant to use them. They use quite a lot of power. Also, they were really cold and wet, and we were worried about somebody applying heat to them.

SWIGERT We tried not to disturb the environment. We had talked about pressurizing internally with the PLSS or the OPSs to make sure that we didn't use the CM REGs or cabin REGs on descent. We had determined that we would not do anything to disturb the environment on the inside.

LOVELL Along with that, too, was the question, "Should we break out the suits and put them on?" Right now, it's still a little bit hazy in my mind whether we should have donned the suits. Without the suits, we were so much more maneuverable, especially in getting rid of urine and moving around, that I was reluctant to put on the suits.

HAISE The problem with suits is that your body can't breath in them. With no hoses plugged in, there is no flow. Even as cold as it

HAISE (CONT'D) was, inside the suit one starts getting hot and sweaty. You've got to crawl out of them about every 2 hours. Then, you're exposed soaking wet to that chilly atmosphere.

10.9 STAR/EARTH HORIZONS

LOVELL So, we powered up. It took about 30 minutes before the LM started getting warm. The windows cleared, and we never did use the heaters on the windows.

We stopped the PTC attitude. The first attitude maneuver was to the Earth. I wanted to make sure I got the Earth in sight again because I knew I was going to do midcourse correction 7. We squared away whether we would do an alinement or not, and we did. We did Moon/Sun alinement with the LM. I'm not so proud of the alinement, but I really don't know what the situation was. It was a stack. We had been doing it with the TTCA. The way we finally did it was: Fred maneuvered, and I told him how to maneuver so that we could get the Sun and the Moon across from the hairlines. I tried to put the mark in as soon as it went to the center. We got about 1-degree star-angle difference.

HAISE 1.1 degrees.

LOVELL Yes, something like that. It's a pretty big torquing angle; but, for what we were going to use it for, I thought it was

LOVELL (CONT'D) completely adequate. Again, we used the filter for the Sun. We ought seriously to consider using the Sun and Moon for alinement, because when you're out there, you just don't see stars. You just can't rely on getting good star alinement if something's wrong with the CMC. You have to use something, and then the only thing you've got is the three bodies.

HAISE You can't do them in a simulator.

SWIGERT You cannot do Sun and Moon alinement; no planets are available in the simulator.

LOVELL Because the Sun shield is so thick, looking at the reticle is very difficult. It's hard to see and hard to read.

HAISE It's hard to pick up the reticles.

LOVELL Yes, it's very hard to pick up the reticles with the Sun. Maybe we're going to have to be satisfied with rough alinements with the AOT when you have a maneuver stack like that.

HAISE It made us feel very good that we had picked up Jack's alinement before we'd powered down the CM.

LOVELL That's how we did midcourse correction 5. I wasn't really worried about that also because it could burn it on the Earth.

LOVELL (CONT'D) But, I wanted to make sure that he got a good alinement from the CM, especially because the LM was getting the rough alinement and then doing the transformation backwards, which we had never done before. Going back and giving Jack the angles to put into the CM allowed him to get a rough alinement in the CMC so that we could do a P52. That's what we wanted to do.

SWIGERT Houston calculated those angles and passed them to us. One key thing to this whole time line was doing that Sun/Moon alinement. That gave me a lot of confidence; even if I never saw any stars or we didn't get my alinement, we had a good enough alinement to get in.

LOVELL This really wasn't the original procedure. Normally, Jack would have been on his own to get an alinement.

SLAYTON When we discovered that we had about 100-percent margins at the time, we told you to power up. That's when you started up. The best way to warm you up was to power up, and once you'd done that, you might as well go the other route also.

LOVELL Well, I was a little bit worried about having to go to a Moon attitude and then a Sun attitude for Jack. It was a lot easier for me to go to those attitudes and then do this rough

LOVELL (CONT'D) alinement, because everything was right in the LM cockpit. Then too, Jack gave me some angles to go to. I thought that approach was best.

HAISE The technique was to aline in the same manner we usually do on the terminator of the Earth, just a pure pitch. I was looking through the AOT, and I'd tell him when it was right in the plane of all the bodies. Then I'd tell him when the next one trickled in. We'd stop around that one and go to work alining on that one. Then, it was just another pure pitch from there to pick up the next body. It was pretty straightforward attacking it that way.

LOVELL We finally got our rough alinement for midcourse correction 7. Houston called up and asked if we would like to do a PGNS burn, and we said "Fine." That's where I really got confused. I guess Dr. Berry thought I was tired. Well, maybe I was tired. I got Fred to go over and check those switches, too, and I think Charlie finally told me what was wrong. We maneuvered manually to what I thought the attitude would be, based on the angles we were reading. Then, I went to PGNS AUTO, and it drove the spacecraft there, but the needles never nulled out.

HAISE Two of them did not null.

LOVELL Yes, two of them didn't. I was worried about whether I should null the needles to get the proper attitude, or whether I should hold what I had, because the computer knew what the attitude was. As it turned out, it really didn't make any difference; because, no matter how I burned, it would have been okay. I think you know I forgot to PROCEED 50 18 or something like that. Charlie said that I should have. Anyway, that's what got me confused. That's why we had a delay. I wanted Houston to find out what the situation was. I really preferred to do the old AGS burn again, because we had done it one time and I knew that it worked. But, this burn was okay. We burned RCS this time. I guess it was 3.1 ft/sec. That worked fine.

HAISE That ended up being an AGS burn, Jim.

LOVELL Yes. Houston finally told us to go to the AGS. There was a lot of confusion about this time. I guess we'll get to it a little bit later on in discussing the entry. I guess there was some confusion on the ground, too. But, anyway, that burn was performed with the AGS, and there was no problem with attitude control once we made the burn. There was some confusion on my part about the exact attitude I should be in. I was also worried about the fact that the Earth wasn't perpendicular the

LOVELL (CONT'D) way it should have been. I found out it should have been 8 degrees off in attitude. Our midcourse correction 5 really should have been that way too, but to make it easy on us, they wanted to do it perpendicular.

10.16 EATING, REST, SLEEP, FATIGUE

LOVELL Fred woke up with the chills before we did midcourse correction 7.

HAISE Yes. I wasn't sure what gave me the chills. I was back in the CM at about that time, and I had to go to the bathroom. I stripped naked in the 42 degree temperature and ricocheted around touching bare metal, and it just chilled me to the bone every time I'd touch anything. You can't help but bounce all around in there. I was really cold for about the next 4 hours. From that time on, it sort of began to catch up with me. I began to feel tired. Before that, I really didn't feel much effect at all.

10.23 FINAL STOWAGE

SWIGERT One thing, Jim. You and I had gone down, and we had practiced installing the CM hatch.

LOVELL Yes. That's another thing.

SWIGERT It also completed the stowage list, which was read up to us from Houston. So, we had everything done. I had completely stowed and tied everything down in the CM. I had gotten the strut lanyards in place, and we had the CM all ready to go before 6 hours 30 minutes before entry.

LOVELL That's why I called down and tried to simplify the procedures. We wanted to run through them and make sure we didn't have any conflicts between what Jack was doing in the CM and what Fred and I were doing in the LM.

SWIGERT We had the procedures worked out. I copied down that long procedure that Ken read up to me, and Fred and Jim copied down the LM procedures. Then, we sat down and went through each procedure item by item to make sure that we interfaced correctly, and we found that everything worked pretty well. There were only one or two items that we had to question Houston about. They had us pulling one more circuit breaker in the CM than we had. But, generally, it was a well-followed procedure, it was well read out, and we had no problems at all integrating the procedure.

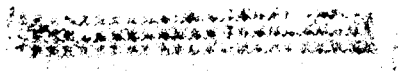
LOVELL The last couple of hours after midcourse correction 7, Jack brought in the probe and drogue, and we stashed those in the

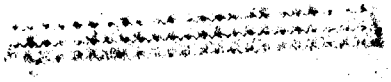
LOVELL (CONT'D) LM. We also got a lot of the debris out of the CM, and we put the trash in bags in the LM. We latched down the ISA because we put a lot of stuff in there. We latched it on top of the PLSS on the floor in the LM. In the last few hours, we had everything we were going to jettison in the LM already there.

HAISE We took a lot of pictures of this. It was pretty interesting looking, although the lighting is not very good inside the LM.

LOVELL The midcourse correction was performed at EI minus 5 hours, and at 4-1/2 hours, we went to the SM jettison procedure.

SWIGERT At this point, I had to pressurize the CM RCS system.





11.0 ENTRY

LOVELL We'll go to that point between the midcourse 7, which was the last midcourse, to SM jettison. We had to power up the RCS system and do the checkout.

SWIGERT Yes. I did this in ACCEL COMMAND. The thrusters sounded just like the simulator. I followed the checklist. I checked everything off, all these items; I checked them off with a pencil. We had good thrusters on both rings; all 12 thrusters fired.

LOVELL We heard them from the LM.

SWIGERT We could probably have seen some of them. I wondered because some of those thrusters pointed almost directly at us.

LOVELL The AOT had them in sight, too.

11.2 CM/SM SEPARATION

LOVELL The separation procedure, which was called up to us for separating from the SM, was very good. I don't know the details of the checklist that Jack went through. When we got to the point to jettison the SM, I thrusted up. Then, Fred went to verify that Jack was going to throw the right switch.

SWIGERT I wanted Fred there to make sure that I raised the CM/SM SEP switch and not the CM/LM SEP switches.

HAISE I did go, but he had gray tape over the LM SEP switches. I figured that was enough of a safeguard, and the way Jim thrusted, I needed to be there to control the pitch again with the TTCA.

SWIGERT You should have seen Fred when we got back there. I was all ready to go; I had the logic up and I was ready for pyro arm. Fred said he would get a GO from MSFN. Then I reminded him that we didn't have any telemetry and MSFN couldn't give us a GO. When I asked if he was ready, he looked at me with a wistful sigh, as if, "Well, go ahead." I put power up, and I could hear the relays clicking.

LOVELL We debated putting the hatches on, but we thought we might as well go all the way.

SWIGERT I was worried if we'd had some sort of relay, but both power systems armed beautifully. I was sitting there all ready to go, and Jim thrusted and yelled, "Fire," and I hit the switches, and the SM went.

LOVELL Did you hear me from all the way down in the LM?

SWIGERT Yes. I safed the pyros immediately, put the guards down on the CM/SM SEP switches, and went over to window 5 because I was supposed to be the first one to see it. I kept watching while Jim was pitching around.

LOVELL The SM jettison part of the maneuver pitched me down instead of pitching me up, which was the wrong direction. I was trying to get back in control to pitch up again. And, of course, we were in that CM/LM configuration, which we have never SIMed. That was the first time I ever had an ACA that would operate. Finally, when I pitched up, I saw it go by, and I grabbed one Hasselblad and took pictures through the overhead window. I don't think I had all the minus-x thrusting that I wanted.

HAISE We got about 1 ft/sec, which in my mind, I didn't argue with at the time. It would have been nice to have had a little separation right there, and they didn't allow for any with the procedure that they gave us. If Jim had been fast on that TTCA, we'd have pitched up there and the SM would have been 6 feet away. How far is it from the LM?

