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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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APOLLO 10 TECHNICAL CREW DEBRIEFING (u)

JUNE 2, 1969

PREPARED BY:
MISSION OPERATIONS BRANCH
FLIGHT CREW SUPPORT DIVISION

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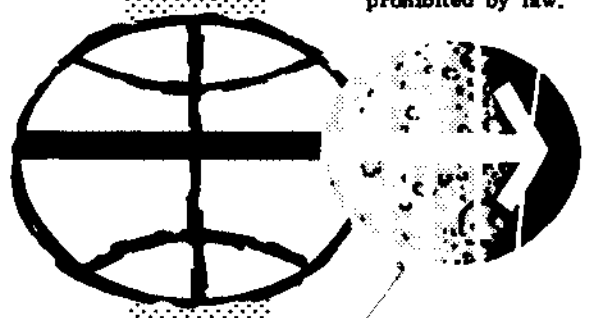
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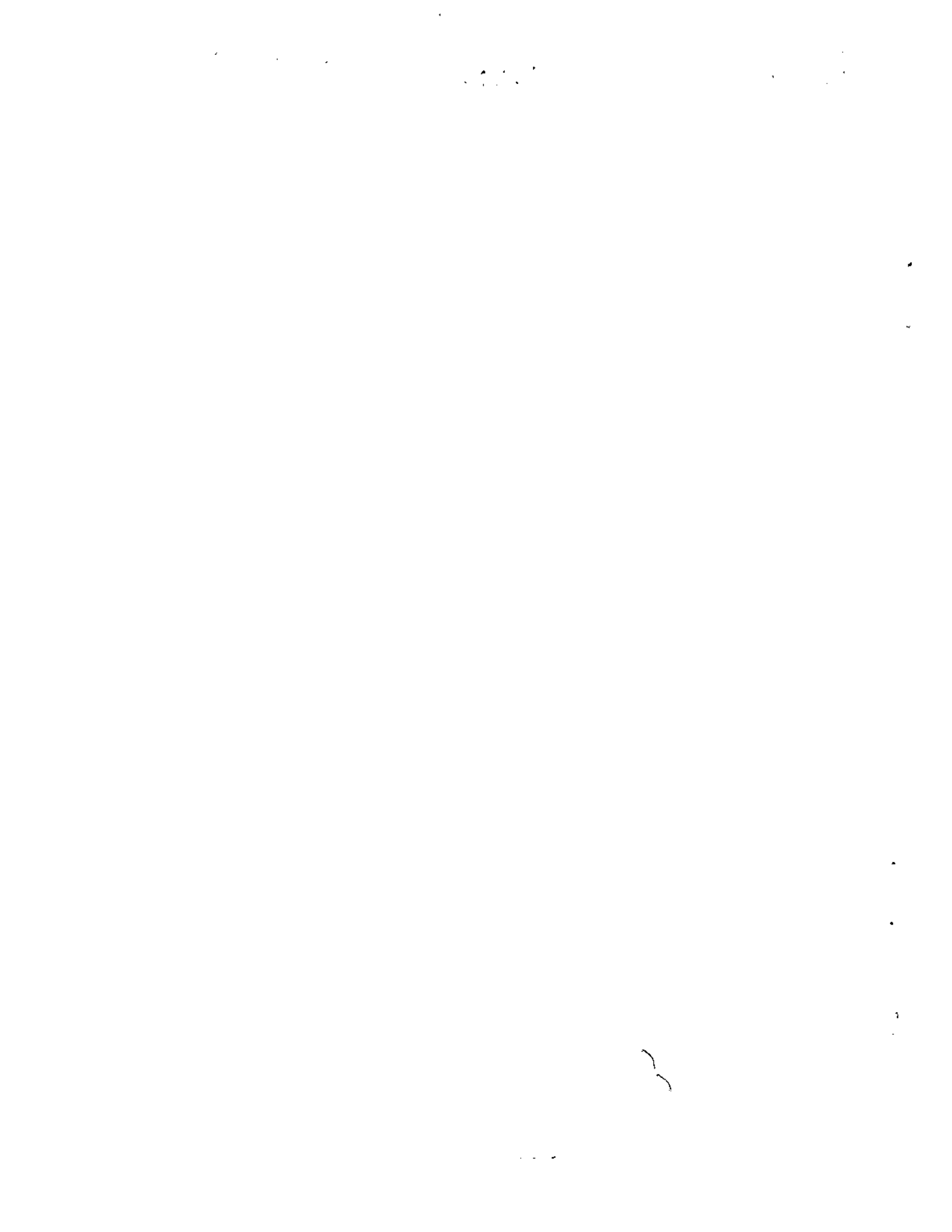
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1-1

1.0 SUITING AND INGRESS

STAFFORD As far as we were concerned, the suiting situation is completely satisfactory. I think the crew should ingress as late as is feasible, and possibly 10 to 15 minutes later than we did.

YOUNG Up to 20 minutes later.

STAFFORD This should be carried out in the following flights, that is, not have a complete suit loop integrity check - pressure check, because the suit is checked individually earlier.

YOUNG Certainly would help.

STAFFORD It should be deleted, because it loosens the straps and everything.

YOUNG That gives us 15 or 20 minutes gravy for our crew ingress.

STAFFORD The coolant loops and everything - I think this problem is all satisfactory. None of us felt too cold or too warm. It was beautiful.

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2.0 STATUS CHECKS AND COUNTDOWN

STAFFORD Status checks and countdown were completely normal - satisfactory.

CERNAN We knew we had a bad fuel cell 1 O₂ meter. In other words, the meter had failed to the zero position. We all were ready to go without it. The ground could see fuel cell O₂ flow rates. However, I was not briefed, and no one told me that when you go to the fuel cell 1 position to monitor the hydrogen flow or any of the other aspects of fuel cell 1, you would get a MASTER ALARM. The only reason that it was discovered is that I was going through the systems on my own, prior to lift-off. When I went to that position, we got a MASTER ALARM. I was told later, after people looked into it, that this is a normal configuration. I sure would like to have known that point before we lifted off.

STAFFORD I think John and I found one item that was omitted by the pad crew, and that was prior to the day of reentry. Before, we noticed that the zero-g brace was hooked up.

YOUNG This is a couch strut brace that braces the couch when you have the X-X straps removed.

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STAFFORD I said, "I don't remember anybody putting that up," and John said, "I don't either."

YOUNG I thought Gene did it. And Gene didn't do it, so obviously, we launched - -

STAFFORD When I ingressed to the spacecraft, I looked down and that brace was there. And none of us put the brace up, so it was never down to the stowed position for launch.

SECS PYRO, COMM verification, emergency detection system - all those went as previously during the CDDT and previous checks.

YOUNG We did no stable-member azimuth check.

STAFFORD The FDAI power, GDC align, and EDS checks were completely satisfactory.

YOUNG Didn't fire the RCS. The DELTA-V check was normal.

STAFFORD The ground communications and countdown were beautiful.

YOUNG There's no reason to have the VHF keying in your ears - whatever it was that was keying. It's difficult to tell whether you have a spacecraft problem or a ground problem. They should correct that because maybe you might launch with an anomaly if you keep going with that kind of a situation.

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2-3

CERNAN It's without question, recognizable: it's like an open mike.

YOUNG It's like an open mike. And I don't see why the dickens they have it. It seems to me like a little effort would fix it.

STAFFORD It appears that it's back in the COMM center where the cross-talk occurs.

YOUNG I see no reason to live with that.

STAFFORD The rest of the countdown was beautiful. No problem.

YOUNG The vehicle did sway prior to ignition. The vehicle swayed and you could see it on the rate needles. With the small winds that we noted, it was a very noticeable swing, but not objectionable.

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3.0 POWERED FLIGHT

STAFFORD S-IC ignition, the Stoney count was right according to the as briefed procedures. He called ignition when he actually saw fire coming out of the F-1 engines. This occurred at about minus 6 seconds. You could feel the rumble and vibration start to build up at minus 3 seconds.

3.5 LIFT-OFF

STAFFORD Lift-off was very obvious - with a slight increase in pressure on your back and a decrease in vibration. Very similar to Gemini.

YOUNG We really had a sensation of motion.

STAFFORD You knew you'd lifted off.

YOUNG Without question.

STAFFORD Lift-off was smooth. We had no problem at all talking to each other.

CERNAN Voice COMM was excellent in intercom. None of us wore anything else except the Snoopy hats.

STAFFORD Yaw tower maneuver - what I observed on the rate needles at the 2-second yaw maneuver - was approximately one half of what we'd

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STAFFORD (CONT'D) seen in the simulator. The deflection on the attitude error needles was approximately one half the magnitude of what I've seen on the DCPS and CMS. This should be corrected. The launch vehicle lights were lit. The dim lights were no problem. The tower clear call was on time, the roll program, and the pitch program were nominal. The rate changes presented no problem, and you could hear the cabin relief - valve operating as the cabin pressure decreased.

YOUNG Cabin pressure decreased at about one minute, didn't it?

CERNAN Yes, it was late - it was - somewhere around a minute to a minute and 10 seconds. But when it did, it was loud and clear. The simulator is a good simulation.

STAFFORD The mach 1 and max q noise levels were less than in Gemini.

YOUNG That's right: I agree with that.

STAFFORD It did not scream and howl like Gemini did.

CERNAN, After we got out of max q, it was like riding a super bird.

STAFFORD After max q the noise of the F 1 engine was less than we had in the Gemini. The F 1 engines were very low and beautiful -

CERNAN A quiet, smooth bird.

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STAFFORD The EDS was turned OFF and we went to manual at 2 minutes. We noticed no pogo oscillations during S-IC boost.

YOUNG There were no problems turning the EDS switch to OFF. I was a little worried that we might have problems reaching the switch under the 3 or 4 g load.

STAFFORD The S-IC inboard cutoff was on schedule, and again there were no problems. At outboard cutoff, we were expecting a negative g. We'd been briefed by the Marshall people that we could expect the outboard shutdown approximately 2 1/2 seconds earlier. We were expecting it at 2 minutes plus 37 seconds, to 38, and the booster burned all the way to 240 - maybe it was a little over 240 when it shut down. Now at this time, we had expected a negative g, and we thought it would just be one pulse, but what we had was a tremendous structural pogo oscillation. It was approximately 4 cycles and we were slammed forward, back, forward, back, forward, and back; the instruments, to me, were kind of blurred.

YOUNG It was loud.

STAFFORD It was the loudest thing I've been on. The noise and sensations to me sounded exactly like an opened pre-valve, on the Gemini Titan, at about minus 45 seconds before ... amplified by 10. I was trying to call staging but I couldn't talk, and when

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STAFFORD
(CONT'D)

everything had settled down, we were burning away on the S-II just as smooth as silk. But it was obvious that it was the S-II stack that unloaded on us, because we still had the dynamics after the lights went out, but we expected this because they have cut over 10 tons of metal out of that S-II.

YOUNG

We think that this thing is just sitting there under tension and then when it stages, the whole thing goes back to its normal form, like in zero g, and it's going to oil can a couple of times.

CERNAN

Like a barrel -

YOUNG

Fuel slosh is going up and down in that thing.

STAFFORD

It was the darnest thing I've ever been through. As far as I can remember it was 4 cycles with a decrease in amplitude per cycle. We were worried about it's breaking hardware in the command module/LM and everything else, but once on the S-II, you could barely hear the engines and everything was very smooth.

CERNAN

The S-II ride was so quiet and so smooth up until we got to staging, that you hardly knew anything was burning.

STAFFORD

As far as any gaseous products at staging - we were going through the pogo at that time, and I couldn't tell you what

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3-5

STAFFORD
(CONT'D)

went on outside. I could barely see the instrument panel because I was being slammed back and forth so much. The tower jet was a very low noise-level thing.

YOUNG

Just - prior to tower jet, I could see - the only way I can describe it is - aerodynamic heating smoke coming across the hatch window and also the right-hand window underneath the BPC before it was jettisoned.

STAFFORD

That reported before, I think, on Apollo 9.

YOUNG

There was no question about it. It was coming between the window and the BPC and it was aerodynamic heating. I could see it on both my right window and on the hatch window.

CERNAN

I don't think you need the BPC, but I can't prove it.

STAFFORD

The tower jet was done on time and again it was less noisy than on the DCPS. It was mostly just like a plunk, then it was gone.

CERNAN

The real cue to tower jet was that the windows all opened up on you.

YOUNG

Yes, you could see it from the rendezvous window.

STAFFORD

Guidance initiated was very smooth, and COMM was very good. Inboard shutdown at 7 plus 40 was right on time.

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SPEAKER Could you feel that physiologically?

STAFFORD Yes, we could. We then got the GO for staging and again, when the outboards of the S-II shut down, we got structural pogo. However, it was lower in amplitude than the pogo that we experienced on the first stage and it abruptly ended at about 3 oscillations. We staged off of the S-II and we were on the IV-B.

YOUNG Let me tell you that was a ride and a half.

STAFFORD Yes, there was noise associated with this. You could hear things - bluh, bluh, blup - like this. It's hard to describe. But then when the IV-B lit off, we were all amazed that one J2 engine growled and rumbled. You could feel vibrations. Where the S-IC stage and the S-II stage were completely smooth, the S-IVB growled, rattled, and rolled during the whole burn. But you could actually feel little vibrations. - It wasn't a pogo - we never had a real pogo throughout any part of the flight.

YOUNG Nothing you could really feel.

STAFFORD But you could feel small lateral oscillations, a little fore and aft, but not a pogo oscillations. The noise of that J2 engine on the S-IVB was louder than any of the engines on the other stages.

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YOUNG Remember this thing that Gene remarked on that was really noticeable just prior to staging?

STAFFORD Okay. Gene has never ridden in the DCPS with us to any extent. I could see the mobilization in the guidance change in there, and to me it was nothing, because I'd seen it in the simulator. And if you've never seen it on a visual before, it'll throw you - like the guidance is going wild.

CERNAN I saw the pitch guidance change about three separate times, where the horizon went on the bottom of my window and went to the top of my window. And then went to the bottom of my window and then went to the top of my window. It seemed to me it was more than a hunting, but Tom then verified that the guidance was good and what was happening. Then it had pitched back. It wasn't hunting as in Gemini where you could see the nose hunt. This was definitely a pitch change.

STAFFORD Yes.

CERNAN It happened three separate times towards the middle and end of the burn.

STAFFORD It didn't concern me a bit because I've made so many runs on the DCPS and I was looking for it and it occurred right on time. However, it is more dramatic when you see it out there

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(CONT'D)

in space. Okay, the main thing about the IV-B was the way that that engine growled and the vibrations from it. We all thought the thing was going to quit any second. But it went all the way and it shut off at the proper time. After SECO, we went through our insertion checklist and everything looked good. We had good communications with the ground. The one thing we noticed was how solid the attitude of that Saturn was using the APS engine. There were no dynamics off the nominal. It was very impressive.

Cernan

From the right seat, I didn't feel or know when any of those thrusters were firing back there, nor could I during ullage for the TLI burn. The only reason I knew we had ullage for the TLI burn was that we could see the DELTA V counter count up.

STAFFORD I could see the yellow flashes.

YOUNG I could see the light at dark. At night time, you could see the yellow flashes.

STAFFORD At night time ...

YOUNG That's right. You could also see the lights on the S-IVB flashing.

STAFFORD Controls and displays completely satisfactory.

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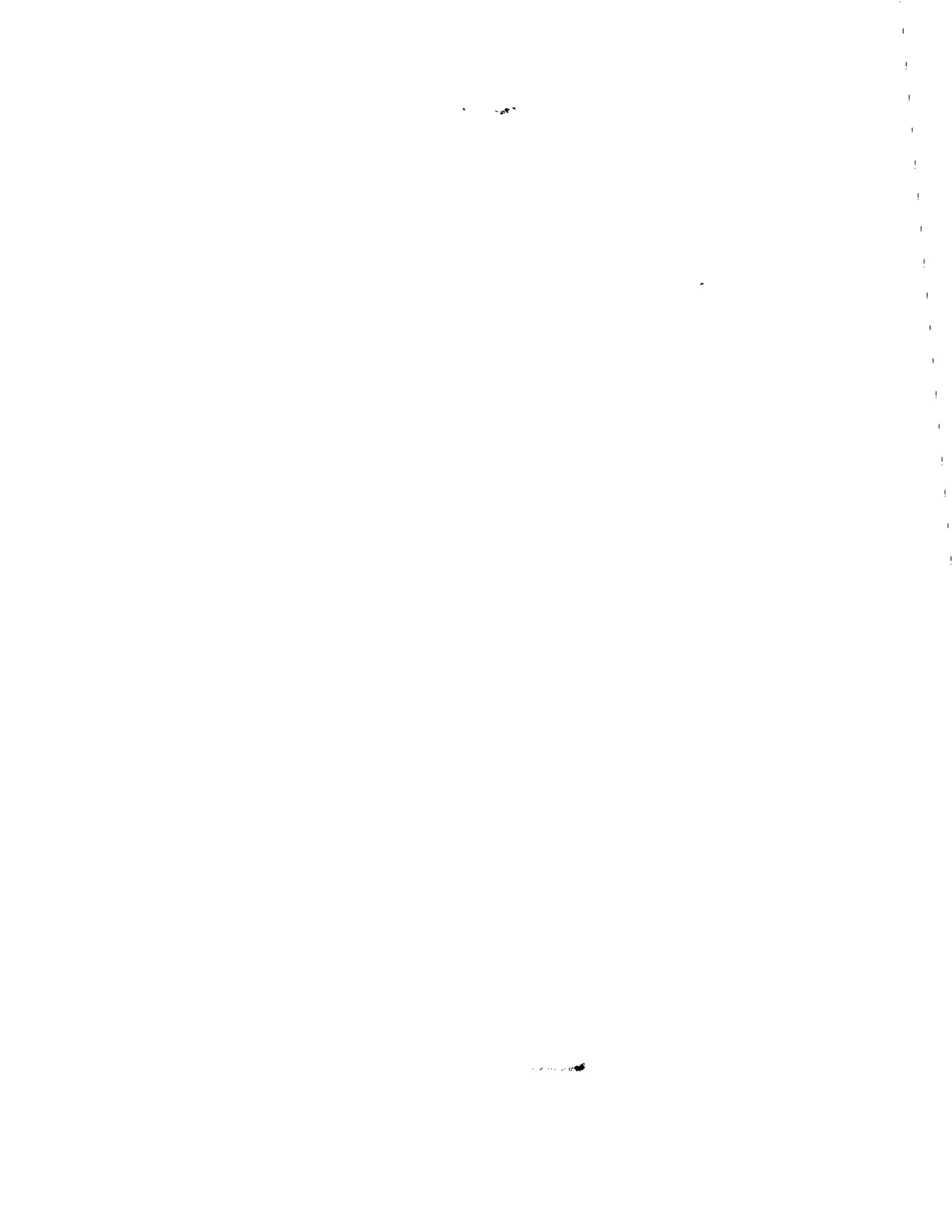
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YOUNG Yes, they couldn't have been better.