SLAYTON It was figured that you'd have about 70 to 80 feet by the time you'd pitched through.

LOVELL Well, it was about that when I looked up, and it was straight ahead. However, when I got to the forward windows, it was farther away than that.

SWIGERT It was good. When Fred called, I came on down because I had the 250-mm lens on the Hasselblad.

SLAYTON Did you get pictures with all three cameras?

SWIGERT We got pictures with all three cameras.

LOVELL The pictures I got were through the overhead. After that, the SM floated in front of the windows over on the right-hand side, so I didn't see it again. Fred and Jack got pictures then.

HAISE They told me to use the lunar surface camera and gave me f-stops and speed, but didn't really specify a magazine. I got a lunar surface camera and slapped on lunar surface film. What they really wanted was CM ASA 64.

LOVELL When I first saw it, I saw that the whole panel, the core panel, was missing off the SM. I could see the interior. I couldn't see any specific damage, but I didn't really know exactly what I was looking at, although there seemed to be a lot of debris hanging out. It looked like insulation-type material hanging out, and the panel went all the way back to the high gain antenna. We saw a streak on the engine bell, and that's about all I saw before I got the camera and started taking pictures of it.

HAISE I guess the two things that were identified very promptly as specific objects sitting out there were two barrel-looking things. I could see one set of tanks that looked to be in

HAISE (CONT'D) place. The streak on the engine was a kind of a green-gray color. When I first looked at the bell, I actually said that it looked like it was cracked. Then it turned around in a yaw maneuver and I looked straight up the bell. It was in good shape; it was not cracked.

SWIGERT I didn't get down there until much later in the time line and it was at quite a distance. I didn't distinguish any of the streaking. I could distinguish that a panel was missing because of the color difference in the other panels and that particular panel. The SM was in a very slow yaw maneuver, which gave us time to observe it all the way around. I did take about 28 pictures with the 250-mm lens. I used the settings Houston gave me, which was f:8 at 1/250th, and it appeared to me when I saw it that the SPS bell was intact. I did see some debris hanging out of the side and even hanging off the high gain antenna. When the SM turned around, either the debris was on the high gain antenna or was sufficiently far out to the side that it appeared to be hanging off the high gain antenna.

LOVELL That's what I thought. Something got to the high gain antenna because it did not look natural back there.

SLAYTON Did you notice whether the barrel was a fuel cell or hydrogen tank? Did it look like it was displaced, or did it look like it was in the proper position?

HAISE No, it just looked like it was - where I would expect it. I guess, from a few schematic pictures I've seen, it probably was a fuel cell. However, it looked physically mounted the way it should have been.

LOVELL I didn't see anything big hanging. I saw a lot of stuff straggling out; you know, floating in the breeze.

SWIGERT I guess the noise at SM SEP was what I expected from what I heard of on previous flights.

LOVELL At about that time, we had a discussion with Houston about controllability. I went to a PGNS ATT HOLD mode and used PGNS pulse to fly. They wanted to go to AGS. I disagreed with them and I finally went back again to AGS. However, the pulse in AGS just wasn't where I liked to fly it, and it was adequate in PGNS. The CM and the LM together made a very comfortable mode of flying. I talked to Charlie and I assume they had the fuel computed in AGS and that's why they wanted me to fly it in AGS.

SWIGERT There was a very large reflection off the LM sublimator and off one of the LM quads. Also, at that time, we were venting something. It appeared to come from the umbilical region, and I surmised that perhaps one of the cutters didn't cut through one of the water tubes or something like that. We were losing some sort of fluid. I asked Jim to come down because I couldn't distinguish any stars because of the stuff that was venting out. I asked Jim to come down and he couldn't distinguish any stars either.

LOVELL No, I couldn't see any stars through the sextant at all. Essentially, I was keeping the CSM SEP attitude with the LM. Finally, we had to go back to that 91 degrees. They gave us four stars that they thought we could pick up, so we held it there and I held that attitude until 2-1/2 hours.

SWIGERT I started the power when Jim gave me a countdown.

LOVELL The next thing, of course, was the alinement. We just waited while the power was up and all squared away.

SWIGERT It took Houston a long time to lock up on telemetry and it turned out that our attitude was bad. They were trying to transmit through the LM. It took a long time for Houston to get locked up so they could give us the uplink.

SLAYTON No, there was a little confusion there, I think. They wanted you to use AGS. They didn't care what you used to maneuver, it was what you used after you got into attitude they were concerned about. They were confused about that one.

LOVELL Oh, maybe that was it. Anyway, I wanted to use PGNS. The ACA PGNS maneuvering with the DAPs load is sufficient to control the spacecraft, that's all.

The powerup wasn't until 2-1/2 hours. We already had the rough alinement with the LM. We already had most of the equipment into the LM, so there wasn't much there.

SWIGERT We really didn't have much to do; we were kind of sitting and waiting.

LOVELL I went to the SM SEP attitude because that was a good attitude.

SWIGERT We were looking to see whether we could see stars.

LOVELL That's right. We went back and forth to see whether we could see stars, and we actually maneuvered from 91 degrees to about 115 degrees to see if that was a better place to see stars. We debated and oscillated back and forth with various angles and pitch.

SWIGERT (CONT'D) I was sitting there just chomping at the bit to get those updates, because I couldn't get my alinement until they got the updates done. We were behind on the time line. I kept looking where we should have been. We were about 5 or 10 minutes behind by the time they finished their alinement. I set the clock and the mission event timer, we got the coarse-aline angles in, and I went into P52.

LOVELL There was something wrong before that, though. Why couldn't we get the computer on the line?

SWIGERT When we powered up, the IMU circuit breaker, the heater circuit breakers, were punched on from the LM power. During LM power-down, I was standing by. I pulled the LM circuit breakers as soon as I got word from Fred. That put us all on CSM power. The first thing in powering up the computer is PROGRAM 06 with the flashing 37. They said to proceed and I would not get the STANDBY light and the DSKY would blank immediately. I tried proceeding, but I wasn't holding it long enough. I slithered back up into the LM and talked to them. They said go down and hold it. I did, and then the computer came up. We got both of those things resolved and they didn't cost us any time on the time line at all.

LOVELL Why didn't we have COMM in the CM, or was that later on in your checklist?

SWIGERT Yes, that came later on.

LOVELL Jack had to come on down to the tunnel and put on a headset to talk with Houston.

SWIGERT This was at a time when we were still using LM power. We didn't have the CSM powered up. But those were just minor problems. We finally got them squared away and I got the coarse-aline angles in and immediately started a P52 and got a PROGRAM ALARM. I knew right away what I'd done. I hadn't set the REFSMMAT flag and drift flag, and I had to reset. I set the REFSMMAT flag and went into P52 and, let it PICAPAR, Rasalhague, and I let it drive to that, I couldn't see it. The next thing I did was pick star 36, Altair, and let it drive that. The two stars were Altair or Vega. At that time, Jim was saying to hurry up because the Earth was getting bigger. He was chomping to get out of the LM. I did pick up a star in the telescope nearby. I put it in the sextant, marked on it, put it in star 40 and let it drive to that, put it in the sextant, marked on it, and got a star-angle difference. It was five balls. I proceeded and asked MSFN if I should torque.

SWIGERT (CONT'D) We had about a 3-degree torquing angle in yaw and less than a half degree in roll and pitch.

LOVELL We had the big torquing angle in yaw in the LM.

SWIGERT Right there, getting that P52 put us ahead of the time line, and we never were pressed from then on. At that point, we went back to POO and closed out the hatch. We put it on LM tunnel vent, and it started venting as soon as we got the hatch down. Jim kept monitoring CM/LM DELTA-P, and things went just like clockwork. Fred and Jim read the checklist.

LOVELL I closed the vent valve in the forward hatch and turned off the oxygen. I closed the tunnel hatch. I had also taken the umbilicals off. Ken mentioned that they weren't required, but I did it to make sure we didn't have anything dangling. I put it in AGS ATT HOLD and then we left it.

SWIGERT MSFN took the EMS check and moved it over, which gave us plenty of time to do it with other time lines. Once we got the P52 through, everything was very comfortable. We got strapped in after we had double checked the stowage for loose items. The EMS checked okay. The hatch contingency check was okay.

LOVELL I don't know what we would have done if it wasn't. I guess we would have just held off jettisoning the LM and tried to get the hatch back again to get a better seal.

SWIGERT We did have some time that we could have put on the suits, although it would have been pushing it.

We actually separated early. We asked if we could SEP early. Jim was maneuvering to LM SEP attitude.

LOVELL I held CSM SEP; it was all squared away. Then they said go to LM SEP attitude, and I got it right here. That's where I said that was a lousy attitude. I found out by talking to John Young that he had tried it and had the same problem. Here it is right here; roll 130, pitch 125, and yaw 12.4 degrees. So I started going there and I kept getting stop, because of gimbal lock in the CM. I wondered how to get to the attitude in the LM without going through gimbal lock in the CM. We had to go way around.

SWIGERT That's exactly what we did. I would tell Jim, and he would get a pitch rate started, and then he would get us away from gimbal lock. I would say to roll a little, then he would roll a little bit. Then, we continued to pitch. We just GCA'ed into the thing.

LOVELL That's what used up much of the gas in the LM. That's where I thought we also had a discussion on whether we should be using AGS or PGNS. I preferred PGNS right there. Anyway, we got to that attitude.

SWIGERT It put us about 65 degrees in yaw on our CM gimbal.

LOVELL That was uncomfortable.

SWIGERT It was!

LOVELL We were very close to gimbal lock. I questioned whether that LM SEP attitude is that critical. Was it so critical to be at that attitude, or would it have been better to stay away from gimbal lock in the CM? At the time, we didn't have a backup. We didn't have the BMAGs powered up. If we had gone into gimbal lock, we would have had to start from scratch again.

SWIGERT We had one BMAG powered up at that time, and we only had one FDAI powered up. I had the GDC powered up, but, of course, with only one FDAI, it had to switch back and forth. I would recommend that if we had to do this again we stay away from the CM gimbal lock region. When we did SEP, we got a continuous pitchup in the CM. I was in MINIMUM IMPULSE. I had my MANUAL ATTITUDE switches in MINIMUM IMPULSE, but I had my DIRECT RCS

SWIGERT (CONT'D) switches ON. When Jim said I was getting near gimbal lock, I just gave it a quick beat down with the DIRECT switches and started pitching down. No sooner had we stabilized then we started to pitch up again. We had a continuous pitchup in this CM all the way through this thing.

LOVELL The first thing we had to do was to maneuver away from the gimbal lock attitude, get on the bellyband, and get set up for entry attitude.

SWIGERT We went to entry attitude, and I got it as close as I could — stabilized. Jim did a secondary star check and a star path. We had a lot of confidence.

LOVELL As I look back on it now, I am trying to see what we would have done if we had of gotten the gimbal lock and lost our alinement. Houston told us about the Moon, and it was a perfect body. The only thing that we could have done would have been to maneuver around to the horizon and find the Moon. We probably could have gotten there that way, but it would have been difficult.