STAFFORD The g forces are so low you can't believe it.

YOUNG Yes I agree, you could have done it standing up.

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4-1

4.0 EARTH ORBIT AND SYSTEMS CHECKOUTS

YOUNG Systems checkout was completely nominal, and we were running 20 to 30 minutes ahead of time, except when we had to wait for specific items. I think the total philosophy on this is to make things as simple as possible. That was the approach we used, and we were always ahead of the game. Roger. Probe extension, which we were told would be very slow, was exactly like it was in the simulator. We heard an audible click when the probe got fully extended.

4.1 EVALUATION OF INSERTION PARAMETER

STAFFORD John's onboard chart and the DSKY had everything. We had a GO right away from the CAPCOMM.

YOUNG That guidance system was absolutely perfect at insertion. It agreed with the crowd, we knew where we were, and if we had had to do a mode 4 or an upstage, we could have done it with every confidence of being able to do it.

STAFFORD The SCS attitude reference comparison was good. The numbers on our dials matched up within 0.1 degree of what I was reading on the primary guidance and navigation system.

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YOUNG That allows alignment of the GDC to the IMU by just using the 2 balls, just getting the roll, pitch, and yaw angles off 1620, dialing them in, and punching a button. Saves you a lot of time.

STAFFORD Right. The drift rates we noticed early in the flight were very low on the GDC. We did have an anomaly on the command module RCS ring 1 due to an isolation disc being ruptured. This procedure was talked over before lift-off. We agreed upon a procedure, went through it right after insertion, and it was all completed 18 minutes after insertion.

YOUNG Turned on the heaters in the ... 15 minutes.

STAFFORD And pulled it - turned them off, pulled the heater breakers to close the isolation valves. COAS installation and horizon check - fine - no problem. The horizon check was no problem.

CERNAN Unstowage and camera assembly was no problem. The problem was retention of all this gear that we got out. We really had pulled out one piece of gear and didn't know what to do with it. On a tight timeline that could bother you. I didn't think it was tight timeline.

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4-3

YOUNG During this entire TLI PREP and unstowage, the commander and LM pilot stayed strapped in their seats (basically, loosely strapped in their seats) and the Command Module Pilot did all the LEB work, the unstowage, the optics, the checkout, and everything. Systems verification and dock and probe extension was nominal. It occurred just like it does in the simulator - all you'd hear was definite click when it got fully extended.

CERNAN Communications were excellent throughout the whole boost phase. We never lost contact, we had good S-band check and good VHF.

STAFFORD SCS attitude reference comparison was excellent. Low drift rates at that time and the DSKY readings were beautiful. We were 20 to 30 minutes ahead of everything.

YOUNG Shoot, it was a piece of cake.

4.14 CONTINUOUS VENTING SYSTEMS AND PLUME

STAFFORD Continuous venting system and plume, no problem.

CERNAN FOD had to update our state vector 2 to 3 times. Everytime we updated it, we were in a higher orbit. ...

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4.15 TLI PREPARATIONS

YOUNG We had agree that we wouldn't wear helmet and gloves for TLI and then chickened out, there, at the last moment and put them on.

CERNAN It was so easy, we were ahead of the timeline, and we had nothing else to do. We said, "Shall we put them on?"

YOUNG It was more psychological than physiological, because you know if anything had happened, there wouldn't have been anything you could do.

CERNAN But it was a case of being ahead of it, sitting there and saying, "Well, why not?"

STAFFORD Translunar insertion configuration was satisfactory; verify the EMS DELTA-V that worked good. Systems readiness was fine.

CERNAN We went through all the component checks and everything checked out nominally.

4.20 ENGINE ALIGNMENT

STAFFORD Engine alignment - S-IVB again, the ground checks that. We got the GO for TLI. Crew readiness and comfort - we were comfortable and we were 30 minutes ahead of schedule - maybe 40 at times. Subjective reaction to weightlessness -

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4-5

STAFFORD (CONT'D) fullness in the head - yes. As soon as I got in orbit, my head felt full like the sensation of head-down position.

YOUNG You better believe it. We felt like we were upside down until about 8 hours.

STAFFORD I had no vertigo - neither did John, and I don't think Gene did.

CERNAN I didn't have any vertigo. I felt like a hundred dollars.

STAFFORD Nausea? I had none, John had none, and Gene felt good.

CERNAN Nothing, Babe, during this whole phase.

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5.0 TLI THROUGH S-IVB CLOSEOUT

5.1 TLI BURN MONITOR PROCEDURE

STAFFORD TLI monitor procedure - the new procedure that we worked out with respect to manual backup guidance worked out very well. We set the ORB rate ball to the lunar torquing rate at 200 nautical miles - the way it should match coming down - and it worked great. We were all confident that - if it were required to do a manual TLI, we could have done it - just no problem. The correlation, there, was great.

5.2 S-IVB PERFORMANCE AND ECO

STAFFORD The S-IVB lit off exactly to the second on time. It started its pitchdown 5 degrees. We were all getting very sensitive to any motion. The thing we noticed right away was the growling of the S-IVB and these oscillations. There were little lateral and longitudinal oscillations and a growl. Then between 3 minutes and 3 minutes and 5 seconds, a high-frequency oscillation noise and vibration were superimposed upon the growling. All three of us thought the flight was going to be over right then.

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5-3

STAFFORD We'd never seen it before and never heard about it. It really scared the hell out of us - not from a safety point of view - we thought the flight was going to be over shortly.

CERNAN And I was trying to figure how we'd do a TLI - plus 10 abort.

STAFFORD But the guidance was just beautiful, and it shut off within a foot per second. It was just fantastic. The S-IVB maneuver to separation attitude was on time right to the degree. It was as solid as a rock. Preseparation configuration was satisfactory; MCC GO for PYRO ARM was good. Again, T&D attitude was good. Okay.

5.7 TRANSLATION AND DOCKING PHOTOGRAPHY

CERNAN We took 16 mm and 70 mm and it was just nothing more than vehicle-to-vehicle photography. It was the first time we used the television and it's the only time we used a closed-circuit technique. We had the time, so I pulled the proper breaker and we had closed-circuit television. Just to make sure we were going to get something on our monitor and that we could point it. When we got the ground, we pushed the breaker in.

STAFFORD We'd worked it out where John and I did practically the whole transposition and docking. We left all the photos to

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(CONT'D)

Gene; there was no interference. We didn't even know he had the system on as far as we were concerned.

Tank pressure looked good - just what we'd seen in the simulators — EDS operation was fine, PYRO operations were nominal. Separation from the SLA, I thought the bang was probably less than what I'd been briefed on. Again, we had our helmets and gloves on. We could hear it, but it wasn't as loud as I thought.

CERNAN

As soon as we separated from the SLA, we could see SLA panels start to go. As we started to turn around, we picked up probably three of the four SLA panels.

YOUNG

There's no indication on the EMS or anything that we got any DELTA-V out of that separation.

CERNAN

It's a good solid klonk.

YOUNG

We applied 0.6 ft/sec velocity to about 40 seconds and nulled the velocity to zero, essentially. We then started our pitch-around at about a degree and a half per second. When we got around, we were about 150 feet away from the S-IVB (which is not a bad place to be). But that's about 100 feet further away than we should have been. I don't have any explanation for this. It took us a little more gas to get back there.

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YOUNG
(CONT'D)

Better to be safe than sorry. We were still moving away from the vehicle when we turned around. It took three different positive translations of 0.2 to 0.3 ft/sec to start closing on the vehicle.

STAFFORD

We used the exact same procedure we used in the simulator. In the simulator, when we turned around, the vehicle would be out there 40 to 50 feet. And in real life, we got more DELTA-V.

YOUNG

I don't understand it, but it didn't cause any problem. If you're going to be safe about it, why not do it that way?

STAFFORD

I thought that the total transposition and docking was done with a very minimum amount of fuel. There was very little thruster firing.

YOUNG

We didn't do any formation flying; we just turned around and went back into docking. Transposition was a degree and a quarter per second to turnaround.

We were doing 0.2 ft/sec and we docked in CMC AUTO. It was easy. There were no vehicle oscillations. Alignment, as far as I was concerned, was absolutely perfect — a piece of cake.

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STAFFORD To show how accurately John had it aligned, we looked at the docking tunnel for the LM activation, and he had the roll aligned to a tenth of a degree. As for the capture latches, both the barber poles went gray. At the same time, you could feel just a little clunk.

YOUNG The CSM handled perfectly. The handling characteristics are just exactly what they were in the simulator. It's easy to fly in AUTO control. There was nothing to it.

Sunlight was no problem. I don't feel that the sunlight will ever be a problem on docking. I don't think there is any need to constrain the angle of sunlight except that you'd like to have it somewhere behind you, maybe within plus or minus 60 degrees of being behind you. It doesn't seem to make any difference. Now, when we were far out there, coming in, because the brightness off the LM, the COAS was washed out. But, when we got in closer, it came back in again and was there the whole way in. As soon as we hit, if I'd fired the bottle we'd have been all right. But I turned everything off and we sat there, and slowly the vehicle drifted down a couple of degrees. I wanted to get it back. So I fired a couple of down pulses and it slowly picked the vehicle right back up and then we fired the bottles and went on in.

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YOUNG
(CONT'D)

I don't really believe we had any misalignment to speak of at contact.

STAFFORD

John gave me the direction to fire the retract bottles, and I threw the switch. The one thing that amazed me, I thought it took a long period of time for the retract cycle to pull in.

CERNAN

That hit me, too. There were 2 things that I was amazed at. In looking out that right-hand rendezvous window, I noticed that the LM moved such a distance during the retract cycle. I didn't realize it was that far away in the capture-latch position. I don't know how far it was but it seemed to me an enormously big distance. I saw it move, but it took what I thought was a long time to get to the capture-latch point. Now, you didn't have the benefit of seeing it move.

STAFFORD

I didn't see it.

YOUNG

I saw it move, and I thought, my golly, how close does that have to come to us before we latch?

STAFFORD

I said to myself, "Is it retracting?" I couldn't see anything. I was waiting for the barber poles to go gray and hear the rings lock together. I just wasn't aware of this total time that is required for the retract cycle. When the docking

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(CONT'D)

latch is made, there was a kind of ripple type of situation, a real rapid ripple.

5.27 DOCKING LATCHES, UMBILICALS, POWER

YOUNG

Docking alarm was okay, sunlight okay, contact okay. Command and LM pressurization equalization was done as per the decal. We did open the hatch at 4 and a half psi on the cabin gage. When we opened the hatch and pulled it down into the spacecraft it was obvious that the Mylar, bonded insulation, had broken loose and we had fiberglass insulation all over the inside of the spacecraft. We shoved the hatch in the bag and crawled back over in the tunnel to check the latches. All the latches were engaged solidly. I felt around the edge, over on the bungees and springs. Springs 3, 4, and 10 were still partially compressed. In other words, they weren't all the way up to the top of the bungee, and that indicated they'd be one shot to cock and they were. I took my helmet and gloves off to attach the LM umbilical. The umbilical configured normally and we applied power, and that was normal. We were suited from pre-TLI through latch verification. We installed the umbilicals, vented the probe, and reinstalled the hatch. There was a great deal of fiberglass insulation that had floated up around the probe. It could be seen stuck on the LM center dump valve. We couldn't stop to do anything

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YOUNG
(CONT'D)

much with it. We had quite a bit of insulation floating around in the spacecraft when we reinstalled the hatch. In general, the hatch removal, replacement, and positioning, now that we've got the hoses reconfigured, is no problem. Managing that big hatch in zero gravity is very easy as long as you don't try to rush it.

STAFFORD

After completion of the tunnel work, I moved to the left seat, John was in the center seat, and we did the separation maneuver as planned.

5.28 EXTRACTION

STAFFORD

John fired the device and you could see a real positive indication as we moved out of the S-IVB SLA area. Then I added 3 seconds aft on the translation controller. The total DELTA-V that I saw on the DSKY was 0.2 ft/sec. I was somewhat concerned about this, so I added one extra blip on the aft firing thrusters — about 1 second. It still stayed at 0.2. When we made a maneuver to the ground computed angles, we pitched over and we could see we were already out 200 to 300 feet from the S-IVB. Extraction was solid as a rock; there were no dynamics at all. No problems with the S-IVB: No adverse plume effects. The separation maneuver was as

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prescribed. There was plenty of time between the time of extraction and the external DELTA-V evasive maneuver.

YOUNG

The roll angle that was computed by the ground when we pitched to the evasive maneuver attitude, allowed us to see the S-IVB out of the left side hatch window. This is an absolute must before you perform the evasive maneuver. You ought to know where the S-IVB is.

STAFFORD

At the time of the evasive maneuver, I would estimate our distance in excess of 500 feet. I could also see we were starting to move a little bit laterally from the S-IVB. The evasive maneuver external DELTA-V went exactly as planned. The residuals were available to the ground and were recorded in the data package.

Regarding the S-IVB sling slot maneuver and venting, we never saw the S-IVB after we did the evasive maneuver.

CERNAN

Yes, we did. We saw it a number of times out there in the distance.

STAFFORD

Way in the distance — 1000 miles away. The maneuver, the venting, and the propellant dump, we never saw any of this.

YOUNG

EDS systems deactivation — we pulled it off and pulled the breakers.

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STAFFORD I was late in doing that. The ground called me on it. The timeline from transposition, docking, extraction, and evasive maneuver was very easy. It was absolutely no problem and we were always ahead of time.

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6-1

6.0 TRANSLUNAR COAST

STAFFORD We worked out a new REFSMMAT and an attitude for translunar coast, and this was completely satisfactory. The first night, when we set up the deadband, we noticed near the end, that when the vehicle would reach the deadband, the thruster would fire. We're trying to sleep. The noise of the thruster was not annoying, but the total dynamic response of the vehicle was. You could feel about three or four cycles and it felt like a very loose vehicle - like a large airplane - something like a B-47 or a C-133, the way that the structural dynamics worked.

After that, the next night, we changed a procedure, that is damped the rates to zero before we set up the mode, instead of setting up the mode and then damping the rates. After that the longest period of time we went without firing any thruster was 18 hours.

YOUNG It's recommended that this PTC setup and operation be considered a nominal PTC G&N mode, and that it be used in all future flights. It's really a gas saver.

STAFFORD It's very simple and it's easy to do. It's just beautiful. You couldn't ask for anything any better. The communications throughout this whole time appeared satisfactory.

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YOUNG Even without thruster firing, on several occasions - for unknown reasons - we'd be sitting there on the second night and no thrusters would be firing, and the whole stack would suddenly give a shimmy. It was very recognizable, because we're all sensitive to zero gravity - unexplainable, but apparently quite normal. The whole stack would sort of resonate up and down. It was kind of weird, but very interesting.

STAFFORD It might have been some fuel sloshing in the lunar module, but it had its own noise. The stack had its own noise. You could hear things rumbling around, and it had its own little vibrations in there. It was a low frequency vibration. Now, we never felt that on the command module coming back. It was when we had the LM on there. Also, with the LM onboard, when you fire one pulse (again the Apollo 9 crew briefed us on this) the whole stack seems to be a very loose structural model.

YOUNG It'd set up this frequency and it'd shake the whole works. Nothing you could see on the rate needles, but you could feel it.

STAFFORD We timed it, and it would go through about 4 cycles. It would damp to zero in 3-1/2 to 4 cycles.

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CERNAN Communications all the way out were excellent. We went S-band OMNI most all the time, especially during the PTC sleep modes. The ground switched the OMNI antennas. They did an excellent job. We didn't have to worry about loss of COMM. We were in SQUELCH ENABLE. We had no noise problems. When we used the high gain antenna, the REACQ mode, it worked very fine all through the translunar coast.

YOUNG We did the IMU realign for REFSMMAT early in the translunar coast period. It is recommended that the ground provide roll, pitch, and yaw angles in which to perform the IMU realign. This will give the crew a chance to see stars. In other words, about 180 degrees from the Sun and yet avoid the problem of old gimbal lock program alarm when you go to gyro torque. Gyro torquing took about 4 to 6 minutes. At the completion of gyro torquing, the P52's appeared to be just as good as if there hadn't been any gyro torquing. Phenomenal.

STAFFORD PGA doffing required considerable effort. In fact, at times we had two of the crewmen helping the third one trying to get out of his PGA. We were really impressed by the effort that was required to doff the basic garment.

CERNAN It was quite a bit more effort than was required in one g to doff it. On the other hand, donning the PGA's was a piece of cake. Except for zipping up the zippers.

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STAFFORD Yes.

YOUNG The problem was in getting the neck ring off over the head and getting the arms out of the shoulders.

CERNAN Right.

STAFFORD The legs came off fairly easily.

YOUNG Optics calibration was extremely difficult because there were not any visible stars to fly to in the telescope. So we put it off as long as we could.

On the way to the Moon, there was never a case where we had more than one or two stars visible, even 180 degrees from the Sun. There was no place where we could recognize constellations on the way to the moon, and there were very few places, where we were doing P23's or P23-type things, where we could recognize individual stars except through the optics. It would be very convenient if there were a routine in the computer which would fly the spacecraft to position a star for optics calibration if they're required for each P23. It would save you a great deal of fuel, especially when you can't see the darned stars in the first place.

When you were doing star landmark tracking in the vicinity of the Earth, you had to do the optics calibration to find a

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YOUNG
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star a great deal further away from the earth than the procedure recommends. The procedure wants you to do the optics calibration in the vicinity of the body that you're tracking. You couldn't do that. The Earth, the Moon, and the Sun cause star shafting across the telescope, and completely blank your vision from seeing any stars with the lunar module on. The lunar module caused Sun shafting into the optics at various positions. From the start of TLI through translunar coast, we were never at any time able to see any stars except through AUTO optics.

CERNAN

Thank God for AUTO optics.

YOUNG

P51's would have to be done with the planets: Jupiter, in the vicinity of the Moon; and Mars, in the vicinity of the Earth, could be seen. And of course they are about 180 out from each other, which would make them very poor. We didn't try to Sun options, but we had filters onboard to use the Sun. I think they would work okay.

STAFFORD

I finally saw the first stars when we were approximately 100,000 miles from the Earth. At that time, I saw Acrux, and Alpha and Beta Centauri, but they were very dim. I saw these out of my side window. As we neared the Moon, I didn't see any more.

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YOUNG Photography during this phase of the flight went normal. We took pictures coming and going. We didn't have any system anomalies going to the Moon.

CERNAN The water boiler dried out during the liftoff. We tried to reservice it in Earth orbit, and it started up again, and it dried up again. We never used the water boiler until we re-serviced it for 3 minutes, at which time we brought it up, and it worked for reentry. So the only ECS problem we had was the water boiler and that really wasn't a problem at all.

YOUNG We found that we had to clean the inflow screen twice a day to keep the insulation which was being scrubbed out of the cabin from clogging it up completely. More on that later. The potable water chlorination was no problem, except that the fourth or fifth day, I forgot to do it and on one occasion when we serviced it, even though I backed the screw out on the buffer to retract the buffer full of water, the buffer thing did not retract, so I didn't get any water back from it. On another occasion there was considerable leakage around the chlorine nozzle and I got a considerable amount of chlorine on my hands, which I dried off and it didn't seem to cause any problem.

CERNAN Communications set up for sleep periods. Most all the way out, well beyond 100,000 miles, we used the OMNI mode of

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CERNAN
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communication antennas, using OMNI Bravo and Delta. We were in the OMNI position and the ground switched it between Bravo and their capability for Delta. They did an outstanding job of it. We never lost COMM. We really couldn't hear the switchover with the squelch enable on. Occasionally, we heard a little low buzz when we were running on a ragged edge of the antenna. Later on, we used the REACQ mode of operation of the high gain S-band plus OMNI B and that operation worked very well. The REACQ mode worked fine. There were no problems with the operation of communications or antennas.

6.12 PREFERRED PTC MODE AND TECHNIQUES FOR INITIATION

STAFFORD The preferred passive thermal control mode is really tremendous. With respect to visibility of the Earth all the way out, once we determined one slight modification to the procedure in flight, we were able to go for a period of 18 hours without firing one thruster — a good operation for saving fuel.

YOUNG The first night, the passive thermal control mode we set up was 0.1 deg/sec, with 20-degree deadband, pitch, yaw, and roll, G&N, and four quad control, with a roll disable. The spacecraft plus X-axis was normal to the ecliptic when we started. This immediately produced considerable thruster firings when the vehicle got to the deadband after a short

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YOUNG
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period of time. The thruster firings continued throughout the night. They were very disturbing and it kept Tom and me awake.

STAFFORD

It was not so much the dull thud of the thrusters that kept me awake as it was the associated dynamics of the vehicle. The vehicle would go through about 3 or 4 oscillations.

YOUNG

We would enter on our 50:18 display, disable two adjacent quads (with the auto RCS select switches) and wait 20 minutes (or as much time as we've got to go from MSFN that our rates were low enough to be into the PTC mode). Then we go with the MANUAL ATTITUDE switches to acceleration command, and enable all the jets, and initiate the 0.3 deg/sec roll rate as called out in the G&N procedures. And when the 0.3 roll rate was initiated, we go MANUAL ATTITUDE and roll to ACCELERATION COMMAND and we would open the deadbands to plus or minus 30 degrees, and put the pitch and yaw rates to RATE COMMAND. When we did this, we had not one single jet firing during the whole night (a period of 18 hours where we didn't have any jet firings). It is recommended that this be the standard PTC mode for translunar and transearth coast operations.

There were two periods of cislunar navigation sightings. One was prior to the first sleep period and one was after the

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first sleep period. It is recommended that with the LM attached, these sightings be planned preflight, so that it won't take a lot of attitude fuel and so that the stars aren't too far for the planet to be observed, because you're really limited with the lunar module on as to how much viewing area you have through which to look with the optics. After discussing this a couple of days prior to flight, we changed those in real time to allow us to save more fuel. The first set of sightings was for calibrating the horizon to my eye (and the horizon I was sitting on, according to the data, was 32 to 34 kilometers). This was a very hazy layer above the horizon that appeared to be the highest line above the horizon where I could see a useful attitude. It was definitely well above the cloudline. The star horizon sightings were no problem and had gone just as in training. A simulator is a very useful device for doing star horizon measurements. I recommend that a slide which shows the same kind of horizon that we saw on an actual spacecraft be put in the simulator to improve the horizon display. During the second period of star navigation sighting after the sleep period, the horizon was much less definite. In fact, it appeared to be almost nonexistent. Those sightings were no problem. The AUTO optics worked beautifully and in many cases a complete pass of star horizon sightings could be done with just the AUTO

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optics alone, and in very case where it was possible this method was used. It is very difficult to fly this vehicle with the CMC with the MIN-impulse controller. You just cannot think "roll, yaw, and pitch" when the axis is 35 degrees from your primary control axis. Optics calibration in both sets was very difficult. It was repeatable in every case where it was required, but with the LM attached it is very difficult to find a star near the body of interest to calibrate. It is certainly recommended that if this is seriously going to be done with the LM attached that some automatic mode be developed to find the star. The optics in the spacecraft handle easily during navigation sightings.

6.17 ADEQUACY OF CSM/MSFN COMM PERFORMANCE AND PROCEDURES

FOR COAST DURING AGA REFLECTIVITY TEST

YOUNG

When the gimbals actuated and ran through the gimbal drive test, the vehicle oscillated and the whole stack shook. It excited resonant frequency in the whole stack and shook it up and down. I think that this should be reflected on the needles on the simulator. And also use some fuel to correct those oscillations.

CERNAN

COMM performance and high-gain reflectivity test — the procedures and the performance of the COMM were excellent. The

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CERNAN
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high gain reflectivity test was done on the transearth coast. The results onboard looked like it had recovered from the reflectivity area on 2 of the 3 tests and not on the other. However, the results of those tests were not discussed and the ground has the data. They were carried out in about 20 minutes without any problems.

STAFFORD

Television preparation and operation is simple and straight forward.

CERNAN

There was no television preparation. All we did was plug it in and there it was. Stowage and restowage of the camera was a piece of cake and caused no problems whatsoever. High-gain antenna performance — when we locked up in high, or in wide, or in medium beam width, on the high gain it locked up fine. As soon as we'd go to high, the signal strength would jump up a couple of notches, and there was no problem. It worked just as advertised. On 21, I believe.

YOUNG

Daylight IMU realign and star check — all IMU realigns and star checks were performed in the daylight on the way to the Moon. There was no darkness except for one period of time when we entered the lunar penumbra prior to LCI.

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CERNAN Venting battery and waste — we checked the battery vents and the only time we actually had to vent the batteries was after boost and insertion. We did it at that time and it was good. All the waste vents worked perfectly. We had certainly no freezing or icing up on any of the systems. Radiators performed excellently and we went the whole distance without a primary water boiler until prior to reentry and we were comfortable.

YOUNG The command module/lunar module DELTA pressure decay was indicative of a very tight lunar module. I don't remember what the numbers were. It is recommended that the procedure previously discussed be used to reestablish PTC. It is recommended that realigns, where practical, be done while still in the PTC mode. They were very easy to perform and suffered no loss of accuracy by being done in the PTC mode and unless it's a critical maneuver such as LOI it is unnecessary to go through the process of killing the PTC operation.

CERNAN The high-gain antenna REACQ check and the PTC mode worked okay. We used the REACQ operation in lunar orbit during sleep periods. We used it in lunar orbit most of the time and often on the way back. It worked fine.

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CERNAN
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Fuel cell performance was excellent until the time we lost one (this gets into the lunar orbit). All through the coast phase the fuel cell performance was fine. The purging worked fine. We lifted off without the fuel cell number 1 oxidizer flow rate gage, but the ground had that information. Depending on the load and flow rate during the coast period, since we were powered up, the load was high enough that the caution and warning and MASTER ALARM would come ON during every purging in either system, whether oxygen or hydrogen.

STAFFORD

Eating periods allowed plenty of time on the way up.

CERNAN

The first eating period was scheduled at 9 hours after we separated. It seemed to be a good time. Our morning eating period was sort of set because we ate as we got things together and posted the checklist in order after we got up. Our second eating period of the day sometimes dragged out to be the last one and we ate when we were sufficiently hungry. That could have been called a noon meal, a midafternoon meal, an evening meal, or a night meal, depending on the day and the circumstances.

YOUNG

We skipped the noon meal on the second day for some reason.

CERNAN

We probably just weren't hungry.

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- STAFFORD Rest periods were completely adequate, and we slept about 6 to 8 hours the first night. I guess the second night out or toward the third we were inactive for nearly 12 hours at a time.
- CERNAN The work load in coast after the tunnel latches are checked and the probe is checked is little or nothing.
- STAFFORD The big work load was on the command module pilot with respect to making those sightings.
- YOUNG Sightings and realigns are all you do. Actually I was grateful for something to do.
- STAFFORD During this period of time we also studied our flight plan for the lunar orbit activities and we restudied the lunar surface maps and the rendezvous procedures.
- YOUNG It is recommended that these be put into the flight plan as standard times for crew study for critical phases of the flight. For example, a certain period of time should be allotted prior to LOI and a certain period of time prior to entry to refresh your mind a little for those critical events. Environmental conditions of the spacecraft — it was comfortable on the way out.

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7.0 LOI THROUGH LUNAR MODULE INGRESS

STAFFORD The realign was done in the lunar penumbra with no difficulty.

YOUNG It was done with no difficulty and for the first time we could see constellations so the star checks were unnecessary, but they were done anyway. Special effort was made on the realign to do a perfect alignment.

STAFFORD Prior to the initiation of LOI burn, approximately 1 minute I would estimate, you suddenly saw the lunar surface at the near-side terminator starting to come in reflected through the LM window and then I could see part of it out the hatch window. There appeared to be no variable transients with the initiation of the burn and the guidance was steady.

YOUNG It was steady, and the thing that was noted about the burn transient, as on the D mission, was that you get continued control in roll; it's up against the deadband, but it gives you a very good feeling of how the vehicle is performing.

7.1 SPS BURN FOR LOI

YOUNG After the second bank came on, chamber pressure was normal, about 102 to 103 psi.

STAFFORD And the chamber pressure increased, didn't it?

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YOUNG It appeared to increase slightly during the burn. The burn residuals were negligible.

STAFFORD Right. We had a zero X burn residual. These are all recorded in the data. At LOI, our monitoring techniques worked adequately for the modes 1, 2, and 3 and the procedures also were perfectly adequate.

YOUNG The SPS burn card was used throughout the mission to perform SPS burns and certainly appeared adequate for the operational performance of the engine, and it seems a shame to have to fool with it anymore.

STAFFORD The burn put us in the expected LOI orbit parameters perfectly. All the monitoring techniques during the burn were adequate.

7.2 POST-BURN SYSTEM STATUS

YOUNG According to the onboard solutions of VERB 82, the chamber pressure went from 98 with one bank and then increased and ended up with two banks at 103.

7.3 ORBITAL PARAMETERS

YOUNG The LOI/1 burn put us in a 169.1 by 59.6-mile orbit.

7.7 ACQUISITION OF MSFN

YOUNG Acquisition of MSFN was without difficulty. We had the high gain attitude to acquire and it came in loud and clear.

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7.8 PTC ATTITUDE

STAFFORD PTC attitude for lunar orbit was fine except we noticed that the quad that was toward the sun continued to heat up; in this case, it was quad A, and it was high off-scale on temperature after the first pass. We did a different roll attitude for the next one. The PTC attitude in lunar orbit was initiated just like during transearth coast; I think in lunar orbit we never fired a thruster at night.

YOUNG Well, we were using only plus or minus 10 degrees in lunar orbit, and we still didn't fire a thruster.

STAFFORD In fact, we didn't fire any thrusters all night long.

YOUNG That bothered us; we thought of firing some on occasion.

CERNAN The only thing that bothered us about not firing any thrusters for so long a period of time (which is great at saving fuel) was not knowing whether or not they were still working. From a standpoint of PTC, fuel saving, and stability, it was a great attitude.

7.9 IMU ALIGNMENT

YOUNG IMU realignment was a piece of cake in lunar orbit. It was dark and there was no problem. The first time during IMU realignment I noted that, by taking special care of

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positioning the stars within the center of the optics, you could repeatedly get five balls instead of four balls 2, or four balls 1 for star-angle difference. I don't think it's of much concern except for those critical events, such as long burns, LOI, TEI, and reentry. I had previously recommended doing that.

7.11 UPDATING AND PREPARATION FOR LOI 2

STAFFORD

The update in preparation for LOI 2 is again just another external DELTA-V, and it was a short burn compared to LOI 1. There wasn't any problem.

CERNAN

We noticed on both of these burns that the PUGS failed to operate properly. On our first burn during coast, we found that the PUGS went to a decrease of about 150, at which time the decrease switch was activated. I caught it close to 200 and brought it back to zero. The decrease switch was then put in a neutral position. Subsequently, on the following burns, the system was able to stabilize out. When the PUGS is used, it is very easily recognizable when going through the 50-percent crossover region in oxidizer flow. The percentage quantities remaining requested an increase in oxidizer flow. The switch was put that way at about 150 on the increase side, and for the subsequent burns throughout

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the mission, the PUGS continued to go toward the MAX increase position and stayed there. We never did get apparent PUGS operation, or the oxidizer fuel balanced back again.

7.15 TELEVISION

STAFFORD Television in lunar orbit was no problem; in fact, we never had any problem with television.

7.16 REMOVAL AND STORAGE OF HATCH FOR IVT TO LM

YOUNG Removal of the hatch was no problem. The hatch was very easy to remove, but once you got it in the cockpit with you, you had a lot of Mylar, a lot of fiberglass insulation in the cockpit with you.

7.17 DON PGA

CERNAN We did not don the PGA's for this operation.

YOUNG We had to pressurize the lunar module over a DELTA-P of a couple of psi, for that purpose, we used a shot of REPRESS C₂ to get us back up to speed. Do you remember how much we used?

CERNAN We went down to about 500.

YOUNG Yes, because we were interested in a rapid REPRESS and ingress, and we did a pressure decay check before we went

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into it, although I think that was unnecessary. I'm sure that also disturbed the insulation more and was the reason we got some additional insulation off the hatch.

7.19 VERIFY THE LATCHES

STAFFORD The latches were the same as before.

YOUNG The latches were identically the same as before. They were reverified and rechecked.

7.20 INSPECTION OF TUNNEL MECHANICS

CERNAN The tunnel was normal. We found a misalignment in roll of minus 0.1, which is practically on the zero mark, almost outside the limits of reading the grossness of the alignment scale.

7.21 REMOVAL OF THE PROBE AND DROGUE

YOUNG The probe and drogue were removed as per checklist. There were no anomalies associated with handling either the probe or the drogue during removal. The thing of interest was that the big probe is very easy to handle. We had no problem in removing it. The probe did not appear to collapse completely as we had seen in other removals. It didn't collapse as much on the first removal as it might have. In other words, it was still partially open. We had a little difficulty getting

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YOUNG
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it around the hoses, but it was nothing we could do something about. We stowed the probe in the command module by tying it with a single snap-strap to the footpan of the right-hand couch. This was a little concern to us, and we did not use the drogue or probe stowage straps. We might have used them if we had had to fire the DPS. The drogue was stowed underneath the probe in the same vicinity and was not restrained in any way. The probe adequately restrained the drogue when it was underneath the probe.