SWIGERT That was a little too close to gimbal lock.

LOVELL We had a discussion about that. My ball was alined with 3, 3, zero. The only thing that I was worried about was roll. I

LOVELL (CONT'D) thought yaw was good, but I had a hard time getting there because of his gimbal lock, and, of course, I didn't want to go into gimbal lock either.

SWIGERT I thought our coordination there was good.

LOVELL It's a gas user. One time when we were getting close, I just went to ATT HOLD. I could hear those thrusters firing.

SWIGERT We had a large rate.

LOVELL I'll have to take a check on yaw.

SWIGERT Then I said, "Start up yaw."

LOVELL Yaw was 360 degrees. I thought sure we had it that way. It took me a long time to get it around that way. Maybe for some reason when I finally got it out of gimbal lock, I went to the other direction.

SWIGERT The LM/CM DELTA-P was 3.5.

LOVELL Yes, we bled it down so we wouldn't have too much pressure in the tunnel when we separated.

11.8 CM/LM SEPARATION

SWIGERT On the CM/LM SEP, the LM moved smartly away and the noise didn't appear to be excessive. Immediately, I noticed a pitchup in the CM about the same time that Jim called a GIMBAL LOCK. We were sitting right near the gimbal lock limits, and he had a GIMBAL LOCK light on the DSKY status lights. I pitched down, using the DIRECT RCS switches. I came off then with the three MANUAL ATTITUDE switches. We did get out of the gimbal lock region and stabilized. All the time I noticed a continual pitchup rate. However minor, it would definitely affect the attitudes, continually pitched up. We went from the separation attitude down to the entry attitude, and Jim performed the sextant star check. Our maneuver from that was to the Moon-check attitude, and we maintained this attitude in a kind of wide deadband fashion until our Moon-check time.

HAISE Maybe it was because of your being busy with the test, whereas I was just an innocent bystander sitting over there, but the LM SEP impressed me as being the loudest pyro event that I heard from stem to stern during the mission.

LOVELL It was encouraging, I know.

HAISE It was very close, and it impressed the heck out of me, I know. It actually rocked me off my seat toward the window when it let go.

SWIGERT I didn't notice that, perhaps because I had both hands at the controls.

LOVELL Now, my only comment on the Moon thing is that the Moon was a perfect alinement factor right through the center hatch. I could see it work its way right on down. I think that you could use that Moon as an entry point if you had the horizon also.

SWIGERT Yes.

HAISE The Moon isn't always going to be there, though.

LOVELL I know. It was there on Apollo 10; it was there on Apollo 12, and it was there for this one.

SWIGERT This particular time, it was the Moon that occulted at the correct time.

LOVELL Yes.

SWIGERT Remember, we counted down to it; and, blink, it went out.

LOVELL Yes, they were pretty accurate on that.

SWIGERT They were.

After the Moon occulted, we pitched down to entry attitude again and stood by for .05g. We hit our RT, and counted up to 28 seconds, which was .05g time according to the pad. We got the change of displays and the computer. However, the EMS did not start within 3 seconds, and I initiated the EMS start manually, by going to the backup on the EMS. It was apparent when we hit the 4000 ft/sec on the V-axis drive that the EMS was slightly behind in range to go over what it normally is because of the late start. The corridor checks came out okay; it gave us lift vector up.

LOVELL That corridor was fine.

SWIGERT The computer drove it throughout the entry and responded well.

LOVELL Yes. The computer was running right with us.

SWIGERT Yes.

LOVELL The control was right with the guidance.

SWIGERT The g-meter, the EMS g value, and the CMC g values all checked very closely.

LOVELL And they were close to pad values.

SWIGERT It was a very quiet entry, I thought.

LOVELL Not noisy at all, was it?

SWIGERT No. I've never been through any other entry, but I was quite impressed with it. Of course, Jim kept briefing us on what to expect, and we did get the small bit of ionization just before .05g. We got just a little bit of glow.

LOVELL Yes. We started getting a glow; in fact, we were all lit up before we started getting any g's.

SWIGERT The CMC control mode was quite effective. We made a single-ring entry on ring 1, and we had plenty of RCS fuel.

LOVELL I saw nothing of that whole entry that was off nominal. Everything worked the way it should have worked. We had automatic apex cover JETT and drogue deployment. You verified the drogues, right? You saw the drogues?

SWIGERT Yes. I got two good drogues. In fact, I called that going to 18 000 feet with two good drogues. Did Houston hear that?

LOVELL They made one call after blackout before we put on anything, I think.

SWIGERT Yes.

LOVELL And Houston confirmed that, too. The COMM, again, was beautiful.

SWIGERT Yes.

LOVELL It was okay except for the blackout.

SWIGERT Yes. And there didn't appear to be any unusual oscillations on the drogues. The drogue had us damped out pretty good.

HAISE There was another loud metallic sort of noise when the pyros went on the apex cover. When that thing went, there was a clang. Again, that would be my second-order number.

LOVELL All that is sort of happening above your head there.

SWIGERT Just above 10 000, we got main chute deployment with three good chutes in a reefed position, and they dereefed in just about the proper 8-second interval. We could hear the recovery choppers calling us. The communications were good during the whole descent.

LOVELL The last thing that slipped out was the main chute after cold soaking for that time. After that, Fred fell asleep.

SWIGERT Jim read the checklists. We proceeded down the checklist. We burned RCS and purged. It was a brownish purge and it left a film on the side windows and the rendezvous windows.

HAISE On both side windows.

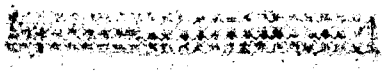
SLAYTON I saw that on TV.

SWIGERT That's the purge rather than the burn. I never realized that before. I always thought it was the burn that did that.

REEDER Too bad you missed the recovery on TV. It was the best one yet.

LOVELL That's great. I'm glad the TV worked out for that part of it. I'm glad you had a nice sight, instead of hearing something whistling through the canvas.

LOVELL Okay. Visual sightings and oscillations — all that was exactly like cake, even better.



12.0 LANDING AND RECOVERY

12.1 TOUCHDOWN — IMPACT

LOVELL The impact was as designed because the sea state was slow and we knifed in. It was less impact than Apollo 8 and we stayed stable I. Fred cut in on two circuit breakers and Jack jettisoned the chutes.

HAISE I think I had only one in at the time he hit the button, but that's all it takes.

LOVELL Everything worked exactly like the checklist worked.

SWIGERT We just went right down the checklist, item by item.

LOVELL The only thing we forgot to do — I guess I forgot to punch to get lat-long out of the computer.

HAISE The last time I saw, we had miss distance of 0.8 mile. The choppers asked us if we had lat-long laid out and, at that time, we didn't have. It might be of interest to point out that, after we hit and had gone through this smoke and entry, we were all three sitting there on the couches, laying in that 81-degree water, blowing frosty smoke out of our mouths. It was still icy cold in the CM.

LOVELL I don't think we ever got swimmer communications, did we?

SWIGERT No, no swimmer communications.

LOVELL But he was out. We could see him and we got word from the choppers about what was going on. The swimmer got up and looked at the window and we were going to open up the hatch. Then we got the new lifevests which I think are pretty good. Jerry wanted me to make a comment on that. We decided to go with these new marine lifevests. Of course, if we had known about no quarantine, we could have used our old ones and never even bothered to open up the hatch, but it was already in work and so we used them and it was okay.

SWIGERT We put the postlanding vent on low to get some air.

LOVELL We used the beacon, which they wanted to turn off.

HAISE But that was on the checklist. We just went down the checklist. It said to turn the beacon on and we turned it on.

SWIGERT And they asked us to turn it off and we obliged them.

LOVELL The ventilation was adequate; there was very little rocking in the boat, so no one was sick.

12.8 COUCH POSITION

LOVELL I put down my couch because I went down to 250 to open up the circuit breaker.

12.11 RECOVERY OPERATIONS

LOVELL Recovery operations were very smooth. They got that down to a gnat's eyebrow. Of course, they had good weather to do it and you saw all the recovery operations.

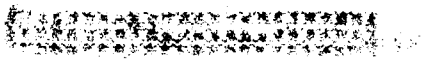
12.12 SPACECRAFT POWERDOWN

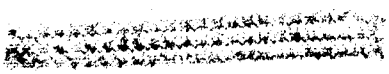
LOVELL We didn't have much powered up, actually.

HAISE We just yanked the breakers on 250 and that did it.

SWIGERT That powered us down.

LOVELL Egress was okay and we had a good crew pickup.





13.0 COMMAND AND SERVICE MODULE SYSTEMS OPERATIONS

13.1 GUIDANCE AND NAVIGATION

13.1.2 Optical Subsystems

SWIGERT Houston did call me at one time to say they noticed a shaft glitching. I took the optics out of ZERO to call up 16 91 and read the shaft angle and I called them and told them what the TPAC was doing and they could rig the CMC. Their advice was that this was something that they had noticed previously on Apollo 12 and they asked me to turn my OPTICS POWER switch OFF, and I could turn it back on anytime I needed the optics. Of course, this confused me because I went down to my first sextant star check and the optics wouldn't move.

HAISE Optics power was off manually. I forgot to tell you about that. That was the only anomaly we had in the optical subsystem.

13.2 STABILIZATION AND CONTROL SYSTEM

SWIGERT Of course, we didn't use any SCS thrust vector control. Minimum impulse was okay.

13.3 SERVICE PROPULSION SYSTEM

SWIGERT We never used the DIRECT ULLAGE button. We never used the THRUST ON button. We made one burn, the G&N burn, that was completely nominal.

13.4 REACTION CONTROL SYSTEM

SWIGERT There is some speculation as to exactly how many thrusters we had after the incident and this is something I don't think that we can resolve thoroughly.

LOVELL They were working normally before the accident.

13.5 ELECTRICAL POWER SYSTEM

SWIGERT I think we've already talked about the fuel cells.

HAISE I've got one thing to add on the batteries, mainly with respect to simulators. I noted that, after we used the batteries to support the gimbal motors operation during my midcourse burn, when I flipped the bus ties off, rather than as in the simulator with the batteries going immediately back to 35 to 36 volts, they hovered around 32 volts. It would take them a long while to increase to maximum voltage. This is a very small point but something that was a little bit different from what I'd seen in the simulators.

13.5.9 Cryogenic System

SWIGERT The only anomaly we had in the cryogenic system was a continual unbalance between the two H_2 tanks which we were endeavoring to adjust manually. We had the failure of the sensor in the O_2 tank 2.

LOVELL Yes. That might be related somehow. I think what ever caused the O_2 transducer to fail might have also been the cause of the catastrophe.

SWIGERT Particularly, when it occurred. They said it occurred at the time we turned on the fan. Remember, the exact time they said we turned on the fan, they said at that instant this tank quantity sensor pegged full-scale high. Houston came back and they said that because this occurred when we turned on the fans, they'd like us to recycle the fans again to see if perhaps we could jar it into operation.

LOVELL I wonder, if we had purged the fuel cell or something like that.