7.22 IVT TO LM

CERNAN

The LMP went into the LM in shirtsleeves. The first thing he encountered, of course, was the LM hatch. In the tunnel area was a lot of floating Mylar debris, or insulation debris from the tunnel hatch. When the LM hatch was opened, the floodlights were on as prescribed, although it was very dim lighting. The first thing that was seen was a mild snowstorm of insulation that, during the pressurization of the LM, had blown through the LM dump valve and into the LM. The hatch was inspected immediately and it was found that there were many pieces of insulation stuck all over the semi-greasy seal, pieces in some cases as big as a dime. The dump valve was inspected and we found pieces stuck in the seal of the dump valve. Pieces that had to be pulled out and picked out.

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Sharp instruments such as a automatic pencil had to be stuck in to force some of these little pieces of insulation out of the dump valve. The hatch was cleaned and wiped, and the dump valve was blown out, physically blown with air from the mouth to try to make sure that it was totally clear.

7.23 INGRESS ORIENTATION

CERNAN

The hatch was locked in place normally and the ingress was complete without any ingress disorientation. All you have to do is go into the LM with your eyes open, and you realize that you are coming in standing on your head with about a 60-degree yaw. Just do an 180 in pitch or whatever else you want to do to get your feet on the floor, and you're in a new environment with a new up and down, very much like you've been in the simulator and you could care less what is beyond that tunnel and what the orientation the command module is. You are in a new orientation all of your own and it's perfectly nominal, perfectly satisfying. The Velcro on the sandals did not restrain you totally, but certainly helped restrain your feet to the surface of the LM floor when you were moving from one panel to the other during the switch-orientation verification. But I want to stress again that, although it was different, if you keep your eyes open and look around and just turn around,

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you're in a new environment with a new up and new down and you just live in it, and it's very familiar.

7.24 LM ENTRY STATUS

CERNAN

We entered the LM as per checklist and found it to be exactly in the configuration we left it at lift-off.

7.25 POWER TRANSFER TO LM

CERNAN

The power transfer to the LM was nominal with the proper lights just as written in the procedure. You might note that although sometimes when the man you are talking to is well up into the command module, you have to lean over into the tunnel and talk quite loudly, almost yell to him. He can certainly hear you and you can hear him. If you have a man in the tunnel, you can almost talk to him in a normal level of voice and he can transfer information without any difficulty at all. Now the problem then that was encountered after a little bit of work and switch verification in the LM was that the insulation was still floating around in zero g. The circulation down in the LM was very poor. The insulation was irritating; it also became warm. You could feel yourself tending to breathe this stuff. What we did was pull a command module LM Pilot hoses (of course, we had the screen on the exhaust hose all the time) and drop them all the way down into the LM and they just laid there and floated freely.

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This blew fresh air around in the LM and from that point on, although there was still a lot of Mylar floating around (and some of it going back into the command module), the comfort level working in shirtsleeves was adequate, and the ventilation level working in shirtsleeves was adequate, and the ventilation was adequate.

7.26 TRANSFER OF EQUIPMENT

CERNAN

This equipment was listed in the checklist, or in the flight plan, which we highly advocate. It was labeled on the transfer bag, such as 16-mm film packs. While the LM Pilot was in the LM making a switch verification, the commander was gathering the gear together and sending it on down. As he sent it, it was stowed immediately where it should be without any difficulty. A piece of cake.

7.28 OPS CHECK

CERNAN

The OPS check was left until the end of that day after all the communications procedures and everything was checked out. One OPS was taken out and handed to the Commander, and he effectively was halfway through the tunnel and was checking it out while the LM Pilot was fully in the LM, checking the other OPS out. The checks went normally with the exception of one item. On the OPS that was labeled Stafford, the heater

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CERNAN
(CONT'D)

lights failed to light during the press to test, indicating that the heater was not operating. Neither light operated. However, the other OPS checked out satisfactory. Pressures were good and as far as we are concerned, we still had two good OPS's except for the heaters in the one. They restowed with very little difficulty. Once I understood that you've got to push that one oxygen supply hose out of the way to get the pins in, I had no trouble at all. The rest of the LM operation that day was communications checks. The only restraint that I used during the shirtsleeve operation in the LM was the Velcro on the sandals, and that is adequate for shirtsleeve operation during LM checkout.

7.30 LANDMARK UPDATES

YOUNG

The system used for landmark updates, which is the map update, LOS 150 degrees west, and AOS, sunrise and sunset times, is excellent. It's recommended that they be used as standard procedures in future flight plans. The landmark-update format for defining the times at which the landmark appeared at the zero-degree line, and the 35-degree-elevation line to start the pitch rate for LM or landmark tracking was adequate. Landmark tracking of the first site, F-1, was done with the sextant by tracking a small crater on the left corner of landmark F-1. The location of F-1 through the AUTO optics mode

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was about 5 or 6 degrees away from where F-1 actually is located, and this happened on every case. We ran the five sets of five marks on F-1 and it was always wrong. It is believed, but I'm not certain, that on the first attempt on B-1 with the LM AUTO optics acquisitioning, an erroneous landmark was tracked. It is highly recommended that, if landmark tracking is to be continued, more thought be given to selecting landmarks, the position of which is known prior to the mission and the acquisition of which can be easily performed with the LM attached. Landmark tracking per se conducted with the telescope or the sextant was easy and was a coordinated effort with the Commander flying the vehicle and CMP tracking to locate mark intervals. It was noted by the ground that we commenced making our marks too early, and after we delayed them 20 to 30 seconds, the system seemed to work properly. There is no way for the crew to tell what is the proper time to start making marks. The geometry of the situation does not lend itself to an onboard determination of what this proper time should be, in my opinion.

7.34 MSFN/CM/LM RELAY COMM TESTS

CERNAN

The MSFN/CM/LM relay COMM tests were effectively not performed at the direction of MSFN. We did the LM COMM checks; we proved out the adequacy of the LM COMM system. We proved out the

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CERNAN
(CONT'D)

anomalies that were expected; although we had time prior to the upcoming LOS, we were directed to forget about the MSFN/LM/CSM relay mode test.

7.35 CONSUMABLES-ACCOUNTABLES

STAFFORD With respect to consumables, our philosophy was that we had to send this telemetry to the ground and let the ground look after the consumables. We would occasionally glance at our gages. As far as onboard recordings, all we did at night was record those listed in the flight plan.

7.36 FOOD AND REST

STAFFORD Rest in lunar orbit was exactly like in PTC, because only occasionally would a thruster fire.

CERNAN We used all three sleeping bags and we were happy we had them, because when you close up the windows in the command module, it gets a little bit cool.

STAFFORD Even in lunar orbit.

CERNAN That is correct. Our configuration, almost every sleeping night of the flight, was one man in a sleeping bag under each left- and right-hand couch and one man in a sleeping bag, keyed to the COMM system, sort of standing watch in the couches. The food was adequate, long, tedious, and difficult

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~~CONFIDENTIAL~~CERNAN
(CONT'D)

to prepare. I guess the food will be covered in more detail as part of the later systems. We can talk about it as far as wet packs and everything else a little bit later. We were not hungry or undernourished.

7.37 TUNNEL OPERATIONS

YOUNG

It was originally thought that we would keep the probe and drogue and the hatch under the couches, but it was noticed that they took up so much room that it didn't seem to be a very nice way to operate, so we reinstalled them. It was more difficult to get the drogue in and out of the tunnel than any other piece of equipment, although this had been anticipated and it was no problem. We reinstalled the probe and unloaded it, and reinstalled the hatch. The total time for this reinstallation was somewhat less than 15 minutes.

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8.0 LUNAR MODULE CHECKOUT THROUGH SEPARATION

8.1 COMMAND MODULE

8.1.1 CSM Power Transfer

CERNAN This is the next day, that morning.

YOUNG Let's talk about that next day some, because that gave us some trouble. We woke up about a half hour early on the next day, so we could get on with the space program.

STAFFORD Right. We wanted to make sure we were always running 30 to 45 minutes ahead of everything we did because we anticipated that we would have some minor glitch. We didn't know what it would be, but something would happen.

YOUNG Sure enough it did. The hatch was removed, and placed underneath the couch. It was not placed in the bag because we didn't figure we would be having it out that long. It was stowed underneath the couch, and there was no chance for it to move. The probe was removed and retained with a strap on the lower footstrut; the drogue was stowed underneath the probe in place, and we started to get on with the program. We didn't eat very much breakfast that day; I think we had some juices among the three of us.

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STAFFORD We were still concerned about all the gas in our stomachs, so we ate a wet pack and just some minor things; mainly we ate a wet pack to give us a lot of protein for the job ahead.

CERNAN Didn't you prepare some of those the night before?

STAFFORD I prepared applesauce and then a couple of juices for everybody the night before and we all had a wet pack and what we prepared, and then pressed on.

YOUNG Tom put on his suit. You want to talk about it in terms of the timeline?

STAFFORD I think we need to talk in terms of timeline. I put on my suit, had no difficulty getting in. John was helping me. He helped me with the zippers and it only required 5 minutes at the most. The people who have a liquid-cooled garment ought to put it on and get all squared away and sleep in that LCG the night before.

CERNAN Right.

YOUNG We moved the canister change back early to get it out of the way of donning the suit. You can't don the suit and change the canister at the same time.

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CERNAN Because of the BIOMED harness change-out, the unstowing and unpackaging of the LCG and what have you, I would highly recommend this all be done at night before you go to bed. You can take all the time in the world. It's not uncomfortable to sleep in. As a matter of fact, it's a little bit warmer than just sleeping in plain ordinary underwear. And it's a much better feeling to come back and get ready to put on your suit and not have to go through an underwear change and a BIOMED harness change and the whole works.

YOUNG In that regard, there were many items that aren't in the flight plan or aren't anywhere — insignificant little things that took up a lot of time. I wish people wouldn't think that, when you got something in the flight plan, that's all you're doing. That's not so. In every case when it says doff or don PGA's, there's no evident — realization made of the little idiosyncrasies of each system; such as, when you take the suit off, you must take all the pencils, pens, tools, and all equipment out of the suit, stow them in your constant wear garment; that takes time, and we never allowed adequate time for it. And it's recommended that, where possible, the guys who are going to have to don their suits the next day completely install the gear into their suits, if they can do so the night before, because it saves them 10 or 15 minutes the next day, which they're going to need for other things.

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CERNAN That's right. Getting in the LCG the night before just made getting in the suit a piece of cake. All I had to do was put on my UCTA and jump in the suit and make the water connectors, urine connectors, and zip it up, and that was it. It took me as long or longer to get into the LCG the night before as it did to get in the whole suit the next day. I'd say I was in it and zipped up with the help of the CMP in less than 10 minutes. Is that right, John?

YOUNG Yes. Less than that.

CERNAN Now, one thing. Let's get the suit straight. On that morning, the LMP (in shirt sleeves) again went back into the LM for a period of about 30 to 45 minutes initiating the LM checkout prior to separation and then the Commander came in fully suited (without helmet and gloves, that is) and activated the ECS system to get his cooling. By that time, the LM Pilot was about through with his checkout and he went back into the command module where he got suited up. This was a great help because we could work in parallel and it kept the command module less crowded, so that it was easier for the two men at a time to put on a suit rather than have three men in there.

YOUNG We had all the equipment transferred the night before except the helmets and gloves.

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8.1.3 IMU Realign

CERNAN We did an IMU realign. The ground had to remind me it was an option 1. However, the difference between an option 1 and the other one was insignificant. It was an insignificant change. It was no problem on the night side.

8.1.4 Assist LM VHF A and B Checks

STAFFORD B simplex worked beautifully and for some undetermined reason, the LM would not transmit on VHF A at that time. We tried numerous checks.

YOUNG I could hear you just in the background in sort of a feed-through mode, but I couldn't hear you very loud. It sounded funny and I knew you were saying something, but I didn't know what it was.

STAFFORD It's been suggested that there might have been a corona buildup on the LM VHF system. The VHF -- I could still read the command module loud and clear.

CERNAN It might have been some sort of antenna-pattern interference. This is what we were concerned about prior to undocking.

YOUNG Well, I switched antennas in the command module, and it didn't fix anything.

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8.1.5 Tunnel Closeout

YOUNG

The tunnel was closed out as per checklist. The drogue was installed, the probe was installed, and it was nominal in every respect. It just went in beautifully in a very short period of time. The probe was preloaded and the estimated breakout force was about 40 pounds, just exactly as it had been on the last probe we used down here. When the docking latches were all released at first, the auxiliary release button had to be used to release latch 1. Latches 3, 4 and 10 were indeed one-shot cock latches and the other latches caught nominally. A final inspection was made of each latch individually to insure that they were in fact backed off and it was reported to the LM crew that they were in fact backed off. The tunnel hatch was installed and sealed and the pressure-equilization valve was closed. When I removed my helmet and gloves, I got an O₂ FLOW HIGH warning light; the reason for that was that the inflow valve had been closed as per checklist. I opened the inflow valve, but you know I was kind of nervous, because it indicated that we had a pressure leak, and when I vented the tunnel, the tunnel would not vent.

STAFFORD

The inflow valve was clogged with this insulation material.

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YOUNG That was part of it, though it was partially caused by the fact that it was clogged by Mylar insulation that had been sucked in the second time and the other thing that caused it was that, when you have your helmet and gloves off with the inflow valve closed, you get an O₂ FLOW HIGH. That's a standard operating factor.

8.1.6 Maneuvering for Landmark Tracking

YOUNG We were told not to maneuver to a landmark tracking attitude. We could not vent the tunnel. We were told prior to this time not to do any roll maneuvers, to deactivate the roll jets, and not to do any roll maneuvers until we vented the tunnel. At this time, we were LOS and we could not vent the tunnel. So, nevertheless, the attempt was made to stick with the timeline, and we attempted to maneuver to the roll attitude. Unfortunately, it had been operating in SCS and neglected to cage the BMAG's which resulted in oscillations in roll, probably in excess of 1 deg/sec. I know we were in excess of 1 deg/sec and this resulted in slippage of the ring, and I'd estimate the slippage of the ring to be 60 to 8 degrees.

CERNAN At this time, we'd say that.

YOUNG Right.

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STAFFORD The docked IMU alignment came off as prescribed, and then, when we went to the fine align torquing angles, I noticed they were probably in excess of what they should be. We had another one from the ground and they came back again. The ground informed us that they suspected we had a slippage on the docking ring. So after that, we did no more fine aligns to the IMU.

8.1.10 Maneuvering to Undock

YOUNG Okay. And we cancelled our landmark tracking, because there was no way we could get to it without rolling the spacecraft. So we just maneuvered in pitch and yaw to the undocking attitude..

STAFFORD We did not reach the total undocking attitude that was prescribed in the flight plan. We didn't, did we?

YOUNG No, we did not. We never maneuvered to the 180 roll attitude, which was the attitude prescribed for undocking. The attitude that we maneuvered to was 014 degrees in pitch and zero. We had some yaw associated with it because we were in wide dead-band. This was not the attitude that was recommended because they said the Sun would bother us too much in that attitude. We were 180 out on the attitude and the Sun had absolutely no

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YOUNG
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effect. I recommend that that 180 roll be eliminated from future missions because it's unnecessary. The ground informed us that there would be no problems undocking at 5 psi differential. The TV was set up prior to undocking. There was only one switch to throw and a lens cap to remove to operate the TV. The sequence camera was all set up and mounted in the right-hand rendezvous window. Unfortunately, we didn't check its run operation prior to separation and the magazine had jammed. I was unable to fix it until after separation. The ATTITUDE CONTROL mode for separation was tight deadband, MIN rates, and it was certainly adequate. The undocking maneuvers were nominal.

8.1.11 Dap Loads

YOUNG DAP loads were nominal.

8.1.12 Undocking

YOUNG Undocking was done 5 minutes ahead of time to square ourselves away with regard to orientation and it was rather difficult from the standpoint of the lunar module.

8.1.13 Stationkeeping

YOUNG Stationkeeping was a piece of cake.

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STAFFORD We had worked out a coordination with respect to the up/down maneuvers. I would do that in the lunar module. This was very easily done, but the left/right and the fore/aft was done with the command module.

YOUNG And I suspect that on a lunar flight where they're fuel critical, they'd do all those maneuvers with the command module. Stationkeeping with the command module was just as easy.

STAFFORD It appears that we have a tremendous propellant budget on the command module.

8.1.14 LM Drift Checks

YOUNG LM drifts checks were nominal.

8.1.15 LM Inspection Photography

YOUNG LM inspection photography was done with the TV. I did plenty of 70-mm photography on a catch-can basis. We had to do a bunch of things simultaneously — stationkeep, write the DOI, phasing, and TDI abort pads, and conduct photographs all at one time and you really wouldn't be able to do that without the ATTITUDE HOLD mode in the command module, but it really performed beautifully. It's difficult to get your head back in the cockpit to do work when you're trying to keep station on somebody.

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8.1.16 Separation Photography

YOUNG Separation photography we got with the television. When I was up and a little above you one time, you were able to ascertain that all four gears were down and locked without having to yaw around. All four gears were down and I really see no need to do that 360-degree yaw except that it gives you a warm feeling. You might do a pitch-up, for example, and face all the gears toward me. A guy would be able to tell whether they're down and locked or not, just by the geometry of it.

The separation maneuver was nominal: 2-1/2 ft/sec down. The VHF was turned on and operated.

8.1.18 Rendezvous Radar and Optics Checks

YOUNG The radar ranging checks were nominal. The AUTO optics was not tracking very good in the mini-football; in fact, it wasn't tracking at all, but we could track them in the telescope. The flashing light on the LM was beautiful. It really wiped us out on the mini-football while we were in the dark.

CERNAN That flashing light could not be seen from within the LM. We never saw it in daytime or nighttime or during AOT alignments.

STAFFORD It was very well designed as far as not being able to see in the LM.

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8.1.19 Compare VHF to V85 Range

YOUNG We didn't compare the VHF to V85 range, but I did compare the VHF range to the raw range from the lunar module, and I recommend that it be done that way. The V85 range would be subject to error through the state vector from the center of the Earth.

8.1.20 Update Pads

YOUNG I could not copy the update pad from the ground, but I was able to get it later from the lunar module. There were some communications problems at this time. Everything that I said to the ground I could hear repeated again 2 seconds later. I never did understand that.

CERNAN We could hear that from the LM much of the time also. They were shooting it right back to you then.

YOUNG Yes. And I recommend that that type of thing be corrected, because that's darned annoying. You don't know whether someone's trying to get you on the radio or not.

8.1.21 COAS Calibration

YOUNG COAS calibration was not performed, because there seemed to be no reason to do it.

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8.1.22 COAS Tracking

YOUNG COAS tracking was not done, because it didn't seem to be necessary. It was certainly not a requirement from a navigational standpoint.

8.1.23 Workload, Timeline, and Flight Plans

YOUNG The workload, the timeline, and the flight plan for this phase of the operation were completely adequate. I highly recommend that only one book, the CSM rendezvous book, be used and that it be complete for this period of time. We were using the flight plan, the update log, and the CSM rendezvous book. And that's entirely too many pieces of paper for one guy to try to fool with.

8.2 LUNAR MODULE

8.2.1 Power Transfer Activation and Checkout

CERNAN A power transfer the second time, just as it was the previous day, was performed without a hitch. We got the proper lights, proper negation of power transfer, and activation, and all the data on the battery voltages, which were very high. We operated off the low taps until we got a lot of the systems well into their power phases. We had a big load connected before we got down to 27 volts. All these numbers are documented. The total checkout went well. The anomalies we ran

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into, with the tunnel vent pressurization problem, cost us some time, so it paid us to be ahead of the checkout. The checkout was conducted for the first 30 or 45 minutes by the unsuited LMP. The Commander came in suited and the LMP returned to the command module to suit up. The whole operation of suiting up and getting back in probably took less than 15 minutes. One procedure that was followed in the LM activation checkout was that when things were done, they were crossed off with a pencil, because, as expected, we had to skip around some times. Any particular documentation that had to be recorded was recorded right in that checklist, and that is the only document we had out in the LM at that time. The Commander had one and LM Pilot had one, and they were identical documents.

STAFFORD

One reason that the activation and checkout went so smoothly was the fact that we had practiced this in real time in the simulators during integrated. We practiced many times unsuited, and also approximately three times completely suited. - We also practiced suiting up. And we had everything down to the nth degree. As a result, we were just where we wanted to be. We were again running 30 minutes ahead of time, until we had to wait for a time-dependent item such as acquisition of MSFN. The docked alignment and the ECS test went real good. The VHF test anomaly on VHF simplex A,

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the transmitter from the lunar module, was as noted. Later after undocking, it was in good shape.

YOUNG

I didn't say anything about the radar transponder checkout, but we ought to talk about that.

8.2.2 PGNCS Activation and Self-Test

CERNAN

The PGNCS activation and turn-on went just by the book. We saw the self-test completed and verified, and it was good. The process of developing this checklist over many weeks in the simulator finally paid off. All the anomalies that we found, time after time after time while going through it in the simulator, finally all washed down; when it came down to the real vehicle and the real checklist, they matched. It was really a comforting feeling to see the proper lights come on at the proper time, and not too little or too many lights come on; to see the PGNCS self-test and the AGS self-test come out as prescribed. It seemed to go that way throughout the whole activation.

8.2.3 ECS

The ECS was powered up without any problems. The glycol pumps were turned on, and when I went to the primary evaporator flow number 1 position, the glycol temperature was up high scale, close to about 80 or 90 degrees, which was no problem. We

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CERNAN (CONT'D) knew it. We did it in the timeline according to the book, but it was about 30 minutes, at least, before that temperature slowly came down to where the glycol TEMP light went out, and it came back within the normal green band.

YOUNG You can hear the glycol pump from the CM.

CERNAN The glycol pumps have bearings that were made out of lunar-surface gravel, I'm sure, because they sounded just like it, both the primary and the secondary pumps.

8.2.4 VHF

CERNAN The VHF problem has been mentioned. We had to be in VHF B because it was the only COMM mode we had, until after separation.

STAFFORD Right. We had to modify proceedings there instead of using A simplex, but that was no problem.

8.2.5 Adequacy of Communications Using the S-Band

8.2.5 OMNI Antennas

CERNAN We had checked out the S-band OMNI antennas the previous day. We had decided to use the OMNI down-voice backup mode which gave us a hot S-band continuous key microphone, but the communications were adequate.

8.2.6 Steerable Antenna Test

CERNAN When the time came to power up the high-gain steerable, our

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COMM became much better, both going and coming. There was no problem with signal strength and there was no problem with an AUTO lockon. I sure do want to say that the procedures we worked out for having the high-gain pitch and yaw attitudes correspond to the command and service module attitudes worked out beautifully. It was always within the realm of the capability of the LM antenna high gain to acquire without even tuning it in manual. There was enough signal strength to acquire at those attitudes, then go to the AUTO position, and lock on. Those numbers were worked out and proved to be very adequate.

8.2.7 Secondary S-Band T/R and Power Amplifier Check

CERNAN

Secondary S-band at T/R and power amplifier checks were made and were adequate. We didn't use them the rest of the flight.

8.2.8 Telemetry Updates

CERNAN

Telemetry updates came through loud and strong without any hitches.

8.2.9 Tunnel Closeout

STAFFORD

The tunnel closeout was as practiced, and I verified that the - -

YOUNG

You installed the drogue.

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STAFFORD I installed the drogue instead of John this time, because it was very easy to do and - -

YOUNG And I made sure it was closed out.

STAFFORD And I verified that the capture latches were engaged.

YOUNG When we preloaded it, he verified that the capture latches were, in fact, holding.

8.2.10 Suit Loop

STAFFORD Suit loop checkout went as prescribed.

8.2.11 Ascent Batteries

CERNAN Ascent batteries were brought on the line. By this time, we had high voltage taps on the descent batteries, and all six batteries were well up there. The values are documented, but they were all within the 35- and 37-volt category. The ascent batteries were brought on and the check went nominally through-out the normal and backup ascent feed system.

YOUNG What is that noise you guys made up there when you banged that thing?

CERNAN The noise had to do with the ECS, with the REPRESS valve. Every time you change a position of the REPRESS valve, it shudders through the whole spacecraft.

YOUNG You should see what it does to the Command Module Pilot. You should have seen my dynamic oscillation.

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STAFFORD We knew about this from the debriefing from Apollo 9 and we expected it, but it was still a loud bang.

YOUNG You caught me on that second one, though. You didn't tell me.

CERNAN I know I didn't.

8.2.13 ARS/PGA Pressure

STAFFORD Because of the insulation problem and the inability to vent the tunnel, we went through the PGA pressure check and the loop integrity check, but we never got to the final regulator check. We didn't vent the tunnel until undocking since the cabin pressure was holding, and it had worked good before. So we assumed that the regulators were all good.

CERNAN The one thing that we had to do was to delay this until we discussed the whole operation with MSFN. We went ahead in our activation and checkout. We picked out some items ahead, then we came back through MSFN contact. In the meantime, we verified our own tunnel-hatch and dump-valve integrity. We were concerned about whether our hatch or our dump valve had any of this insulation in it and was feeding the tunnel, keeping it pressurized. We pumped the LM up to 5.4 and watched it. We held the cabin pressure solid as a rock which gave us a very warm feeling. We were finally able to make

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(CONT'd)

sure that we had the hatch sealed and the dump valve clean of this insulation and that it was not a leak from our spacecraft that was feeding the tunnel.

8.2.14 AGS Activation

CERNAN

The AGS activation went beautifully, and the self-test was nominal. It gave us assurance that the AGS was in good shape. We were not able to do an AGS calibration because the command module was limited with the use of its roll thrusters and could not hold the attitude. We got the original numbers at the start of the calibration but were unable, because of constraints, to finish the calibration. The AGS alignment was done procedurally, just as planned after the update. We put P27 into the PGNCS. The AGS update to the PGNCS went nominally. We got a good alignment. Everytime we aligned the AGS to the PGNCS, in switching from the PGNCS to AGS, we could always see just a little flicker on the 8 ball. It's not really an attitude change but a flicker.

8.2.15 S-Band Antenna

CERNAN

The S-band antenna has been discussed. When we got anywhere from 3.2 to 3.4 signal strength on the S-band antenna, we could tune it in manually up to about 4.0 if so desired. As long as we had about 3.4 to 3.6, if we went to the automatic

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CERNAN mode, it would start moving around and lock on itself auto-
(CONT'D) matically to a signal strength of about 4.2.

8.2.16 ORDEAL

STAFFORD The ORDEAL initialization was done according to procedures
and was no problem.

8.2.17 MSFN Acquisition PCM-LBR

CERNAN The PCM low bit rate and high bit rate, as far as MSFN was
concerned, apparently had no problems.

8.2.18 DAP Loads

STAFFORD The DAP load went according to procedures.

8.2.19 DPS Gimbal Drive and Throttle Tests

STAFFORD The DPS gimbal drive was omitted preflight due to the problem
that we anticipated with the DPS gimbal. In fact, we even
anticipated that we could make both the DOI burn and the
phasing burns with the gimbal off due to the low c.g. travel
for the amount of DELTA-V applied. The throttle test was
done and everything was nominal in this case.

CERNAN The pitch and yaw gimbal settings were those used at preflight
(plus 501 and 547, as per IM-4).

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8.2.20 RCS Pressurization and Checkout

CERNAN The RCS pressurization and checkout were nominal except for the numbers recorded out of the PCNCS.

STAFFORD We noticed this in the simulators. The numbers out of the PGNCS were a little different, but the ground gave us a GO.

CERNAN I have all these numbers. It was in the rate-command check of the Commander's ACA to the LGC - the ACA pulse cold fire in CES. This is where we got the number anomalies. The ground was watching this entire test. After a short consultation, they said that the RCS was GO; and all of our hot fires were GO. We got good, solid, firm signals.

STAFFORD When we came to the maneuver-controller checkout through PGNCS, I could hear the thrusters fire; but we had to wait a long time to get the indications on the DSKY's. Therefore, I omitted it. I could tell that we were getting the signal through the PGNCS, and I did not want to waste any fuel.

CERNAN We got four of the six signals. The two we didn't get were yaw left with minus Y and minus Z.

STAFFORD We could tell the thrusters were firing, and everything sounded good.

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8.2.21 Rendezvous Radar and Self-test

CERNAN Rendezvous radar and self-tests came out just beautifully.

The radar was slewed out of mode 2.

STAFFORD The rendezvous radar and self-test went as prescribed.

CERNAN The numbers are documented in the checklist.

8.2.22 DPS Preparation and Checkout

CERNAN The DPS was pressurized as planned.

YOUNG You're talking about your hot fire and cold fire. During the hot fire, the rates that the vehicle set up were easily noticed in the command module. They were quite evident. There appeared to be no problem, but they were noticeable.

CERNAN I just want to make note of the fact that we verified both PYRO logic batteries on the buses. When we pressurized the DPS, we did it under logic power A with the logic power B circuit breaker open. Later, when we deployed the landing gear, we deployed it in logic power B with the A breaker open. Then, we closed both breakers to verify that it was down and locked.

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8.2.23 Deployment Landing Gear

STAFFORD The deployment of the landing gear went according to procedure. In a way, it seemed just like the landing gear of an aircraft coming down and locking. You could hear the PYRO fire, and the vehicle shuddered a little bit. I heard one initial crack; then finally I heard a bang-bang as they locked down in place; and the flag went gray.

CERNAN Our ambient pressures told us that we obviously had a good PYRO. It went from 1570 prepressurization to 1440 postpressurization.

YOUNG When you deployed the landing gear, I could hear a noticeable "thunk," and all the rate needles jiggled. It was really evident that the gear was down.

CERNAN Also, the forward landing gear could be checked visually from the LM windows. We had questionable items that were eventually resolved. Every time you resolve an item, it takes time. We spent a lot of time preflight on this in the simulator. We felt this was one of the most important parts of the entire flight, that is, getting ready for the rendezvous. If we ever got behind, it could cost 2 hours or a whole additional REV to get ready. We got ahead of the checklist and we stayed ahead so that, when we had a problem,

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CERNAN
(CONT'D)

we had enough time to resolve it. One thing that helped us out tremendously was the precheckout of the LM. We did all our housekeeping, we had our pencils up, we had our cards and data up, we had our lights up, we had everything done that had to be up. When we went in there the next day, we were ready to go to work, and there was no fooling around. We started right out on the checklist.

Just for the record, the Commander wore his special earplugs in his Snoopy helmet. The LM pilot took his earplugs with him but did not wear them. From my point of view, I had more than adequate COMM to overshadow any noise that was in the LM.

STAFFORD

The earphones do increase the dB level. I found that on VHF in the altitude chamber I had it up at 9. In flight, with those ear plugs on, my VHF was down to a setting of 3.

CERNAN

I guess it's dealer's choice. It was an operational experiment. We had one man with them and one man without them, and each had adequate COMM. The only anomaly, from the final switch or circuit-breaker setting prior to undocking, was that we pulled the cabin fan breakers because they were noisy. They were not so noisy that we couldn't stand them,

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CERNAN
(CONT'D)

because we did turn them on later for a while. They really didn't give us much cooling or circulation.

8.2.24 Undocking

STAFFORD

We could not go to our preflight prescribed attitude because of restrictions on maneuvering caused by the tunnel. Undocking was made at a different than nominal attitude, and then the command module maneuvered to the prescribed separation attitude between the preflight worked-out procedures.

We had no problems on stationkeeping. At this time, I noticed the first indication that the rate needles were off the zero calibration. I would zero the needles, have the command module in my COAS, and also use general attitude references. Then, I would start drifting off. There were several cycles of this over a period of about 1 or 2 minutes that made me realize that the rate-error needles were out of calibration. In undocking, veiled transients were noted even with the pressurized condition, because the tunnel vented as soon as we broke. We went right through the prescribed maneuvers.

CERNAN

We did undock with a pretty fair DELTA-V. We had a pow as we separated and we moved out.

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YOUNG I really believe that it didn't have anything to do with the fact that the tunnel was pressurized. As soon as we separated, it vented. Then you were moving on out to the end of the probe. We looked like we had about 0.4 ft/sec.

STAFFORD I was amazed. It was bigger than I had anticipated from the simulator.

YOUNG We really backed off from each other.

STAFFORD We had to go to a different attitude. I rolled right 120 degrees and pitched up 90 degrees to get to where John was. Where he needed to maneuver to was different from what we'd seen before, but there were no problems.

8.2.25 Visual Inspections

CERNAN We made visual inspections. They're all recorded on 16-mm and 70-mm film. The command module looked good to us.

8.2.26 Effect of Earthshine

STAFFORD Earthshine doesn't mean anything. Earthshine is nothing.

8.2.27 Adequacy of Illumination, Time Alloted, and

Any Other Unusual Visual Phenomena during

CSM Visual Inspection of LM

YOUNG It was adequate.

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CERNAN Completely adequate, although the roll angle was 180 degrees out of what had been recommended by FCSD for undocking in the first place.

8.2.28 Update Pads for DOI, Phasing, and Insertion

CERNAN Update pads for DOI phasing and insertion came right after separation. They were copied down without difficulty. The Command Module Pilot needed these pads passed to him later from the LM Pilot.

YOUNG Those were the DOI phases and PDI ...

CERNAN PDI abort pads. That's correct. Insertion pad came later.

8.2.29 Formation Flying

YOUNG Formation flying was a piece of cake.

STAFFORD No problem on the stationkeeping or formation flying.

8.2.30 Lunar Landmark Recognition

CERNAN From the LM point of view, we were not particularly concerned with lunar landmark recognition. We were now over planet X in the process of getting ready to perform our DOI CSM separation burn and the DOI burn. The AOT was unstowed and set to the forward position without any difficulty.

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STAFFORD During the period of time after separation, the radar was turned on, and we noticed it had no lockon.

YOUNG At this point, somebody on the ground recommended recycling. We checked the radar and checked the circuit breakers in the command module. They were in. They recommended recycling the power switch. We recycled the power switch; and as soon as we did, the systems test meter, which had been reading zero and should have been reading about 4.6, came on. We got immediate radar lockon from the LM.

CERNAN Just prior to this point, we had called for a recheck on simplex A which we had not been able to use up until this point. And behold! It worked. On the LM side, we went from simplex A to duplex A, which is duplex B on the command module side. This was our VHF-ranging configuration. We checked to see whether it would work, and lo and behold, it also worked from a voice communication point of view. During the rendezvous radar checkout that was just mentioned, we also did the VHF ranging check and compared the two.

STAFFORD During this time the radar COAS boresight was checked and found to be extremely accurate. With the radar needles centered, the command module was exactly centered in the

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STAFFORD
(CONT'D)

middle of the COAS. This meant there was no bias. It was
right there. It was the best I've ever seen.

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9.0 DOI THROUGH RENDEZVOUS

9.1 COMMAND MODULE

9.1.1 Monitor LM DOI Burn

YOUNG The command module was able to monitor the LM DOI burn. I tracked them optically. I could see the burn being performed in the optics. There was a big light when the engine fired. I could not see the LM until the engine fired in the dark because it was pointed the other way. It was quite clear when the burn was being performed. As soon as the burn was completed, P76 was updated nominally and it showed the spacecraft to be in a 61.2 by 9.2-mile orbit. Within a very short period of time after the burn was completed, the VHE' ranging data showed over an average period: at 3.8 miles, the vehicle opening at 73 ft/sec; at 4.82 miles, it was 70 ft/sec; at 6 miles, it was 65 ft/sec. These opening velocities were within about 1 ft/sec of actual velocity, and it is recommended that this procedure be used to verify DOI for the lunar module.