SWIGERT The way Pete was talking, even the relief valve couldn't handle the particular flow. The heat source had to generate something like 8 to 10 thousand Btu's an hour to exceed the relief valve. The surprising thing to me is that I did not get a CRYO PRESS light. I don't understand that.

LOVELL We were getting a CRYO PRESS light on the hydrogen, you know.

SWIGERT On the low end. We got it on oxygen, also, when we first cycled the fans. Remember I was telling that there was an

SWIGERT (CONT'D) indication of stratification, but we never did get anything on the high end.

13.6 ENVIRONMENTAL CONTROL SYSTEM

LOVELL We had no problem up to the time we had the accident.

SWIGERT We had no problem at all.

13.6.7 Waste Management System

SWIGERT We found that, during the initial first 8 hours, when the waste storage valve was open, when we went to dump urine and used the urine dump - -

LOVELL We had two vents open.

SWIGERT We had two vents open but, for some reason, it didn't seem as if we were evacuating that urine.

LOVELL Very, very, slowly.

SWIGERT Very, very slowly. And then, after we got through purging the cabin, we turned the waste stowage valve off, the efficiency of the waste management system seemed to improve.

LOVELL There is a technique to operating that thing. You've got to sort of push that stuff down by gluing it, somehow; otherwise

LOVELL (CONT'D) it all sticks around the honeycomb and the next guy who comes to open it up finds a nice big glob of urine sitting there.

SWIGERT So we developed a technique, before using it, of turning the vent on, tapping it a couple of times, and raising the cover up and down a couple of times. Then when you opened it up, it was fairly clean.

LOVELL That urinator requires the same technique.

HAISE There's no question about your impression about the vents. In fact, the first few times I went, I filled it up to the brim, with liquid. You just sit there and watch it slowly go down. It held its meniscus and didn't break out. Then later on it would go right on down.

13.7 TELECOMMUNICATIONS

SWIGERT We did not use VHF.

LOVELL We had a little difficultly locking up sometimes. What was causing that?

HAISE I never had trouble locking up. The problem I had was I just had the switch in the wrong position MANUAL and REACQ. So when Jack maneuvered, it didn't track.

SWIGERT I didn't have any problem with communications. Some items like USB emergency keying were not used. The ground operated the DSE. Our tape recorder worked adequately. We probably had the minimum tape recorder usage of any flight that's ever flown.

13.8 MECHANICAL

LOVELL Did you check the Y strut on entry?

HAISE Yes, when Jack was up there, it was unlatched. Jack tied it up.

SWIGERT We had the CM in good shape before leaving the LM. Fred kind of went around and double checked me.

13.9 MISCELLANEOUS

REEDER This might be a good place to answer these questions, that those guys are interested in. Why don't you just read the questions and give an answer?

LOVELL Technical Crew Debriefing Questions Generated from Data and Photo Review. Was the oxygen tank on the SM gone? I cannot tell. I don't know.

SWIGERT I could not tell either; because, by the time I got down there, it had gone.

LOVELL As long as I looked at it before grabbing the camera, I didn't have a good enough look to see. It was all being reflected back in.

Was the hydrogen tank canted? I can't answer that question either.

Was the panel cleanly removed? Yes. It was just completely removed away from where it normally swings out and no pieces of panel were still attached that I could see. Did you see anything of those panels?

HAISE No.

LOVELL They were just blown out.

SWIGERT Were all bolts sheared uniformly?

LOVELL We don't know, we weren't that close.

Was there any positive damage to the SPS nozzle? Not to our knowledge. One side of it was stained with something, but we didn't see any bent part of it, pushed in or dented or cracked or anything like that that we could see.

Was there any indication of where explosive flow could have exited, streaks, et cetera? Except for the streaks on the

LOVELL (CONT'D) engine nozzle and the fact that it looked like it was more damaged back by the high gain antenna than up forward, that's the only indication that I have. It looked like the damage occurred back in the high gain antenna because it was messed up inside.

HAISE Yes, it appeared that there was some material like insulation or something like that still attached to the high gain antenna.

LOVELL Do you have any knowledge of damage to radial beams, size of hole, shape, et cetera? I have none.

HAISE No.

LOVELL Was there any other noticeable deformation on the bays? It looked like the basic structure itself was still intact. It wasn't warped or anything like that. It was just that the panel was missing.

SWIGERT It appeared that way to me, too.

LOVELL Did you see anything different?

HAISE No.

LOVELL The last question is how many bangs? Was there a second bang? To the best of my knowledge, there was only one explosion.

SWIGERT I agree.

14.0 LUNAR MODULE SYSTEMS OPERATIONS

14.1 PRIMARY GUIDANCE AND NAVIGATION SYSTEM

LOVELL In the PGNS INERTIAL, I saw nothing.

Optical — Nothing there except the use of the Sun filter was a little more difficult than I anticipated because of not being able to see the reticle.

HAISE Something peculiar to the configuration of the AOT is that, out the front detent, the CM docking light hung down on its staff almost to the center of the AOT field of view.

LOVELL For alinements, the CM probe (the docking light) hung way into the middle of the AOT. And if the Sun is behind you and you have a bright sky, you can see the stars and can get an alinement. The Sun reflects right off this thing, so it's like having a light staring at you. We used the rendezvous radar only one time and that was to move it with the PGNS, and it worked. We never used the landing radar. The computer subsystem worked as advertised. G&N controls in space were okay. Procedural data — We went around a lot of the procedural data, but what we had was good.

14.2 ABORT GUIDANCE SYSTEM

HAISE In the AGS modes of operation, all we used were the body axis aline and the zero and three accelerometer addresses, but we didn't really use any of that — the normal modes, the external DELTA-V included. Concerning the initialization, we didn't do any. We didn't do any calibrations — we just accepted the ground test data. We didn't do any rendezvous radar, engine commands, or burn programs. We did use some AGS controls and displays; namely, 8-ball and the error needles associated with the AGS — really CES rate needles. They all worked quite well.

14.3 PROPULSION SYSTEM

HAISE We have talked about the descent system.

LOVELL The DPS burns worked nominally; we had no problems with them. We never used the ascent engine or pressurized the ascent tanks. We always had an ASCENT PRESSURE light.

14.4 REACTION CONTROL SYSTEM

LOVELL The attitude control modes were just as I had been briefed, and the operation of the thrusters and the responses to the controls were unusual because we had a different configuration; however, they were manageable. I think we covered that adequately in a previous briefing. The translation control worked as advertised.

HAISE The only thing I noticed funny was during every pulse the fuel and the OX manifolds, whichever one you were looking at, would get about a 20-psi delta drop. I'm not really sure if that was from some kind of hydraulic shock in the lines or an actual drop. I can't remember reading about that before.

SLAYTON Did it stabilize there?

HAISE No, it was momentary. Just very quick and then right back up to normal.

14.5 ELECTRICAL POWER SYSTEM

HAISE It was great. There was one MASTER ALARM one night with a battery light that quickly turned out to be an obvious sensor problem.

LOVELL That was another one of those little things that worried me when I first came up.

HAISE So, basically, the electrical system was flawless.

SWIGERT It appeared almost impossible to have any problem with the battery, because we were down at 10.3 amps and the total amps didn't change. So, it couldn't have been reverse current. We surmised that it was a temperature sensor problem. It was almost instantaneous.

14.6 ENVIRONMENTAL CONTROL SYSTEM

LOVELL We never used the suit circuit. The water-glycol was as advertised. The cabin atmospheres were good.

The cabin atmospheres were good. Oxygen cabin pressure — no change there. We did "kluge" up the CO_2 scrubbing system with the CM canister and that was the only change.

14.7 TELECOMMUNICATIONS

HAISE Concerning the monitoring, most of the time we were using the SBA down voice backup mode. I guess we were forced to use that because of the power margin, but probably you know more than we do, Deke. I understand it could be pretty noisy and you couldn't hear us very well. But from our end, the uplink was great all the time. We never had any problem hearing Houston, regardless of the mode we were in.

Later on, we arbitrarily went to the so-called base band down voice backup mode voice band, which means throwing the BIOMED switch one way or the other — just because I wanted to get off the hot mike for fear my Commander would come awake and say something he shouldn't. Then when we had high bit rate, I had the amp in and they wanted high bit rate and all that.

HAISE (CONT'D) Then we'd go back to normal voice, which would give you better voice clarity. We never operated the high gain the whole mission. I guess what I am really talking about now is the S-band. We never operated VHF. We had no problems with the audio centers. The volume controls were quite adequate. We never operated the flight recorder. The DSEA was never run.

SWIGERT One thing, I did want to go back in the CM subsystems in RCS. This was the first time we had ever preheated the CM RCS engines. I think, when we started out, the 3.9 volts was the minimum value I recorded. I reported to Houston what the values were when we first started and it strikes me that 2.8 volts was the lowest engine. We did go a full 20 minutes and at that time there were still several engines below the 3.9 volts. However, after I turned that switch off, I went back down about 5 to 10 minutes later and took a couple of extra readings. There was enough heat soakback that soon we had all the engines over the 3.9-volt minimum. So you might expect the fact that there was some thermal lag in this system and that it might have been 15 minutes. If someone is worried about 20-minute operation of these engines, they might turn them off at 15 minutes, wait 5 minutes, and see how the temperatures have come up — because they increased significantly, maybe half a volt, a significant

SWIGERT (CONT'D) temperature rise after I turned off the heater. I did want to mention that because no one has ever preheated engines before.

15.0 FLIGHT DATA FILE

15.1 COMMAND AND SERVICE MODULE

SWIGERT We went right down the launch checklist, and it worked well. We had no problems.

The entry checklist from EI minus 19 minutes was the nominal checklist with a few items changed. Prior to that, from EI minus 6-1/2 hours, we rewrote the checklist. We had no problem getting updates. Launch keycards are good.

The systems operation G&C checklist was completely adequate. Systems data were good. We read off the malfunction procedures item by item. We used the flight plan right up to 56 hours, and it was completely nominal. We logged things in the flight plan. The solo book, the rescue book, and the star charts weren't used. We used a lot of clips, but that's all.

15.2 LUNAR MODULE

HAISE The LM was almost as easy. We didn't use the data card book. We lived out of the contingency checklist approximately 60 percent of the time. That was really a base line from which Houston passed up changes that we built on; either erased or added to. About the other 30 percent of the time, we put the

HAISE (CONT'D) LM data in the CM update book, which had a large blank section in the back that was a photo log. That was a convenient place with blank pages to use. The other place we worked was on the activation book. I think we only broke out three of the cue cards; one of them was the DAP card that also had the DPS RCS pressure data on it; another was the BUS loss card; and also we had a DPS card. We used the systems activation checklist, of course, for the first LM entry. We used a few pages of it, and the one addendum page for the tank pressure. Then we used it again, "kluged-up" by Houston, to go to only certain sections to do the first LM activation after we had the problem. Jim may have used the front of the G&N Dictionary. I used every pad I had in the back. We had a lot of P30 pads in the back of the G&N Dictionary, and that's about all I used to write all our pads in. In fact, I ran out of P30 pads. The last pad they gave me was the last blank one I had.