9.1.2 AUTO Maneuver to Sextant Tracking

YOUNG AUTO maneuver was done to sextant tracking. Unfortunately, the AUTO optics positioning was not accurate enough to allow

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(CONT'D)

the vehicle to be picked up. At this time, we were coming into daylight, and I could not see the vehicle. Fortunately, I saw it in the telescope at close range, but I lost the vehicle again at 14 miles when I was tracking manually. I tracked manually through about 100 miles, and then I rolled 180 degrees and pitched up 70 degrees to acquire the MSFN.

9.1.4 Optics Track — Ease of Tracking LM from Any Unusual

Visual Phenomena Observed During LM Descent

YOUNG

The command module commenced optics tracking, and the AUTO optics maneuver did not put the lunar module in the telescope. I positioned it manually in the telescope and tracked manually until the command module was 14 miles away. When we reinitiated tracking prior to the phasing burn, the AUTO optics did not position the vehicle in the telescope for the second period of tracking. VHF marks were taken and they did bring the thing in so that we could track the vehicle in the optics — and take several optics marks prior to phasing.

9.2 LUNAR MODULE

STAFFORD

We'll work this as an integrated debriefing between the CSM and lunar module because of the nature of the total maneuvers and trajectory. The separation burn was made by the command module on time. The anomaly with the radar has already been

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STAFFORD discussed in the previous sections. After darkness, the lunar
(CONT'D) module made the AOT alignment.

CERNAN Right after the separation burn, as we went into darkness in
the lunar module, the first P52 IMU alignment was made. The
dock alignment that was made with the command module appar-
ently was excellent, because the AUTO optics put the stars
Antares and Acrux well within the scope of the AOT.

STAFFORD Can you remember how far from the crosshairs?

CERNAN It was real close. It was very close. We updated the AGS
state vector, aligned the AGS, and loaded the AGS. I noticed
one anomaly here which I will explain. The anomaly was: I
could not get the proper numbers loaded into the AGS for
this particular burn. The reason I could not get the
proper numbers loaded into the AGS for this particular
burn was because I failed to put the external DELTA-V
flag in the AGS, which is ADDRESS 410 to 5000. I
realized this after the burn, so the AGS was not available
to monitor the DOI burn. That was a problem induced by the
LMP.

YOUNG During this period of time, the command module was operating
in the DAP mode, wide deadband (0.2 deg/sec) to save fuel.
It was operating perfectly satisfactory.

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9.2.4 PGNC S Performance During DOI

CERNAN We had been through P30; we then went into P40. We verified our spacecraft attitude, both ORB rate and inertial. We verified the star, Scorpi Delta, for the burn. We were satisfied that we were in the proper attitude for the first critical LM burn. We were on PGNC S control, and PGNC S did control the burn.

STAFFORD The ullage and ignition started on time. The engine throttled up to what appeared to me to be about 15 percent on the gage. It was more than 10 percent. We had 10 percent commanded on the right side of the gage, and we had over 15 percent. I checked my throttle, and it was in MIN. Exactly at 15 seconds I throttled up, as the profile called for, to 40 percent. The engine went right to 40 percent with no chugging as has been noted previously. We were monitoring the burn and counting down as our procedures called for.

CERNAN The residuals were minus 0.1, minus 0.3, and minus 0.5.

STAFFORD The X residuals were trimmed to minus 0.1.

CERNAN That was our final residual (minus 0.1). We did not trim the DOI. That was the DOI residual. This was the targeted final burn. There was no trimming of the residuals. Those are the final residuals from the DPS

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CERNAN
(CONT'D)

burn. The tank pressures were nominal. This indicated to us that we had no air in the line and the whole system was working nominally.

STAFFORD

After DOI, a pitchdown was made that placed the Z-axis on the command module and we locked on with radar. With the technique that John worked out, he had our range rate before I could lock on with radar. He used VHF ranging.

CERNAN

This was procedurally seen in the simulators all the time. The PGNCs with those residuals gave us a 61.2 by 9.2-nautical-mile orbit over the lunar surface.

YOUNG

And that's what I had.

CERNAN

That's exactly what you had; that's right.

YOUNG

Fantastic!

CERNAN

So we felt very good about it in spite of the fact that we did not have the AGS monitoring the burn. We felt good about the command module agreeing with that orbit. Then, when we did the VHF ranging and the radar data check, the numbers proved to us that we had good information and that we had a good DOI burn with a good perigee.

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STAFFORD It appears that our procedures were adequate for monitoring the effects of the DOI burn. This had been worked out in great detail.

CERNAN The systems status was checked immediately after the burn just to make sure that, after our first big burn, everything was nominal. All systems were still GO. There was no change during the period of the burn.

STAFFORD Various attitude maneuvers were made after the burn at prescribed times. One deviation was: two additional 180-degree roll attitudes were not accomplished, so we could try to get an early lockon on the landing radar and also look at some of the sites.

CERNAN We wanted to get a little bit ahead on our visual recognition for our approach path to the sites.

STAFFORD It's recommended that on the 11 mission a minimum of attitude maneuvers be made after the DOI burn. Save that for PDI. The landing radar was turned on early, and the landing radar test was initiated by the computer. It appeared evident from onboard read-outs that we locked on right away — at least on a couple of beams. This was far in excess of any altitude that we had anticipated. That's when I was at a

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STAFFORD
(CONT'D)

theta of plus 10 degrees. As we continued our descent approach, we pitched to the theta = 0 position at the prescribed time. I noticed that it was more difficult to maintain a value of near zero than it was in the simulator. This was further verified by the rate error needles on the FDAI. They showed that a true zero rate did not indicate zero on the needles. As a result of this, I had to expend fuel in trying to keep it close to zero by looking at the DSKY for theta and then extrapolating from the ball. This required more attention with respect to flying the spacecraft than I had anticipated from our simulations. As a result, I didn't get as many photos or as many observations as I would liked to have taken at this time.

CERNAN

During this time of attitude changes, the LGC was updating P30. We inserted the phasing pad because, as far as we were concerned, we were GO even before we had MSFN contact. All our systems were GO. I did check the AGS for AGS perigee. It gave us an 8.6-nautical-mile perigee. The command module came into contact with MSFN prior to us and gave the ground our GO. Then when we had contact, we gave them the postburn results. We had P30 all loaded and everything ready to go for the phasing burn about 25 minutes early. We were starting down our track, 25 minutes prior to phasing because we

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(CONT'D)

wanted to focus all of our attention on the recognition, photography, and landing radar tests coming across the landing site from 25 minutes to 10 minutes before phasing.

Monitoring the landing site approach path was easy to both the Commander and the LMP because we studied these and looked at lots of charts and maps. We had a chance to see this approach path from the command module for a short period of time the day before. This aided us tremendously in recognition. We both thought it was — it was extremely easy to recognize the landmarks, the craters, the rilles, the ridges, and everything that we were looking for in order to find our way through the hills and maria up to the landing site. We proceeded on our nominal photographic mission to photograph this landing site both with 70-mm and 16-mm camera. We also did the landing radar test during this same period of time.

STAFFORD The orbital velocity at approximately 50 000 feet has been simulated previously in a T-38. It matched nearly identical as far as tracking targets with a relative bearing rate was concerned. From this, it was easy to maneuver the camera when I had time to take the targets that we had already picked out. It seemed like our trajectory was exactly on track from what we had previously determined from our strip monitoring chart. Pitchover was made a minus 11 minutes and 40 seconds,

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STAFFORD
(CONT'D)

to a pitchdown of 30 degrees from the local horizontal, to monitor the landing site. At this time, the Commander's Hasselblad camera started to fail. It would take longer to sequence in between the films. I think it failed just as we approached the landing site. I looked at the site, which was easy to recognize by the three clusters up in the far corner. I could estimate 25 to 35 percent clear area. It compared with the desert in California around Blythe. The circles in those fields look smoother than those in the smooth areas. It appeared that the near end of the landing site was smoother than the far end. If the targeting ends up near the far end, the lunar module may have some difficulty with respect to fuel reserves and maneuvering to an adequate place. This was all accomplished within a few seconds because of the orbital velocity that we were at.

CERNAN

At the sun angles we had, the landing site was easy to recognize coming up upon it obliquely and when we were going over it vertically. There was no observable washout at our sun angles when we passed over the landing site. We continued to take photographs as we continued to pitch now to the X-axis in the plus-X direction for the phasing burn. That effectively completed our landing site acquisition requirements. At that point, we went into our 7-minute check prior

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to the phasing burn. This is very similar to the DOI procedures. As we went into the phasing burn, right up to the time of ignition, everything appeared nominal and was basically a duplicate of the DOI burn. After going through our 4-minute check, we did review the mission rules. By that, I mean we reviewed the DELTA-V we wanted to get and what we would do if we didn't get it. We could either stage or complete it with RCS.

YOUNG

The position of the lunar module was such that the field of view of the sextant and the landmark line of sight were in the optics view at the time. Since the LM was 120 miles away in sunlight, it appeared as a semidim star and could not be seen against the background of the lunar landmark line of sight. It was a red line of sight, and later on it was seen in this lunar landmark line of sight as a bright star. It appeared to be traveling over the lunar surface even though it was way up above the lunar surface.

CERNAN

We came to the burn and had ignition on time.

STAFFORD

The burn started exactly as the DCI burn at 10-percent thrust. Immediately thereafter, a master caution light, with a red warning light of the descent propellant quantity, came on.

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STAFFORD
(CONT'D)

I immediately pushed the caution and warning light out and checked the gages again. An oxidizer pressure gage had already gone to zero. It turned out that it was an instrumentation failure. The fuel pressure was holding real good, and engine chamber pressure looked good so we continued on. Immediately thereafter, we had an amber warning light showing that the DECA gimbal had failed. We had been anticipating this warning light because of previous test runs on the lunar module. I was standing by to throw off the engine — to turn the off position in the engine gimbal enable switch; however, the rates were nearly zero and it appeared good, so we continued. The engine throttled up to 100 percent very rapidly without any chugging at the prescribed time of ignition plus 26 seconds; and immediately after reaching 100 percent, the master caution light came on again — was triggered by the propellant descent quantity light. It was pushed off again and the burn to — out to the required DELTA-V was monitored and the engine shut-down, the following residuals were noted:

CERNAN

After trimming, we ended up with plus 0.2, minus 0.5, and minus 0.9. This time, the AGS was programmed correctly in external DELTA-V, and the AGS counted down very closely with

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CERNAN (CONT'D) the PGNCs and gave us good results with residuals of approximately plus 0.7, minus 0.6, and minus 1.4. We felt that we had a good burn with a resultant LGC orbital parameter of 190.8 by 11.8, which is very, very close to nominal.

STAFFORD Did you see our descent burn? Our phasing burn?

YOUNG No, I couldn't see the phasing burn.

CERNAN Okay. We did try and take pictures of this burn vertically from the LM, and whether any of these came out, I don't know. It was apparent, at least to the LMP, that there was no great noise associated with the descent engine burn, nor any great acceleration either.

STAFFORD We could feel the acceleration when it throttled up from 10 to 100 percent for MAX thrust, but the level of acceleration was still low.

CERNAN My feeling in the right side of acceleration was watching my two computers count down; and when I saw them go from ullage to 10-percent thrust to the 100-percent thrust, I got my feel, I think, of acceleration and watching this burn go on. I don't recall any noise level change or increase at all.

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STAFFORD The basic noise level on the LM is such that it would take a fairly loud engine noise; with the suit-air noise going through, I thought I could feel maybe a minor vibration in my feet, but it was real low in intensity and it was just a smooth engine operation all the way through.

Immediately after shut-down, a maneuver was made to the precise tracking attitude, and the rendezvous radar was locked on to the command module.

YOUNG Immediately after the LM did its phasing burn, I did in the command module a P20 to the tracking attitude; however, we could not see — it was so dark then, we could not see the lunar module in AUTO optics, so we started taking VHF marks and reinitialized the W-matrix after three marks. We continued to make marks all during the lunar module P52. One thing about taking marks was that it was much easier to take than in the simulator. Optics tracking was very smooth. The VHF marks and the sextant marks were processed much faster than they were in the simulator. At this time, large updates were received on the first VHF ranging mark, so it was rejected and an optics mark taking it was received with a update mark; this was on an order of 20 ft/sec. The data are all available. But that mark was accepted because the optics

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(CONT'D)

mark was the same, and from then on all updates were very small, reasonable, and appeared proper in every respect.

CERNAN

You want to comment about the voice-quality procedures in the VHF ranging?

YOUNG

The LM was essentially on hot mike. The LM was essentially on hot mike and I didn't find this objectionable in any respect, because it kept me in good touch with them and I knew exactly what they were doing and I almost felt like in a lot of cases that they were sitting right there with me, and that enabled me to plan ahead. But there were some objectionable operations in that every time we made a transmission, we apparently heard ourselves talk; we recommend this problem be corrected for future missions.

CERNAN

This was more than likely in the S-band that we heard this feedback, possibly.

When the LM went to a P20 to acquire and track the command module, and this was done in almost all cases, the CM Pilot went to this attitude manually, knowing what attitude he had to go to because of our preflight planning, and also he went there with the aid of the AGS needles. The AGS 400 plus 20 000 was called up and he had the AGS needles to tell him exactly where the target was while the LMP was

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CERNAN
(CONT'D)

cleaning up the PGNCSS, getting the residuals, and getting P20 set up for radar acquisition. It appears that our first mark in almost every tracking stage and in the VERB 93 W-matrix initialization was a five-figure update (a four- to five-figure update) in both range and velocity which was absurd to us. We rejected that first mark and the second mark came right down in within reasonable, expectable error levels and we started accepting those marks. In the case of the LM, we were updating the command module state vector for this tracking prior to insertion. The VHF ranging and the radar agreed very closely throughout the whole flight. We took some five marks at this point from the LM and then designated the radar. And, by the way, every time we designated the radar, it worked properly and went to the attitude position we prescribed for it. We went into a P52 and to the REFSMMAT align on Acrux and Antares which are, again, very easily recognized. We did a star check, we used AUTO optics, we did a COAS calibration, calling up mode 5 in the LM for the P52, and calibrated the COAS on Antares.

STAFFORD

The COAS calibration produced a star, Antares, that was aligned exactly on in yaw, and one-third of a degree down in pitch, which is considered completely satisfactory for COAS alignment.

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CERNAN Okay. We went behind the Moon. We were going to take 70-mm targets of opportunity up at 190 miles; unfortunately, we had no workable 70-mm camera. The time period in there was relatively light after the P52. We actually even had a chance to get a drink. We started to track again with the lunar module, with the command module updating the command module state vector from the LM at about better than an hour prior to insertion. At 40 minutes prior to insertion, we commenced our checklist, getting ready for the staging sequence by connecting the ascent batteries and connecting the descent batteries, two at a time; starting to monitor and pressurize our ascent helium system, and our ascent propulsion system. Then we took another series of marks at 36 minutes before insertion, updating the command module. We were going to take another series of marks updating the command module state vector again, however, this is the point at which we were approaching close to MAX range and we were unable to get radar lock.

STAFFORD Originally, I got radar lock. The AGC voltage indicated exactly what we should expect at that range, and then slowly, it just faded out.

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CERNAN Now, whether that was an attitude problem with the command module or whether it was a range problem, I guess we don't know yet.

YOUNG How is that called an attitude problem with the command module?

STAFFORD Because it was locked steady and it was steady, then it slowly faded out; and the way that it faded out was indicative of what we had seen before in the simulator and also in flight when the command module made an attitude change.

YOUNG I'm sure that's true, because I had VHF range to 300 miles. And, about that time, I decided I had better go to the attitude, because it was coming up on the insertion burn.

STAFFORD That's what did it.

CERNAN Go ahead, John, have you got anything to add for that period of time?

YOUNG I think that I went to the attitude about the right time frame for what's called out in the flight plan. We'd never thought of that before. Concerning the VHF communications at phasing and insertion: when you were doing the phasing

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YOUNG
(CONT'D)

burn, I couldn't hear you and when you were doing the insertion burn, I couldn't hear you. Not at all.

STAFFORD

I bet that was due to our attitude being face down and the antenna we had selected.

YOUNG

That could very well be.

CERNAN

This brings us down to staging.

STAFFORD

I was in the staging attitude approximately 8 to 10 minutes before the event was to occur on both the ORB rate and the inertial ball. In all these major maneuvers, we used the checklist, and I put my finger on each switch and looked at it to verify the position of the switch. The one thing that we had noticed before was parallax errors caused by head positions. In the simulator, we had stools measured exactly to calibrate our eye position that would exactly match what we had seen in the altitude chamber, which, from my position, was just looking straight forward at the crosspointers. I found that in zero g with the hoses attached, and the limited strength of the Velcro, I was actually floating up on my toes most of the time, so I had one restraint cable hooked to my suit. Even with one restraint cable hooked to my suit, but not in the locked position, just under tension, I would

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STAFFORD
(CONT'D)

occasionally float up nearly on my toes, which would put my head 2 to 3 inches, even as much as 4 inches, above what it normally was. So, I looked down to verify when Gene called out ATTITUDE HOLD. I had my hand on the switch and I could see that the luminescent bar that runs the length of the switch for identification was aligned right with ATTITUDE HOLD. And I went through the rest of the switching. That was just one step in a sequence. As we approached staging, we were aligned in the right attitude; the vehicle was solid as a rock in that attitude, and we were in mode control pulse.