LOVELL Yes. We used the back of the pads.

HAISE Do you have any comments concerning the front part of that book?

SWIGERT No.

HAISE Charlie ran us in once, and we used the P52 business.

LOVELL I did the P52 out of here. We also did the Sun check out of here. Everything in here was adequate.

HAISE I had occasion to use the systems data only to total up my consumables and to start calculating where we stood. I didn't use my function procedures. We never used the Time Line Book.

LOVELL We never used the star charts.

HAISE No, we never used the star charts. We did use part of that EVA book, not in its normal usage, on the cartridges.

LOVELL We used the voice recorder for guitar music.

HAISE Well, I recorded one whole half hour of LM noise. I decided that I'd save old Aquarius's grinding and moaning, squealing glycol pump, and suit-fan-running noise for posterity. I guess none of us used any charts listed here.

SWIGERT No. We didn't use any of the CSM monitor charts or any of the orbital science charts.

15.4 GENERAL FLIGHT PLANNING (FDF)

SWIGERT As far as general flight planning is concerned, I have no comments on the solo phase, because we didn't get that far.

15.5 PREFLIGHT SUPPORT

SWIGERT I think for the CM that Ken would be more appropriate to answer the preflight support, because, as far as I was concerned, it was entirely adequate.

LOVELL I thought that we were well ahead of the game, mostly for preparation for the launch. I think that was based on several items. Number 1 is the fact that we've already gone through this landing phase before, and we had that extra month, which I don't recommend, to get the Flight Operating Data File a lot earlier than we have ever had to my knowledge before, either in Gemini or Apollo. We had data on Apollo 13 to train with earlier than we ever had before.

16.0 FLIGHT EQUIPMENT AND GOVERNMENT-FURNISHED EQUIPMENT

SWIGERT The knob came off a portable timer in the CM. Other than that, our timers and controls were adequate. That one timer is very useful, by the way. It could be used to time fuel-cell flow, purges, and so forth, so it was disturbing that the knob came off.

LOVELL I don't know how to discuss the clothing and related equipment. Obviously, the inflight coveralls we had weren't adequate for the conditions we had. The coveralls are great for a nominal mission. I hate to imply that we ought to carry liners or something like that with us. I sure think we can improve the footwear, though. I know that Grumman, down at the Cape, has for their checkout people a soft boot that is worn in the LM. An insulated soft boot would have been much more adequate than what we had.

HAISE With the addition of probably just one set of Nomex thermals, we'd have been in good shape. We needed a set of thermal underwear on.

SLAYTON What did you end up wearing?

LOVELL Constant wear garments.

HAISE Two constant wear garments.

LOVELL Did anybody have any problems with the sensors on the BIOMED harness? I didn't have any problems. We left the sensors on all the time.

SWIGERT Oh, yes. I got a rash. I got a rash from the sensor paint. I have never been tested for this particular phase, but the doctors attributed this more to the tape reaction than to the paste reaction. I left them on the whole time. They were there when we unsuited.

LOVELL We had no problems with the pressure garments and connecting equipment, but, of course, the suits came off right after TD&E and we stowed them.

SWIGERT I tried my suit on once to make sure that I could get it on by myself.

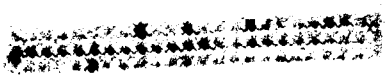
LOVELL There were certain things that Jack wanted to make sure that he knew how to do. One was to put the suit on by himself. During the quiet period before the accident, he put the suit on by himself. We also mounted all the cameras to make sure that Jack was checked out.

LOVELL (CONT'D) We had no problems with couches that I know of. The restraints were adequate. No problems occurred with the inflight tool sets. We were keeping logs on food and everything else.

HAISE The only shortage we had was what I mentioned on the air. What we really needed was a big, blank pad of paper for our unusual situation.

LOVELL We used to carry a crew log on Gemini to put comments on.

HAISE On the number 2 lunar surface Hasselblad, we had to push the trigger offset to the left to make it work very easily. It was very difficult to work if you pushed it low, center, or to the right side.



17.0 VISUAL SIGHTINGS

17.1 COUNTDOWN

LOVELL During countdown, we saw the swing arm go back, and that's about all.

17.2 POWERED FLIGHT

LOVELL We saw the horizon at the proper times. We saw the flash from the separations and some debris go forward.

SWIGERT Did the BPC hang together in tower JETT? Could you see it?

LOVELL I just saw it go, I saw a big light, and I went back in.

HAISE It looked like one big cone. Would that mean that it stayed on?

SWIGERT We didn't get any moisture on window 5, so it's apparent we didn't have any water under the BPC.

17.3 EARTH ORBIT

LOVELL There was nothing unusual in Earth orbit.

17.4 TRANSLUNAR AND TRANSEARTH FLIGHT

LOVELL We saw the S-IVB. We reported the last time we saw it, we saw the SLA panels. I think that Fred was mentioning the fact that during one part of the flight we saw some parts of the SLA panels on the S-IVB close by post 5. We could see a blinking star that was probably the SLA panel turning.

SLAYTON Did you see the light flashes in the CM?

LOVELL Yes, we did. They're right. I didn't see it after the accident. When my eyes were closed, and occasionally, a streak would go through.

HAISE It's amazing; I didn't see them after the accident either. We never saw them again.

SWIGERT It is a CM unique phenomenon.

SLAYTON It would be interesting if you noticed it in the LM or not. Nobody has ever had a chance to do that before.

SWIGERT I didn't note it at all while I was in the LM.

LOVELL I won't build a story. I won't say they're there or not. We were so preoccupied after the accident that we weren't looking for something like that.

REEDER You didn't sleep in the CM any time after that?

SWIGERT Yes, we did.

REEDER You still didn't see anything?

LOVELL I wasn't thinking about it.

HAISE I think I saw them the very first time after the incident; the very first time I went to bed. I think I saw them then.

LOVELL I only saw them with my eyes closed.

HAISE Yes. I have never seen them with my eyes open. There were more directs than there were streaky ones.

LOVELL Yes. You're right; more pinpoints.

17.5 LUNAR FLYBY

SWIGERT Tsiolkovsky stuck out.

LOVELL Our particular orbit around the Moon brought up Tsiolkovsky very nicely.

HAISE Yes. That was the first actual landmark I saw on the back side that I recognized.

LOVELL What about the oblong craters that we saw? I'd like to just go back and look at the back-side photography, because you can really see that. The Moon has these oblong craters on the back side. I don't know exactly where we were.

HAISE I directed a lot of pictures out the right window. Our track was kind of the normal Apollo belt. It might be of interest to somebody, although the Apollo belt has been covered pretty well without pictures. We were starting to gain altitude almost immediately. Fine detail just wasn't really ever there. I mean I never saw anything I could say was a boulder; we never were down that low. The best you could tell was that there was slumping inside some of the craters, on a very large scale.

Actually, I disagree with Jim. When we came up on the back-side terminator in the CM, the color I saw was a combination black to a reddish-brown to white mantling on some of those features.

SWIGERT My description would be dirty beach sand.

HAISE Even right at the terminator?

SWIGERT That's right. I would say it just looked grayish, a grayish brown, like a white sand that had gotten dirty.

SPEAKER That's the way I look at it. I thought that was a good description.

17.6 ENTRY

LOVELL Were there any visual sightings in entry?

SWIGERT No.

LOVELL The main chutes.

SWIGERT Well, I did get main chutes, but there was so much film on that rendezvous window that the drogues and mains did not stand out. If somebody had asked if any panels were missing from the main chutes, I couldn't have told them. I could spot the chute itself. But the purge put enough film on there that distinguishing fine detail was impossible.

HAISE I didn't get that much out my side apparently. I don't recall ever losing sight of the mains.

SPEAKER Would you have known if you had panels out?

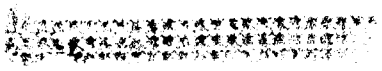
HAISE Yes, pretty sure.

SWIGERT I could see just by the diameters when they reefed.

HAISE I was watching them when they were going from reef to full.

18.0 PREMISSION PLANNING

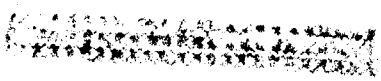
No debriefing was conducted on this section.

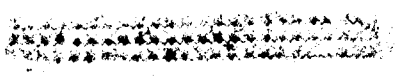


19.0 MISSION CONTROL

LOVELL We can't give enough praise for what they've done. They were up at all times with consumables, especially after the accident. They kept a pretty handy eye on consumables. Real-time changes were exercised to the utmost. We had a tremendous number of real-time changes, and I think they were handled very adequately.

Communications, in general, were good. I thought the LM communications were especially good.





20.0 TRAINING

20.1 COMMAND MODULE SIMULATOR

LOVELL You might have a comment on the availability because you didn't have priority for both the training simulators.

SWIGERT I thought the training that the backup crew received was good for the time involved. Ken and I split the simulator time until right near the end. I think that's the way it should be.

LOVELL You might comment on your reaction on having to replace Ken at the last moment. What did you think about it? Should you have known about it earlier?

SWIGERT The earlier you know about it, the better off you are. We could have used a session or two together in some of the areas that we didn't have time to run. I had worked with you in one rendezvous before, and I didn't have any misgivings at all about working with you. I thought that we might suffer a little bit on the lunar-orbit activity, but this was a low-priority item, so I had no qualms at all about being prepared to do the job.

LOVELL I think the story here is that, if we have a backup crew and a prime crew, we can replace a prime crew member with a backup

LOVELL (CONT'D) crew member if he's had the background training that Jack had. Jack was knowledgeable on the CM to start with. He had worked all the malfunction procedures. He had a lot of good simulator training in our training. The simulator was available so we could give the backup crew 50 percent of the time up to the last 3 weeks of training. In the case where somebody comes aboard new and becomes a CMP, then you're going to have to analyze exactly how much simulator training he has had and what his background is. We had no problem even with the minimum amount of training we had with Jack. We were time-line wise and flight-plan wise. We were going right ahead of the game, and I had no problem at all. I think that was a good decision we made to go in April.

HAISE Part of the thing we were supposed to discuss here on the CMS/LMS was the fidelity of the simulator. I've already broken it out in pieces. I want to discuss them again in the CMS. I mentioned the voltage/fuel-cell-flow relationship with the gimbal motors and the battery not regaining its voltage as quickly after having the main bus back on.

LOVELL If you duplicate the noise, I would suggest that you have it such that you can turn it on or off.

HAISE The only other funny thing I noticed on the LM was the very quick spiking of the RCS pressure when we fired jets. Everything else seemed high fidelity. We were doing things with our CM/LM configuration that we'd never looked at in the LMS. I don't have any idea what the comparison is there. I thought the firing of the LM stack (the way we did it, with the translation controllers) was easier for pure pitch and pure roll in real life than it is in the LMS for doing the burns.

LOVELL It's easier to do the burns that way.

One thing I think that we can prove on the CMS and the LMS is using the planet bodies for an alinement. That's one thing that we didn't do adequately enough using the unit vectors. We don't have the simulations set up where we can get accurate alinements.