CERNAN

We went to guidance control AGS and were all set in middead-band; then we hit the mode control switches, which should have given us ATTITUDE HOLD. A part of this - let me say, from the PGNCS point of view, we had set the DAP for the lightweight vehicle. So we were all squared away from that point of view.

STAFFORD

Right. We set the DAP up for the light-weight vehicle. The vehicle was holding. I went to mode control when we called up P47 to determine average g. In this period, I would stand by to throw the stage switch, Gene would pull aft on the translational controller down for 2 ft/sec, and then start

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(CONT'D)

forward. At that time, I would stage the vehicle. Seven was called up at the staging minus 1 minute and then the switches were placed in mode control at, I would estimate, approximately 30 seconds. At this time, the vehicle started a movement that was a combination of pitch and yaw.

CERNAN

It was a movement sort of like an Immelmann. It was either pitch and roll, or sort of a yaw and roll type of maneuver, but very much like an Immelmann in an aircraft.

STAFFORD

We wanted to go ahead and stage the vehicle, so Gene thrust aft, and it appeared that, during the thrusting, the dynamics did not increase any, as far as the movement — that the rates did not build up any more than what we had. Even I could see it was going off in attitude, so we would have plenty of authority in there. So I said, "Forward." He thrust forward, and I threw the stage switch. It staged, and I'd say we were off of our prescribed attitude about 20 or 30 degrees. The vehicle was still in a retrograde attitude, basically, but was about 20 to 30 degrees off. Then immediately, it started a rapid roll and I could see that we were approaching gimbal lock and I made a big pitch maneuver on the stick, and I started working attitude control switches. It happened very fast, and I could see that some

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STAFFORD
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of the pitch took effect. We zipped right by gimbal lock. We got the gimbal lock light, but the no-attitude light did not come on, which indicated that we did not coarse align the platform as will happen with true gimbal lock. We got the vehicle under control after about, I'd estimate, a 360-degree maneuver.

YOUNG

How close did you get to gimbal lock?

CERNAN

Close enough to get the warning light on.

YOUNG

Better than 5 degrees then.

CERNAN

Somewhere between 15 degrees and 5 degrees. I'm not sure how far around we went. I was able to see the horizon out the window and the lunar surface start moving and I don't know, on the 8-ball, exactly what attitude we realized. We could have maneuvered 30 degrees or we could have maneuvered 90 degrees. All I know is that it was fairly slow, but positive. Whether we did a 360-degree maneuver is difficult for me to say.

STAFFORD

I was, by then, looking outside for an attitude, but that didn't help me too much at that time. I looked inside at the 8-ball, at both of them, because when I saw the gimbal lock warning light, I initially thought that maybe my 8-ball would

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(CONT'D)

freeze at the no-attitude, coarse-align position. I would say that we traveled at least 360 degrees.

CERNAN

Let me explain the posture we were in at the time that the Commander yelled that we were in gimbal lock. Of course, we had had good positive staging, verified through the gages. So, there was no problem. We had an ascent stage, and a programed insertion burn 10 minutes later when he yelled "Gimbal lock." I was back in the cockpit with the 8-balls and I was not aware that it was really not gimbal lock. So, we actually didn't have gimbal lock. Tom got it stopped, and then started going over to the prescribed attitude for the insertion burn. I immediately started getting the AGS loaded as the procedures require for this particular burn. We had a posture where we could have gone to AGS and made this insertion burn in AGS and then gone ahead and aligned the PGNCS to the AGS, done a P52, and set the REFSMMAT and drift flags, and we would have been back in business as we do a P52 after the insertion burn anyway. So it would have been a case of having to do the insertion burn on AGS. As far as the switch positions and settings are concerned, we had maintained the posture in our checklist that control-system switch settings (such as PGNCS pulse and attitude control through VERB's 76 and 77; any AGS, PGNCS guidance control switching; or any AGS, pulse, attitude hold) were not put

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CERNAN
(CONT'D)

down. Any of these switchings cannot be put down in the flight procedural book, because they are used, and switched back and forth, so many times. They were not put down in this case. The only thing that was put down was that we definitely did do this particular maneuver in AGS control. As far as the position of mode control switches or attitude control switches, we followed the posture of never putting any of those down anywhere in the checklist; and that's the posture I would continue to follow in the future.

STAFFORD

Again, during this maneuver, I know that I changed the switch, brought it under control, and finally went to DIRECT to stop the maneuver. I remember I went to DIRECT to get it under control. But then I had the whole vehicle stopped. I could see that I was in gimbal lock. Right away, I pulsed right around to our burn position for the insertion burn and rechecked what was on the inertial ball; I checked what we had on the ORB rate ball and could see that we were in good shape.

CERNAN

We could recognize visually that we were face down in retrograde; the AGS was loaded through our 7-minute check; we verified that the PGNCS was in good shape; and that our IMU and LGC were in good shape.

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STAFFORD Also, when we called up P42, maneuvered in AUTO attitude to the exact attitude that we had on the pad for MSFN. So we were very confident that the PGNCSS was in good shape. Again, the total time, from the time of the actual staging sequence to the time we had her under control, I'd estimate, was less than 1 minute; and the time we were back in a good attitude for the burn was, I would estimate, 2 to 3 minutes. Again, you can look at the time history on the telemetry.

CERNAN And we were right down on our 7-minute checklist. We went through our 4-minute checklist for ascent engine burn. We reviewed the DELTA-V mission rules for the ascent burn, as to what we had to do if we didn't get it. We verified our attitudes and made the ascent engine burn, which was very rapid.

STAFFORD We anticipated that there would be some oscillations after reviewing the data from the LM-3 ascent burn to depletion, so both restraint cables were hooked up and the restraint cables locked. At burn initiation, the vehicle went to dynamics that would be characterized by a Dutch roll in an aircraft. We had yawing and pitching rates, I would estimate, up to 5 deg/sec, and the vehicle basically snaked along. The shutdown produced a total vector that was of an excellent nature.

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CERNAN It looks to me like the final residuals were zero zero and minus 1.3, and the AGS gave us plus 0.50 and plus 0.9, which put us in a resultant orbit of 46.7 by 11.0 miles, which was pretty close to nominal.

YOUNG Okay, can I say something here? During this time, the command module was maneuvering to the backup insertion burn attitude. There's no place in the command module checklist for insertion of the CSM backup insertion pad update in the plan as given by FOD. This is an oversight. I recommend it be corrected on later flights. Also, it was agreed prior to flight that the backup insertion burn would be done at precisely 3 minutes after the LM insertion burn. In fact, the time passed up by the ground to do the burn was something different than 3 minutes after the insertion burn, which caused some confusion in that I thought I'd copied their number wrong and went and loaded the LM insertion time. They called me later and told me it was incorrect and then I had to reload the time after I was already in P30. The setup to maneuver to the attitude and the operation through P30 and P40 were nominal in every respect. At this time, when the lunar module was having its problems with the pitch-around, I was out of voice communications with them. I could not

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YOUNG
(CONT'D)

hear what they were saying. The ground was telling me they were monitoring it and for me to stand by and then they reported to the lunar module that they were approaching gimbal lock. If the command module had had to make this burn, because the lunar module was in gimbal lock and the GDC had had some kind of problem or because the AGS had had a problem, it would have been very unfortunate in that we didn't have voice communications and we weren't getting this update soon enough. So, after that, we went to the voice relay mode where the lunar module relayed the voice communications through the ground and it came back up through the ground S-band. It's recommended that in every case where the command module loses voice communications with the lunar module that this relay mode be established immediately by some communications procedure. I think it's essential that, if the command module is going to have to do one of these one-man burns, he be allowed to set it up as quickly as possible, so he can go through his checklist as many times as he can to get everything right, because those are the burns that he can't afford to make any mistakes on. It's recommended that the relay mode be established in every case where communications are lost on VHF.

CERNAN

Following the insertion burn, we went directly into our third P52. This is the first time we did it with an ascent stage only. The authority from PGNCSS pulse was far greater than

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CERNAN
(CONT'D)

you would desire with a semilight-weight stage. It never allowed you actually to stop the lunar module movement or the start of movement in the AOT. It allowed you to slow it down, but not really stop it because of the magnitude of the PGNCs pulse thrust. However, it was performed and we got a good star-angle difference; we got a good torquing angle. We made an alignment check and it put the star right smack in the center of the reticle. We took three sets of stars instead of five sets because, as experienced in the simulator at minus 30 minutes before CSI, we've always had to make a backup range-rate calculation for the backup CSI charts. The time between the beginning of the alignment darkness and the beginning of the alignment and the 30-minute mark (which required radar track and lockon) took you half that 30-minute mark; so we cut our alignment off at three sets each. It gave us a good alignment. We went immediately from there into manual radar acquisition in P20 and then into P32. We went there adequately early to get that minus 30-minute range rate for the CSI chart.

STAFFORD

The lockon was made after insertion. The lockon was made manually.

YOUNG

That's right. We started taking marks right on from there through CSI and did our normal procedural recycles. We got

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our recycle data for CSI, for CDH, and we saw the values come in very close to the point. When at CSI, we had the ground, the ground and the LM agreed exactly to 0.1 ft/sec; and the command module, if you subtract 1 ft/sec, was only 0.6 ft/sec off. So the charts were a little bit high, but were well within the region of agreement with the final solution error of about 4 ft/sec high, which wouldn't have hurt us if we had burned it. Everything in P32 worked fine, except the anomaly when we took the first mark after locking on P52, and got four-digit and five-digit updates which were rejected. After that, the marks came down and the arrows came right on in. I had no radar bias or radar drift problems and never had a side lobe blockout in any of the radar data acquisition in P30 routines. We took backup marks at 20 and 10 as prescribed; and procedurally, it just came right down the track. We made the CSI burn of 45.3 ft/sec.

STAFFORD Okay, talk about the plane change.

YOUNG We were computing a plane change for the CSI burn. The LM computes it out of VERB 90 to be compared with the command module and in any event throws its own out-of-plane out; but it computes the plane change just for drill and takes the command module out of plane. In this case, the LM produced its own Y dot of plus 4.1 ft/sec, which we thought was pretty

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YOUNG
(CONT'D)

high. The command module interpolated that the LM would have to burn minus 6.4 ft/sec, so there was a 10-ft/sec difference; one was on one side, and one on the other. We felt both those numbers were large.

CERNAN

We were tracking up the bellyband and so we decided at this point to ignore our out-of-plane burn and so forth for CSI and take and take another look at it again at a normal plane-change time between CSI and CDH.

YOUNG

I'm not sure this is not really a significant factor, because I'm not sure that after LM insertion off the surface that you can afford to ignore a plane change.

CERNAN

You may have something.

YOUNG

Yes. You don't get a good alignment on the surface.

STAFFORD

You want the good alignment.

YOUNG

But you should know what it is.

CERNAN

We went on to make the CSI burn. We did an AUTO maneuver. We did the CSI burn in the plus X-axis with RCS; we did it with ascent feed which worked normally, except you did not get the true indication of where the valve was set from the flags until you took the finger off the spring-loaded switches and let them go back to their neutral position. When, for

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CERNAN
(CONT'D)

instance, the main solenoid valves were open during the ascent feed and you went to close them, you didn't get the gray until you let them spring back to the neutral position. This was true of almost all the ascent feed switches and the crossfeed switch (which was never used, but was checked out) and also the main solenoid valve switches. We ended up with excellent residuals of zero, minus 0.4, and zero, and we were in a 48.2 by 41.6-mile orbit, which I believe at this point agreed very closely with the command module.

YOUNG We had it in a 48.2 by a 41.0-mile orbit.

CERNAN So that takes care of the RCS burn, CSI, and orbital parameters. That brings us up to the plane change. Our whole lunar-orbit phase had slipped 10 minutes because of our late arrival at the Moon. Because of our updated CSI time and our new CDF time as computed out of P33, we had to pull a number out for the plane change. Our nominal number was going to be halfway between CSI and CDH.

STAFFORD 104:02.

CERNAN Yes, 104:02 was nominal and, of course, that was updated by at least 10 minutes because of our late arrival at the Moon. The time we recommended to the command module was 104:15:00, so we based our plane change upon that particular time. Here

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again, we did not interrupt our updata tracking in the LM, but we did call up a VERB 90 in preparation for the burn. In the LM, we got minut 3.1, in contrast to the plus 4.1 Y dot computed for CSI. The command module came out with plus 1.1 for the LM burn; because we were relying on the command module update for out of plane, this was within our 2 ft/sec. We decided that there would be no plane change. Now, this was without doing any plane change at CSI.

STAFFORD

I think that's significant to see how the command module really came in there.

YOUNG

I think so, too. I think the command module solution was getting better all the time. We were tracking optically all the way during that time. And that's the time when it really got bad, optics tracking with a lunar landmark line of sight being down there, because we were 140 miles away and against the background of that surface. We were just about in the middle of the day there while we were doing that tracking, while looking at the LM. It's a star against the bright background of the lunar landmark surface.

CERNAN

Normally, when we do the plane change, we terminate P32 and go into P30, external DELTA-V for the plane change. Of course, we're taking marks this whole time, until we go into P00 for the plane change itself in the P41. Well, in this case, we

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did not do a P30. We did not do a P41 and stayed in P32 this whole time. Normally, after we do the plane change and go back into P32, it requires a VERB 93 or a W-matrix initialization after the first four marks in P32. I talked about this in the simulator; the case where you don't do a plane change and you stay in P32. You still want to reinitialize the W-matrix, which was done.

YOUNG The same for the command module.

STAFFORD It was a P33, CDH.

CERNAN We did reinitialize W-matrix after the plane-change times, only it was at 15 marks on the DSKY, in a continuous P33 track. Here again, as soon as we initialized, we had been tracking and getting small numbers, small errors, and NOUN 49 numbers. As soon as we initialized, I got a big five-number update at the first mark after VERB 93, this is something we had seen before, so we rejected this one. The next mark was right down within tolerances, and it just tracked and updated beautifully from there on to CDH.

YOUNG Can I say something about this? The command module updates in every case, after the initial large update, one initial large update, although we had been led to believe that we would, in fact, have large updates on every start of tracking, but they

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9-33

YOUNG
(CONT'D)

just weren't there. They were low, they were reasonable, and in most case, after two or three marks, they got below the threshold of R_{max} and B_{max} , 2002.

CERNAN

Our recycles and our final COMP for CDH showed us to be in a 14.9 DELTA-H, which was about as nominal as you can get. We showed very small numbers. We showed plus 0.1 ft/sec, zero, and 3 ft/sec out of the LGC. The CSM came up with plus 0.50 and plus 2.9, which made us feel very warm that the computers were tracking and updating side by side. We powered to our final COMP in P33 for CDH, we called up another VERB 90 to check what our out-of-plane was going to be, and the LM came up with minus 5.2 ft/sec. The command module came up now with a burn for the LM of plus 4.2 ft/sec. So we decided here, again, since we were tracking on the bellyband from both vehicles, that we'd just go ahead and ignore it. We ignored it three straight times, and it bounced from one side to the other, so we ignored it again and we burned zero out-of-plane at CDH.

YOUNG

That's the right thing to do but, boy, it's just a question of operational judgment.

YOUNG

I tell you — You sure didn't know it at the time that we were doing the right thing.

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STAFFORD Well, I think this may be in the noise, down in the operational noise level of the systems and how we're operating. I think if you'd had a big one, a real big one, it would be obvious to both systems.

YOUNG I've heard by hearsay it's a fact that the R2 models can't hack out of plane.

STAFFORD Chris told us that last night, but we determined the altitude does indeed get out of plane. They've just determined that; we didn't know that.

YOUNG Man, I tell you, that thing really bites you on an insertion burn.

STAFFORD But it didn't hurt us, and we just kind of used our engineering judgment up there by not making those burns which would have wasted fuel.

9.2.36 Targeting PGNC3 and AGS

CERNAN The AGS was targeted in external DELTA-V, and delta residuals showed that it performed very adequately; it agreed very closely with the PGNC3, and I'm convinced that we could have done the external DELTA-V RCS maneuvers on the AGS if we had had to. We used the AGS control system, as we had planned.

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CERNAN
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in the simulator - a great deal of the time in pulse mode. We used the AGS knowledge of the target position for helping us manually pitch up or down to the target or find the target after a P52. For future tracking in P20, this - the needles, the AGC steering needles worked well, and the AGS acquisition needles worked extremely well. We monitored them against the radar and the PGNCS needles, and they all three agreed very closely. So I'm convinced that the AGS, as a control system and as a computer from the standpoint of holding a state vector in pretty good shape performed very well.

9.2.37 Updating AGS with Rendezvous Radar Data

CERNAN

That brought us through - we did not update the AGS with rendezvous radar data for either CSI or PGNCS because it was not capable of accepting it. That brings us up starting into P34 for TPI. John, do you want to say something?

YOUNG

Can I say something about the CDH backup burn? From the standpoint of what the command module would have been done, if we had done it at plus-X tracking it would have been done at a 90-degree attitude maneuver; so we elected not to do that - just hold the attitude, and we'd have made the burn - if we'd had to make it - across axis, but that would have allowed us to get back to tracking the lunar module immediately after

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the burn, which of course would be necessary to get a good TPI solution.