SWIGERT The CMS is limited so that you cannot do planet alinements or Sun alinements. You can make optics calibrations only on selected stars. I couldn't go down and do a set of P23s because invariably it's only by coincidence that the optics calibration star is one of the stars that you can perform an

20.2 LUNAR MODULE SIMULATOR

HAISE I'd said the thruster noises on the LMS are, at the normal level that they have for us when we're unsuited, not quite as loud as they really are in the LM itself. I noticed that, when things popped, they really popped, particularly when they were the forward quads that are right outside the window. They really bang. The big things that are really missing in the LMS, which from a training standpoint I don't consider pertinent at all but in real life it's something that you have to get used to, such things are the glycol pumps and the suit fans running. They make powerful squeaking noises in the LM.

SWIGERT They change frequency, and they gurgle. I assume the fluid goes from turbulent to nonturbulent, and it just doesn't sound like it's acting right. That's just the way the LM sounds, and it was pretty rough. Fred told me any time you don't hear those changes, there's something wrong.

HAISE I'm not really knocking the LMS for that reason, but that was a distinction of what you hear. That's a fairly high-level noise, too, and something that you have to get used to. I've slept for many hours of tests in the LM with all that stuff running, so it didn't bother me much for sleeping.

SWIGERT (CONT'D) optics calibration on in the CMS. Also, you cannot get any of the stars that are non-Apollo stars into the sextant. All our P23s had one or two non-Apollo stars.

LOVELL The simulations and the actual operation of what we were doing were excellent. We never expected the amount of work we were going to do with Mission Control after the accident. That was all new. But there's nothing that will ever substitute here.

20.3 CMS/LMS INTEGRATED SIMULATION

LOVELL We never got to see the areas where we had integrated operations because we never undocked. The only thing we did integrated was trying to get power to one vehicle from the other.

20.4 SIMULATED NETWORK SIMULATIONS

LOVELL The network simulations are really required. That's the best type of simulation work you can get because it gets you to talk to the guys and see how well you work back and forth. Also, it's good for the CAP COMMs, too.

20.5 DCPS

LOVELL The DCPS was good. The boost phase was just like our SIMs and just like the DCPS.

20.6 LMPS

LOVELL We never really got a chance to evaluate the LMPS.

20.7 CMPS

LOVELL We used the CMPS and the LMPS for rendezvous.

20.8 CENTRIFUGE

LOVELL Did you get a chance to run the entries in the centrifuge?

SWIGERT Yes, I did. I didn't do any G&N entries in the centrifuge. I did the EMS entries, and I feel that the guidance was comparable. The control input seemed to increase the g much like I saw. Bank inputs increase and decrease the g during entry.

SLAYTON Do you think it's necessary?

SWIGERT Yes. You're used to zero g, so 1 and 2 g's seem like a lot more than one g. You'd think that you could take 1 or 2 transverse g's with no sweat at all, but after zero g, 1 or 2 transverse g's is a significant amount. I think it would be good to have a guy fly centrifuge entry and be able to take over and do it manually.

SLAYTON Where in the training cycle?

SWIGERT I'd do it farther along, I'd say a month or two before launch. Just once is enough.

LOVELL If I were going to fly entry, I think I'd have wanted the centrifuge run just to see how I could do it with respect to the EMS. For G&N entry, the simulator is good enough. It's doing the work, and you're just sitting there monitoring. If you're doing an EMS entry, I'd like to do it.

SWIGERT I had a number of hours in the entry simulator where they put all sorts of failures in. I didn't have any problem recognizing the failures, taking over, and steering. If I'd had to take over at entry the other day, I felt that it would be much more difficult to do it under a g-load, so I think one centrifuge run would be worthwhile.

20.9 TDS

LOVELL The TDS is no longer here, and we never used it anyway.

SWIGERT We used the TDS in the CM side where we put CM moments of inertia in and maneuvered. I did it once to see whether it was worthwhile, and I don't think it's worthwhile.

20.10 NR EVALUATOR AND GAEC FMES

LOVELL I never used either the North American evaluator or the FMES at Grumman.

SWIGERT I used the North American evaluator.

HAISE I used the FMES right at the end of Apollo 11.

SWIGERT It was interesting; you could run some of the rational programs, some of the ropes.

LOVELL We used FMES only to check out our new AUTO 66. Someone else did the checkout. I think this is the only way you're going to be able to do it. I don't think it was worthwhile going up there.

20.11 EGRESS TRAINING

LOVELL Egress training is required for people going through the regular training cycle. It's exactly like you're going to see it. You ought to leave it in there. We had no problems with that.

SWIGERT I guess when John, Charlie, and I went for pad egress training, I had tongue in cheek as to whether it was worthwhile. I'm glad I did go. When you get there for real, you know where to go if you have any problems getting off that booster. I think the backup crew ought to go through it.

LOVELL Yes. You never can retrace that after you make a change, especially when it's that late in the game.

20.12 SPACECRAFT FIRE TRAINING

LOVELL We had spacecraft fire training on Apollo 8. We didn't do it this time.

SLAYTON Do you think Jack got it somewhere?

LOVELL It's good training.

SWIGERT I had fire training. I did not have the Gulf egress training. I did have the tank training.

LOVELL You didn't go out in the Gulf?

SWIGERT No.

LOVELL No wonder you stumbled over this all the way in.

SWIGERT We had the frogman there. He said, "When I get the net positioned, you leap in." So I leaped in, and up I went.

SLAYTON I was under the impression that you had gotten that. I didn't know you hadn't.

REEDER They got it in the tank. Gulf egress would have interfered with some SIMs that seemed more important at the time.

LOVELL That's correct.

SLAYTON John and Charlie already had Gulf training, didn't they?

REEDER John did; Charlie didn't.

SLAYTON I think we will probably want to keep scheduling the training for the backup crews.

SWIGERT I didn't feel like I was handicapped in any way because I didn't have it.

LOVELL I think that type of training is good to have just as a part of an astronaut's general training. If you had it for a previous flight, it would carry over for the next flight.

SWIGERT Yes, I agree.

REEDER We got into a bind on that training because someone kept wanting to wait until the procedures for quarantine were firm. We ended up doing it too late. At that time, the training would have taken the astronauts away from something we considered to be more valuable, and so we didn't do it.

LOVELL Right.

20.13 PLANETARIUM

LOVELL I didn't use the planetarium on this mission because I didn't think it was required.

SWIGERT I didn't use it either. I did visit the planetarium once for the Apollo 11 mission, but I didn't feel that I needed it at this time.

SPEAKER It was concluded some time ago that the simulator visuals are good enough. They also give you the field of view you're going to see in flight.

LOVELL I think the planetarium is for general training, but it was not specifically needed on this mission.

REEDER Ken did go to Moorehead for half of a day, primarily to familiarize himself with the new stars that he would be needing.

20.14 MIT

LOVELL MIT did brief us on the changes to our guidance systems. That was mainly for Fred and me and was on the automatic landing program to which they had incorporated a number of changes. We had no training at MIT.

SWIGERT Ken and I went to MIT once to use the simulator that would duplicate the — the atmospheric layer of the Earth. We could mark there and get an idea of what kilometric value you were using for your atmospheric layer.

LOVELL Fred did that on Apollo 8, and it was good for that mission. Of course, you went there for Apollo 13.

SWIGERT I don't think I would make a special trip up there for that. I would combine it with something else.

LOVELL They use your MIT results as base-line data to compare with what you do in flight.

SWIGERT I think that I was pretty near the actual value. I came out with 17 kilometers while I was in flight, and I was using 19 kilometers at MIT. So, it was actually pretty close.

20.15 SYSTEMS BRIEFINGS

HAISE On our side, we didn't go through any of the CM part at all.

LOVELL We had deltas and briefings on the last-minute changes and anomalies that came up during the last couple of months.

HAISE Whatever we did on the LM side was done way early. We had already been through that once on Apollo 11 and it wasn't particularly needed.

SWIGERT I didn't feel like I needed it. I did have some systems briefings on systems I thought I could use. They were not very extensive.

20.16 TOPOGRAPHY TRAINING

SWIGERT We spent an extensive amount of time on topography. This was lunar topography.

HAISE We really needed more.

LOVELL There were two types of topography training: One was the landing area. We did a lot for this one. Then, there was the area we were to fly around. Ken did more work on that than Jack, Fred, and I did. I still felt that I wasn't up to speed the way I really wanted to be, before launch on

LOVELL (CONT'D) orbital geology. We knew some things would have to be cut out, and that was one of them. We never had the time to get it done. Fred and I spent more time learning about the landing site.

20.17 LUNAR SURFACE TRAINING

LOVELL One thing especially, I think we should change the geology training techniques, and this is basically based on Fred's inputs. It should be more what we would expect to do on the lunar surface. We used walkie-talkie radios and equipment and we kept the time line down to something that was similar to what we were going to do. We learned to be observers and to discuss what we saw. I think that the training along this line is really taking a different curve toward what we're trying to get out of lunar geology.

HAISE We should use only the same scale maps they have from Orbiter pictures of the Moon. In some cases, they laid out known traverses from a known starting point. At other times, we played the game that we didn't know where we landed and we reoriented on the map, built our own traverse, coordinated with the ground station, and operated with CAP COMM and SPAN room people, all the time.

LOVELL I'm only sorry that we didn't have a chance to exercise our training to determine whether it was adequate. However, I did feel that it was adequate.

HAISE To me, the KC-135 has the best fidelity of one-sixth g. The POGO seems to help you develop a kind of low running technique, but even it was distorted somewhat. I was working a lot harder there than I was in the airplane doing the same kind of tasks. When I used the mobile POGO, there was a 30- to 25-knot crosswind. One leg was completely distorted but the other leg was shielded by the truck. It felt quite comparable to the centrifuge rig. However, both of the simulations distorted my balance; of course, the things I was lugging around were one-g weight, not one-sixth g, and my limbs were one g and not one-sixth g. My heart rate was also saying the same story. It was costing me a heart rate of about 140. On the airplane, I know I got going faster than that, and I bet I could have gone all day without getting above 110.

LOVELL One g walkthroughs — again we can't prove it, but it seems to me that walking, using those pressure suits and doing that stuff, was the best thing in the world — even though it was horrible. That type of training, according to Pete, is far more difficult than the actual, which makes things easy. I

LOVELL (CONT'D) recommend it just to get in condition. We tried to limit the field trips this time to ones we thought were profitable. Early in our training, we went to California. I thought that was profitable, only for the fact that it trained us as observers. The Hawaiian trip was training us for operational time line and for things we thought were peculiar to the lunar surface and the phenomena we should expect on the lunar surface. Although I really didn't think too much of it before we went, I think the last trip out to Flagstaff was very good. I thought Kilbourne Hole was the least interesting, and the least productive. During the training at Flagstaff, they gave us the lunar map that was degraded purposely in the same way that our maps were degraded. They drew holes and it showed this in the traverse. They showed us an actual crater and then showed us what it would look like on the map we had. We could compare that with the Fra Mauro region and get some idea what the crater size would be. That was good training. I think SESL training should be done only as a confidence check concerning your equipment. I recommend that we keep doing this.

SLAYTON Were you aware that we are planning to drop this for future training because of budgetary problems?

LOVELL No, I wasn't.

LOVELL What are the alternatives?

SLAYTON We can use the 8- or 11-foot chamber. We need to give E&D guidance on some things we'd like to update there to make it good training.

HAISE It's the same chamber we were using before on the preliminary runs you mean, the small one?

SLAYTON Yes.

LOVELL Well, my point here on the SESL runs is that it gives you confidence that your PLSS and OPS and everything are working right, and that you can actually perform in a vacuum.

SLAYTON You can do the same thing in the 8-foot chamber.

LOVELL That's why in Gemini, I was so adamant that we should have one-g chamber run.

SLAYTON I just wanted to make sure you understood, if you had any strong feeling, you should express them here.

LOVELL Well, I guess what you're saying is the SESL also gave you the thermal environment. I think we've already proved that, but we do need chamber testing and chamber training.

HAISE You can do it easier in the 8-foot chamber. We had that on Apollo 11, but we didn't have it this time. The 8-foot chamber was used to run off nominals, but they weren't in the SESL. It took a little in-house training to get them to allow you to do anything offnominal very often.

LOVELL The briefings. Every time we wanted a briefing, the people were more than happy to respond. We had to work our briefings in with simulator training; so, in most cases the briefers ended up sitting around for an hour.

CONTINGENCY EVA TRAINING, KC-135, WIF, AND ONE-g WALKTHROUGHS

HAISE We only had one session of contingency EVA training.

LOVELL I guess it wasn't adequate. If I had to go out by myself, as in a one-man EVA there was going to be a little talkthrough. I did train to deploy the ALSEP by myself. I looked at how the drill operated, but I wasn't very proficient at it. There would have to be a lot of talkthrough.

SLAYTON This topic was primarily for transfer from the LM to the CSM, if you were not properly docked.

LOVELL We did the WIF exercise, and my feelings were that if we ever were faced with that in reality we were in deep trouble. As a matter of fact, we came up with a new technique.

HAISE We had several ways to go. You go through the tunnel or you could go outside. All we determined was that we couldn't make it through the tunnel.

LOVELL No, but we were trying to determine if we could use the PLSS from the lunar surface. Remember we wanted to leave the PLSSs on instead of taking them off.

HAISE We never had a PLSS on, in the water tank.

SLAYTON It should be OPS.

LOVELL Remember that late in the game we were talking about using a PLSS with John down at the Cape in the one-g mockup. I'm trying to see what the situation was that set us up so we could use that. We said instead of taking the PLSS off and putting the OPS on - -

HAISE We never did any training for that though.

There was some idle conversation about that one day, because the hatch jammed and wouldn't seal. It was stuck in there and we couldn't pressurize the LM.

LOVELL Yes, but the normal thing was to get rid of the PLSS.

HAISE Yes. Do a vacuum mate/demate.

LOVELL I think you would be much better off to leave the PLSS on and do the EVT with the PLSS, because you would have communications and you wouldn't have to do all that vacuum demating and mating and get all that stuff squared away.

HAISE You never get even one-g, on the ascent stage. Why don't you just lift off with the PLSS on your back, and go into orbit that way?

SLAYTON It depends entirely on what your failure mode is. Even in that case, if you get docked, you can get repress from the CSM and get back to normal, anyway.

LOVELL We were looking at the case where we had no LM pressurization, and, we couldn't go to the tunnel. We had to go exterior. We thought that we could even recharge our PLSS with the LM system under vacuum conditions, better than we could take off the PLSS, put on the OPSs, and pressurize. We were willing to launch with the PLSS on our back and transfer that way, because we would have communications that way. It would take a long time, maybe 4 hours to recharge the PLSS. That was the only change we had on that.

20.19 MOCKUPS AND STOWAGE TRAINING EQUIPMENT

LOVELL My training suit is just about gone, but all this equipment is adequate.

20.20 PHOTOGRAPHY AND CAMERA TRAINING EQUIPMENT

LOVELL We were a little late getting the Hycon camera. We felt that we needed more time on that, although Ken knew it pretty good.

SWIGERT I had a good briefing on the Hycon camera. I didn't have any qualms about setting it up and working it.

HAISE We were in pretty good shape on the LM side, all along.

LOVELL Yes, we had the lunar surface cameras soon enough to practice with.

20.21 LUNAR SURFACE EXPERIMENT TRAINING

LOVELL The equipment on that is getting pretty poor. It's worn out, and we're going to have to start replacing it.

HAISE A good part of that is replaced just by having a new ALSEP package, Jim. There are no more ALSEPs like that one.

REEDER There will be a new one coming along for Apollo 14.

HAISE Yes, a different one though.

LOVELL The cameras were shot too; all that stuff is worn out.

HAISE We just brought two back.

REEDER We just quitely didn't push the backup crew the last couple of weeks, because we didn't want to wear the gear out before your last EVA.

SLAYTON We'll review that whole subject.

20.22 LUNAR LANDING TRAINING

LOVELL Well, we can't even talk about that.

HAISE I have one little thing that isn't listed as an item. Going back to the TV, I felt, by virtue of picking up the old Apollo 12 surface camera and having it to use a few times in conjunction with our surface EVA exercises, that the live TV was pretty well integrated for the lunar party operations. But the TV mockup in the CM doesn't even have the things that turn; the things that force you to an f-stop, or force you to set a range or zoom in or out. You just kind of fake that; at times we'd just play games in the CMS and normally I'd get the mockup out and stuff it in the bracket behind my head and then stick it out the window and then forget about it, and press on about our business. Then all at once that day came and things

HAISE (CONT'D) were a little different. I couldn't stick the handle in that bracket to begin with. I had to handhold it because I just couldn't hold it straight out. I either had to hunch back or move forward to get the right picture and it was a game of focusing. We also had to be the commentator on the other end of it, trying to tell what you were supposedly showing while doing the other job with the other hand.

SLAYTON This is CSM specifically.

HAISE That, to me, was one thing that should be trained for, too. Now it would help if the TV mockup in the CMS could be made so that the end piece was such that you turn to make a change in f-stop and ranges.

20.23 PLANNING OF TRAINING AND TRAINING PROGRAM

LOVELL It was packed; but quite adequate.

SWIGERT I think we did some unique things in this flight that hadn't been done before, and we should ask the simulator people, both here and at the Cape, to lay out a training program so that we could accomplish, as far as the CMS goes, all the specific mission phases. We did the same thing in the rendezvous simulator and I'd recommend this plan. When we went over there, their approach was, "What do you want to do?" We came back and

SWIGERT (CONT'D) said, "Well, if we knew what we wanted to do, we wouldn't be here. You tell us what you think we need." They developed this approach and I'd recommend it.

SLAYTON We've got a base-line training plan with all the details laid out. What you are saying is that we need to be a little more aggressive in telling you on a specific day to do this rather than leave it up to you?

SWIGERT That's right.

SLAYTON Eventually we get around to that.

SWIGERT They keep track of things. They say "All right, you've done many mode II's but no mode I's."

LOVELL I guess when you have a time limit, you have to figure out what you think you're really not proficient at.

SWIGERT Well, this is, of course, in the latter mission phases. You come down and they say, "Well, now you're getting pretty well near the end," and they'll give you a choice of activities and you will say, "Well, I'd like to run some more time-line work and so forth."

LOVELL I thought training was very good this time.

SWIGERT I did too. If it wasn't good, I don't think we'd have been able to switch like we did.

LOVELL Yes. Maybe that extra month in there was well worth it then.

SWIGERT We had a good training coordinator.

LOVELL I tell you, though, that training is a bottomless pit. You get an extra month and you think you're all set to go; but, before you know it, every day in that extra month is taken up. The LLTV took an awful lot of time, and if it weren't for the slip, I don't think I would have gotten that in.

21.0 HUMAN FACTORS

21.1 PREFLIGHT

21.1.1 Preventive Medical Procedures

LOVELL I'm not going to say a word.

21.1.3 Time for Exercise, Rest, and Sleep

LOVELL This is a complaint, I guess. I really don't know what to say about it. After you run an EVA and the simulator all day, you don't feel like you can do any exercise. I had a hard time getting Ken to come back to rest, sleep, and things like that. But I really don't know what we should do differently.

SLAYTON Tell them just to keep working at it.

LOVELL Yes.

SLAYTON If you think they're working too hard, just slow them down.

LOVELL If we hadn't switched CMPs the last few days, we would have had the last few days free.

SLAYTON Yes.

LOVELL And we wouldn't have done anything. Having to switch, though, made us do extra work.

21.1.4 Medical Briefings

LOVELL The medical briefings were adequate.

21.1.5 Eating Habits and Amount of Food Consumption

LOVELL I think that we're now taking a practical view towards preflight eating. I don't think we had any problems.

SWIGERT At the Cape, Lou wants to feed you like he thinks you're starving to death. Now, you've been down there, and you know exactly what I'm talking about. I don't need that much food. As a result, I found myself not eating that much, because I just can't take that amount of food.

LOVELL I guess if we were a little bit stronger, we could probably prevail on Lou to cut down on the food. Maybe I should have told him not to feed us like that.

SLAYTON I think it's an individual preference. It's up to you to decide how much you want.

LOVELL Fred, do you have any comments?

HAISE Well, I guess our training schedule didn't really allow a lot of time for exercise. That was one item that kind of slipped by for me. I normally get a little more exercise than I was getting in about the last 6 weeks of training.

REEDER EVA didn't give you enough exercise?

HAISE No, not the right kind. I would have approached the last item a lot differently if I had known the way this mission was going to turn out. If I had known the mission was going to last less than 6 days, I would have gone the route of no bulk foods, and I'd have cavitated the whole system back to the tummy as best I could with enemas and everything else, and I think we'd probably got by the whole time without having to worry about it. As it was, I went three times in 5 days. It's a terrible inconvenience. Jack did the same, and I think that was just because he continued to eat. With a 10-day mission, I don't think you're going to avoid the issue.

LOVELL That's the way I felt before launch. I'd gone through this low-residue-food, clean-yourself-out-good routine at night. Then, I went through the entire flight without going. I said to myself, "One of these days, you're going to face facts that you just can't last 28 days or 56 days without going. You might as well start living normally again." So, that's what I did. I went once.

21.2 FLIGHT

21.2.1 Appetite and Food Preference

HAISE The first day I didn't have much of an appetite. The next morning, I was a bit upset. Then, from there on, I started eating everything that was in each meal.

SWIGERT We were given no meal A on the first day, but we were given meals B and C on the first day. Of course, our launch wasn't until 2 in the afternoon, which was after meal B.

LOVELL We also had snacks stuffed in our pockets.

SWIGERT As a result, none of us ate either meal B or meal C on the first day, but we did eat the snack. We started off eating regular meals on the second day. We also kept a log every time we ate anything.

LOVELL I have one general comment on the food. It was good. I thought that the wet packs were a step in the right direction. The bread was good, and the spreads were better, but some of the food was a little difficult to handle. Some of the spreads dried out a little because the water went to the top. They separated, too, so it was hard to spread them because they were hard and because the water floated. That problem can be worked out, though.

LOVELL (CONT'D) I think that the packing of bread packages expand because the pressure goes down. When they pack them, there's 14.7 psi, and there's only 5 psi in the CM. So, you never can get the bread back in the package. But each package, each complete meal, is in a package by itself and is on a string.

SWIGERT Yes, that's all right. I think you eat more, because you can't get the food back in its package. You have to do something with it, so you eat it.

LOVELL We could have packaged the food better. I know we do have more room for food stowage in the CM. The food is too compact. If you pull out one thing, a whole bunch of food comes out. I think we have room enough in the CM that we can devote a little more space to food stowage. They really pack it in there. They must have spent a lot of time packing the food. That's great, except that, in zero g, if you reach in to get one thing, you pull out a bunch of food; boy, it's hard to get the food back in the package.

Also, each bread slice is not vacuum packed. That stuff just goes all over the place.

SWIGERT The orange juice was much better than the orange drink. I'll tell you, those juice drinks really saved us. We used up all

SWIGERT (CONT'D) of them. In fact, we were even getting into the last meals to get out the juice drinks. But, of course, that was because of our shortage of water.

HAISE I had a comment on the pantry. The THC cable route interfered with opening the rear door of the pantry. We had to be very careful on the forward door, and I had to be especially careful when I raised the door so that I would not ding the THC cable. I had never noticed that before. I don't know whether or not this is something peculiar to this spacecraft.

SWIGERT The routing of the THC cables was pretty much standard; so, I think you're going to find that there is a degree of interference. But you're right, the door did hit the cable when you raised the door about 60 degrees. The door didn't raise the full 90 degrees.

21.2.3 Food Waste Stowage

LOVELL We used one temporary stowage bag for the food waste stowage. It's the same old thing, too. The amount of trash really piles up in a hurry, and you have to keep ahead of it. We were keeping ahead of it up until the time of the emergency.

SWIGERT We didn't even do too badly after the emergency.

HAISE Is that all it was; that trash bag sitting down with it?

LOVELL I have been thinking that if we could have jettisoned the stuff in the LM, just gotten rid of it, that would have been fine. Again, if we had a little bit more room in our food-stowage area, we could replace the food that we use with the debris that's left over. And we could use that as a stowage spot. But we couldn't do that adequately because of the way the food is packaged now. It's just packaged too tightly. Once you get that food out, you just can't put it back into its package. If you could put it back, it would be much more efficient.

HAISE The bags of bread needed patches of Velcro on them.

SWIGERT Did the wetpacks have Velcro on them?

LOVELL Yes, the wetpacks had Velcro.

HAISE The ketchup packages did not have Velcro on them.

HAISE We had one emergency in the LM that you didn't know about.

SWIGERT Fred went up to get a volts and amps reading, and he said, "Here, hold my frankfurter." When he came back I said, "Fred, I got an emergency here. I squeezed too hard, and it drifted off someplace." I said, "Check around for two loose frankfurters." That broke Fred up for about 5 minutes. I was still holding that empty package when he came back. We had a few laughs over this one.

HAISE I thought you had eaten them, that's why. You just can't trust these CMPs when you leave them in charge of the LM. The Spoon-bowl packages worked pretty well.

LOVELL That's a step in the right direction.

21.2.4 Water

LOVELL We chlorinated the water, and even in the beginning, we saw gas in the water.

SWIGERT There was gas in the CM potable water all the way through the mission.

LOVELL The water was hot, and hot water was fine.

SWIGERT You know, something we all commented on is that none of us noticed a taste of chlorine in the water the next morning.

HAISE That's right. I thought that it tasted almost as if Jim hadn't chlorinated it.

SWIGERT There was always some gas in all the juice bags when we filled them, even up to the very end of the mission. Even when the fuel cells weren't working, there was always gas in the water.

LOVELL I don't know what we're going to do about that situation.

SWIGERT Jim, you probably can make a comparison between the Apollo 8 potable water and the Apollo 13 potable water. Did you think there was more or less gas?

LOVELL I thought it was about the same. A good way to tell is by drinking from the juice bag. A lot of gas makes it difficult to drink from the juice bag, because you're drinking air, gas, and juice.

I got a little thirsty towards the end of the mission, because we ran out of CM potable water.

21.2.5 Work, Sleep, Rest

LOVELL I guess we should talk about the worst sleep cycles before and after the emergency.

SWIGERT The first night I didn't sleep as well as I did the second night. I guess it's just a matter of getting used to sleeping in zero g. The second night I had a good night's sleep.

HAISE Yes, the same was true for me. I guess I had some sleep the first night on the couch. All I did was set up the couch and fasten my lap belt, and I had a feeling that I was rocking up and down all night. I don't know whether or not this rocking contributed to the severe headache I woke up with in the morning. If I had to do it over again, I think I'd also bring the shoulder harnesses down and latch myself in completely.

LOVELL Did you wear your COMM carrier?

HAISE Yes.

LOVELL On the first night, I wore the COMM carrier. I don't think I would recommend that, though, because of the audible tone. I think we could have taken off the COMM carriers.

HAISE No, I'm sorry. I didn't wear the COMM carrier. I wore the lightweight headset.

LOVELL If there's a switch in S-band and OMNI antennas, the antenna will tend to wake you up. Also, we had a third sleep restraint, which I didn't even know we had on board.

HAISE Yes.

LOVELL Don't you think the sleep position underneath the couch is better than the sleep position on top of the couch?

HAISE Yes.

LOVELL This is true mainly because the sleep restraint under the couch keeps you in position.

SWIGERT That's right. I agree.

LOVELL Maybe we ought to think about rigging up a similar sleep restraint on the couch.

SWIGERT I suspect there are places down in the LEB that a restraint could be tied without any problems. One example is the G&N handhold.

LOVELL And then, we would have three good sleeping positions. I slept on the couch the second night, and I didn't get as good a sleep as I did the first night for two reasons. First, a MASTER ALARM occurred just about the time I was falling asleep. That really made me jump out of the couch.

SWIGERT We never did find out what that was.

LOVELL No, and the second reason was that the hose by my side was rotted. It was blowing cool air on me all night, and that distracted me.

21.2.10 Medical Kits

LOVELL The medical kits were adequate. We used aspirin.

SWIGERT I used two Lomotils and one Dexedrine.

LOVELL I used Dexedrine and we also used quite a bit of aspirin and one Darvon.

HAISE You used two Lomotils?

SWIGERT They didn't do any good.

HAISE Are you sure you got the right compartment?

SWIGERT I think so.

HAISE And we used seasickness pills.

LOVELL No you didn't.

SWIGERT I took the Marezine.

LOVELL Dexedrine.

SWIGERT I took a Dexedrine.

LOVELL I just took one (Dexedrine).

HAISE I didn't take any because the seasickness pills had that in it.

LOVELL Yes. I was a bit concerned about taking too much Dexedrine. I was afraid it might wear off before I got down.

21.2.11 Housekeeping

LOVELL We kept up with all the debris. We never had any loose packages around. After every meal, we immediately used the pills and the debris went in the garbage bag.

SWIGERT Even after the incident, we always had a clean house. There were never any odors; never any mold or anything.

21.2.12 Shaving

LOVELL Fred, why don't you talk about shaving?

HAISE The problem was one of two things, I guess. Deke's point that it had been done before, and quite successfully, leads me to believe that our selection of the type of cream — the Mennen — was not the right one. What happened with all of us was that the shaving cream caked underneath the razor blade on the Techmatic we had and it allowed the blade to skim very neatly over the rest of the face without even touching the whiskers. You really had to apply a lot of pressure and scraping back and forth to get it to dig in a little bit to do any cutting. It

HAISE (CONT'D) was a very long-term, meticulous job to get a decent shave with that apparatus. I guess the next guys should follow more in line with that used previously — which I didn't have any knowledge of — or make use of a more selective sampling in the available creams. We really only looked at two — Gillette and Mennen. I thought if any of them would be good, those two would. I guess that wasn't necessarily true for the environment we were in. Another possibility we thought of before the mission was the benefit of having a razor that you can either remove the head or move the razor to allow cleaning of the blade. With the Techmatic, we weren't able to do either.

21.2.13 Radiation Dosimetry

LOVELL We erred here a little bit. Fred and I took off our suits and left our dosimeters in our suit pockets. Because we already had them stowed and wanted to be very careful with the suits, we were reluctant to unstow them. So we relied on Jack's dosimeter as an overall dosimeter for the flight, after the accident. After the accident, we couldn't bother with taking any dosimeter readings.

SWIGERT I did give them the dosimeter out of my pouch. It was stowed underneath the LEB in one of those little pouches underneath the optics.

LOVELL The PRDs were not worn throughout the mission. Two of them were stowed in the suit bag and one was stowed down by the LEB.

SWIGERT We didn't use the radiation survey meter.

LOVELL We activated it one time when we couldn't find a dosimeter, to see if there was any change. We didn't see anything in excess of the 10-mrad/hr range. It was outside the radiation belt.

21.2.14 Personal Hygiene

LOVELL I've always thought those wetwipes were too small, whether they are packaged with the food or packaged with the other. They're very small. I'd much prefer the wetwipes packaged in the AF inflight lunch kits. At least they smell good. We've had these things from the Gemini days. I don't know what they put on them, but they're awful, and they are small. I guess that's something we can live with.

SLAYTON Do you know of any reason why we can't improve them?

LOVELL You know, we're looking toward Skylab and long-duration flights and improving crew comfort.

SLAYTON I don't know why we can't use the same thing they use on the airlines.

LOVELL That's right.

SLAYTON Was potable water used for personal hygiene?

LOVELL Sure it was. We used it to keep our faces clean, and for shaving. We used the hot water to try to soften the beard.

SWIGERT As far as tissues go, there was plenty of tissues.

HAISE Yes, we never ran out of tissues.

22.0 MISCELLANEOUS

22.1 MEDICAL REQUIREMENTS

LOVELL Deke could probably better explain it than I could, but it seemed to me that this physical was different from the Apollo 8 physical. This time, we had a physical every day, something which came as a complete surprise to me. I must have missed the briefing somewhere along the line.

SLAYTON We've been doing that since Apollo 9; the physicals are in terms of a quick look each morning. They are just a kind of nose and throat check to make sure nobody is getting a red throat or something. Before Apollo 9, we weren't conducting physicals each day. But remember that all of a sudden we came along and had a problem. So since then, from T minus 5 days to lift-off, we have been doing physicals each day.

LOVELL I didn't know about it until Jack Teegen said, "Where do you want to take the physical?" I said, "What physical?" He said, "Well, we have to look at you every day."

Another thing I thought of, which you might want to consider, is that the backup crew and the prime crew never follow the same physical regimen.

SLAYTON That's right; from T minus 30 days to lift-off.

LOVELL If you have to repeat what we experienced, you might think about changing that technique.

SLAYTON Again, I think it worked out all right, because from T minus 5 days to lift-off is really the critical period.

22.2 PAO REQUIREMENTS

LOVELL There was no interference by PAO requirements with flight preparation.