CERNAN

I might add that where the tracking gets heavy and the communications gets heavy between the command module and the lunar module, where you have to pass back information, such as: postburn information, did you make the burn, what time you are going to make the burn, and what are your NOUN 81 numbers going to be. In fact, I think we conducted about 90 percent of all the rendezvous we did in an integrated fashion, when we found out initially we had problems with understanding each other's signs. We had problems knowing what the other fellow was going to need in terms of times to update his computer. There was (as far as we're concerned) I believe, no confusion at all. When the numbers were needed, they were passed. If they were needed a little earlier, they were asked for. As soon as we started tracking for TPI, for instance, we got our first TPI - our best TPI number. It was passed to the command module and he used it and started zeroing in on his TPI solution. As we got a better number on our updates, we passed it. We kept each other abreast of what our computers were doing in our recycles, as far as coming up with what the burn times and what the burn numbers should be. All along, it appeared that they were both zeroing in on the

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CERNAN
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same number, which is a good solid operational warm feeling. And I think this type of communication is needed, but it does not come naturally. It comes with a lot of integrated type of simulation.

STAFFORD

The whole secret here is the integrated simulation of training you're going through, one after another. You can have the procedures outlined in front of you, but until you get in there and integrate it, it just doesn't work.

YOUNG

The procedures will not jell until they're run through integrated. No matter how much you look at them and talk them through, until you see the timeline, particularly with regard to how long it takes the computers to cycle, you can't get a feel for how much time you're going to need to perform each step.

CERNAN

While we were in P34 and P20 updating for the TPI burn, because of a lot of preflight discussions, we did not update the AGS with radar because there was not adequate time to get the numbers that people required to do this. We did update the AGS state vector from the PGNCS from 25 minutes. Then we went through an AGS external DELTA-V TPI search routine with the AGS, which is sort of a manual type of routine: a punch in the numbers and getting out answers, while the PGNCS was sort

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of on its own, doing its own tracking and updating. The AGS came out with the benefit of the latest PGNCSS state vector, the AGS came out with almost the exact solution we burned. It came out with the good angle when we recycled the PGNCSS for the first time to find out what its solution was. The AGS and the PGNCSS agreed for the total DELTA-V within 0.2 ft/sec, and agreed within 10 seconds of the time to initiate TPI. What I'm saying is, it doesn't say that the AGS is a totally redundant system capable of producing this, because we did steal a PGNCSS state vector, but it does say that its computation routine certainly is adequate if given the proper state vector information. We went on, and with our normal procedures of saying that the PGNCSS was GO at 15 minutes, then we decided to disband the AGS, TPI, search return information, and program the AGS for external DELTA-V. At 12 minutes, we went into the final count for TPI, compared our number with the CSM numbers; and, here again, they agreed. The LM had for a NOUN 81 for DELTA-V_X plus 21.7, the CSM said to burn plus 21.8. For DELTA-V_Y, the LM said to burn minus 5.7 and the CSM said to burn minus 4.5. In DELTA-V_Z, the LM said to burn minus 9.6 and the CSM said to burn minus 10.4, so you can see the solutions agreed and the time agreed, I think, within something like less than 20 seconds. So, we feel our LM solution was good. However, because of the differences we'd

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CERNAN
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seen in out-of-plane solutions in the past during CSI and a plane change and what have you, we made a decision to bias our out-of-plane slightly by making it smaller. So, what we burned was our plus X and our minus Z, but instead of our minus 5.7 out-of-plane, we reduced that to the command module's minus 4.5.

YOUNG

It's the dock 5000 foot out of plane ...

CERNAN

Yes, we used the interconnects, we had a result in out of plane. I guess we ought to analyze in which direction it was and whether this would have affected it or not. We used the interconnects and they worked nominally and we got good residuals. We completed a TPI burn without any other incident. CDH was burned under AGS ATTITUDE HOLD control. It was planned that way. It was done that way without any problems, and in our own mind, it convinced us that there was nothing wrong with the AGS ATTITUDE HOLD control because of the experience we had back there at staging.

YOUNG

The whole track and moving to the mirror image burns and the ones that weren't mirror image burns was done in tight dead-band, and 0.5 deg/sec rate that was initialized prior to insertion. After CSM, sure enough the sun was setting, and I couldn't make any optics marks until the sun completely set.

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Optics marks were much easier to make, and I made four or five quick optics marks and was able to get an immediate good solution. Our TPI times agreed. When I finally got their elevation mark and recycled, it agreed very closely. Now, in order that the LM could get the backup range mark that he needs 5 minutes prior to TPI, the maneuver to the backup burn attitude was not initiated until that mark was made at 5 minutes prior to TPI. This puts you in kind of a bind, particularly if you had to do a big attitude maneuver change, which you might have to do in event of a rescue type case where you have large ellipticity. Still, all in all, it was feasible and we were at the burn attitude with about 2 minutes to go.

CERNAN

Because of the problems that the command module has in waiting for the last 5-minute mark before TPI, it is also a problem in the LM; it reduces our capability. We have to maintain radar track and do some extra special timing because we're in a LGC recycle and we don't really see the new TPI time until right in the middle of these two marks. I'm not so sure that we shouldn't optimize the backup charts - optimize the backup charts so they fit in operationally when everything is going nominal. If you have to slip times around, and, as a result, accept a little error on the end of the backup charts, slip them around such that if your primary guidance

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control system fails, the charts are adaptable to coming up with the best possible answers. Sometimes, you've got four hands going, you're trying to run two computers and run back-up charts, and then something has to suffer and something has to be compromised. I think it would be desirable, certainly, if you're intending on using the command module to back you up, to take that mark a little sooner for that last one. There's a time there when you might not make it.

9.2.41 Midcourse Corrections

STAFFORD

During this time, after the alignment and P52, during the Z-axis track, the spacecraft maneuvered from one deadband limit to another in a far more rapid fashion than had been observed in the simulator. In the simulator, it would be indicated by one or two thrusters firing, at the most. Then over a period of time of maybe 3 to 4 minutes, another one would fire. In flight, it was just 20 seconds between thruster activity and they continually went back and forth through the deadband.

After we noted what the radar updates were, I put the spacecraft control to PGNCs and pulse. I let it drift in a wider deadband manually and could see that there was a considerable saving in fuel. I monitored NOUN 49 and ascertained that

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the radar updates did not vary any in magnitude. The data is on the downlink; but, if the radar angle bias is not of any significant nature, this may be the cheapest way to approach the tracking phase of rendezvous. However, it does require that one person fly the vehicle all the time. The simulator should also be updated to show the high torque inertial ratios. On a lunar-landing mission, the problem will be magnified because of the lighter vehicle.

CERNAN

P35 and P20 worked like a gem. Our updates, which we looked at a number of times, were zero in range and zero in velocity. Our midcourse corrections came out very small. The first time they were minus 0.8 minus 0.4, and plus 0.8. We were plotting right up the pike; range rate was nominal.

STAFFORD

We were debating whether to make the first midcourse or not, but we did decide to go ahead and do it since we wanted to evaluate the system from a performance standpoint.

CERNAN

For the second one, we got plus 0.8, out-of-plane was plus 1.4, and minus 0.8. The first midcourse gave us minus 0.4. The second midcourse gave us plus 1.4, and then, when we were coming into the final braking we saw some resultant out-of-plane. But I don't think there's anything else to say about the midcourse, except that backup solutions were made. They

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CERNAN
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agreed fairly closely with the PGNCS. The CSM agreed, and we burned them. The CSM agreed almost number for number in most cases with the LGC. We plotted right up the pike; we were plotting the proper ranges and the proper range rates, and the elevation angle was within a pencilwidth right up the nominal track up to braking.

9.2.45 Braking

STAFFORD

As we approached 1 nautical mile, we had approximately 32 ft/sec. Our braking gate calls for 30 ft/sec at 1 nautical mile. I could not see braking just for 2 ft/sec at that time, particularly since our angular rates were zero. We continued on in. The range rate was reduced according to our braking gates at 3000 feet. The minor out-of-plane error was corrected at approximately 8000 feet.

YOUNG

The command module was maneuvered to X-axis track, and it arrived there with the lunar module at about 3-1/2 miles in the center of the COAS, between the width of the lines. It was absolutely incredible. It was about 2-1/2 degrees high, and it continued to drift up a little, just like it's supposed to. It was beautiful all the way.

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STAFFORD The total radar performance was fantastic. The calibration curves we obtained from the contractor for the AGC strength versus range match exactly, like the small card I had in front of us, which gave us a total correlation of the regime we were operating in and the indication that it would not be locked on a side lobe. The inertial angle needles followed prescribed nominal approach. At about 27 minutes Alfa dot went to zero. We did have one small out-of-plane when thrusting was made, and the inertial and the vertical needle went to zero and from there we continued in.

At 1/2 mile, the range rate was reduced to 19 ft/sec. At 1/4 mile, we reduced further on down, and finally we arrived at 500 feet with 4 to 5 ft/sec. During this time, we continually made comparisons between the VHF ranging and the radar ranging on the lunar module. It was apparent that they were in close agreement in every case. In the final part, we were able to call ranges in the command module down to 300 feet, 180 feet, and get precise comparisons with the lunar module. It appeared that the equipment was working most satisfactorily.

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9.2.46 Photography

CERNAN We got 16-mm strip photos of the CSM, from the point where it first became an object to the point at which we pitched down after braking and stationkeeping.

9.2.47 Stationkeeping and Docking

STAFFORD We reached a relative position of zero R-dot at approximately 25 feet. At that time, we decided since we were out in daylight to go right ahead to the docking phase and not waste any time. I used pulse, pitched over 90 degrees, had the command and service module in the overhead window, then rolled to an attitude that I approximated from there on, the command module directed the lunar module exactly what attitudes to go to. Then I went to AGS ATTITUDE HOLD with a tight dead-band, and noted the rate error needles were off of zero deflection. We were closing within 10 feet when we had acquisition and MSFN. I directed MSFN to stand by, that we were 10 feet closing.

YOUNG I was trying to save a little gas, so I was trying to maneuver in pitch, roll, and yaw to line up, just holding station out there, and trying to direct Tom to the lineup on the crossbar. It worked pretty good. I got in about 2 or 3 feet of having the crossbar all lined up. Unfortunately, every

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(CONT'D)

maneuver I'd make after that just seemed to make things worse. So, I finally gave up and went on in to dock.

STAFFORD Docking was the same as before. It appeared to be no problem, although it was evident that the lunar module was a little more sporty as far as holding attitude. But, it seemed to hold attitude very well, and it was no problem to line the crossbar and go on in and dock. I used AGS ATTITUDE HOLD minimum deadband.

YOUNG Right at contact, I gave the word and Tom thrust forward; we got a capture.

STAFFORD John hit the drogue right in the dead center. There was never a mark on that whole drogue.

CERNAN Capture from the LM was very evident. Retraction was not, but when those latches went, it was extremely evident.

YOUNG It really was loud. It was a lot louder than the one that we did from the command module.

CERNAN Maybe it's because we had a pressurized LM this time.

STAFFORD It was a lot louder the second time.

CERNAN Of course, we had our helmets off.

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STAFFORD No, I had my helmet on.

CERNAN We had them on, babe. You had a big hatch there, but you were punching holes in our drogue and we were not about to leave our helmets off.

STAFFORD Our procedure -- as soon as capture occurred there were a couple of minor thrustings until we killed both attitude control systems.

CERNAN We were just partying.

STAFFORD Then John damped the maneuver. A loud ripple bang was heard as the latches latched.

YOUNG A sigh of relief was given by all.

CERNAN The LM rendezvous book was extremely adequate. I'm very happy with the way it was. For any off-nominal performance, we appreciate we would have had to go to another couple of charts for the abort type of rendezvous. With a nominal rendezvous from our point of view, it was good.

YOUNG Well, there's always ways you can improve things. I can see some things in here we could change.

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STAFFORD I think that the total books correlated closely together, and the data flow correlated.

CERNAN That's the important thing. It's the integration of the two procedures. That's the thing that just wipes you out when you first start on it.

YOUNG Boy, I mean to tell you. We end up putting in numbers backwards, and that blows the whole thing.

CERNAN If you do something to the LM rendezvous book and you don't coordinate it with the command module rendezvous book, chances are it's not going to work.

YOUNG It's not going to work the first time.

9.2.49 Single Crewmember LM Rendezvous Capability

CERNAN I don't know why you'd want it unless you leave someone on the surface. I think the capability certainly is there. If you assume that you're going to ignore all backup charts and all AGS work.

STAFFORD The PGNS is perfectly feasible. I think I could have made that whole thing on PGNS and never used the checklist.

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CERNAN When I say ignore AGS, ignore the AGS computer. You've still got the capability with a one-man rendezvous using all the AGS attitude control systems. As far as the computations and everything, you would be flying and using the radar in PGNCS for your solution. The usefulness of the CSM rendezvous radar beacon light to the LM is practically zero because we never could see it.

STAFFORD We never could see it.

CERNAN We knew it was on. When we separated, we saw it very bright and shiny. We never saw it except within 10 miles or less.

YOUNG No, it was less than 4.

CERNAN Less than 10 miles?

YOUNG You need it with the radar.

CERNAN Oh, I'm sorry. I'm talking about the flashing light.

STAFFORD Flashing light.

CERNAN Flashing light. We could never see it.

STAFFORD Never see it.

CERNAN Babe, we never saw it.

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STAFFORD We never saw it.

CERNAN Until you came up close, then we saw it.

STAFFORD Yes.

YOUNG It was working.

STAFFORD Yes, one thing I forgot to mention. I first saw, from the LM, the command module in reflected sunlight at about 70 to 80 miles, and just as a faint, orange-yellow dot. It's exactly like we've seen the Agena targets around the earth.

YOUNG While I was tracking optically in the sunlight, I was tracking the lunar module in excess of 200 miles, maybe 300 miles. We ought to look at the data.

CERNAN Yes.

STAFFORD I never saw you until just about until you broke it.

YOUNG I could track your light at 300 miles. That's fantastic.

STAFFORD Direct control's good. The pulse mode on the ascent stage — you can never null the rates to zero like you can on the descent stage. I doubt if we ever used rate command more than a couple of seconds, just to look at it.

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YOUNG The only way that you can tell the difference between the lunar module and a star in sunlight, when you got it in AUTO OPTICS, is watching for motion of stars behind it. If the stars behind it move, you know you got the right thing. If everything moves, you know that it is a star, and you better not take a mark on it. That's the only way you can tell, because it looks like a star.

9.2.54 Cross Coupling Rotational Factors Observed

On The FDAI

STAFFORD When you put in the pitch maneuver, there was very little cross coupling. Your cross coupling was on the translation maneuvers. When you made the translation maneuver, you had cross coupling. As far as pitch and yaw and roll, practically no cross coupling was in there at all.

CERNAN Equipment preparation for transfer went very well. The stowage for the APS burn depletion went very well. I think we found out that we were better off moving one guy to the tunnel and putting the other guy down on the floor of the LM. This gave him more room to work. It wasn't so much the body volume; it was dragging the hoses around with the suits that got you all tied up and tangled and twisted around.

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YOUNG The ground told me to go to LM PRESS to vent it and to see if we could blow this Mylar out there. I got all carried away with the rendezvous, and just flat forgot to do it. So, when we docked, I hadn't done that. I went to LM PRESS and immediately repressurized the tunnel. Just like that, boy. So I opened the hatch, pulled the hatch down inside, flipped the drogue out, took the probe out, and then took the drogue out. The probe was hot as the dickens, and it increased the cabin temperature about 15 degrees. It really warmed things up in there. And then there was sort of a funny burned smell associated with that whole business, too.

CERNAN The nose of the probe at braking was so bright it could have been an extremely high candle power light on the nose of that spacecraft.

STAFFORD It blinded me from seeing the rest of the probe.

CERNAN Yes, it was like a little Sun.

YOUNG Boy, I'll tell you, that baby was nothing but hot.

CERNAN Equipment preparation for transfer went good. The APS burn and depletion was a piece of cake. All there was was copying down some words and loading into the P30.

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9.2.57 Tunnel Operations

CERNAN Tunnel operations — I think that was great operating through the tunnel. Plenty big enough to go through with and without suits. No hose problems because we transferred without hoses. S-band tests were done the day before, so we didn't do any that day.

LM stowage for jettison went as planned, with the addition that we loaded some very lightweight but large-volume waste gear from the command module on the empty LM pilot's side of the cockpit. This caused no problems at all. We transferred the film and the cameras and what have you back to the command module and went through the LM closeout procedures as prescribed. We verified, just before going back, with MSFN that all switches were in order. Then we came back, closed out the LM, and left the tunnel vent valve because we went back to check it in AUTO. So that was it.

YOUNG We closed the tunnel, wiped down the seal of the tunnel, put all our gear in the command module hatch bag, and shoved it in there. It took away about 7 or 8 pounds, I guess. We wiped down both the seal on the spacecraft and the seal around the hatch, and they were both pretty clean. I expected to get some stuff in there, but we didn't have anyway to verify

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that we had a good pressurization seal. So, we used a REPRESS system and then we brought the cabin back up to about 5.7. We measured the LM DELTA-P there for a while. The CSM/LM DELTA-P looked pretty darn good.

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10.0 LUNAR MODULE JETTISON THROUGH TEI

YOUNG We reloaded the DAP with the LM ascent stage only and maneuvered to the undocking attitude. At this time, we could not vent the lunar module tunnel, so we built up the cabin pressure to about 5.7 or 5.8 and made sure that the cabin was sealed. When we were given the GO from MSFN, we turned on the LM tunnel SEP switch and jettisoned the LM.

CERNAN You might say that our command and service module attitude was constrained by the attitude which we had been in to set the LM S-band antenna in the manual slew position, so that it would reacquire coming around the front side of the moon for the APS burn to depletion.

YOUNG All of that was done prior to LM closeout. So, as soon as the ground had high-gain lockup with the LM, they gave us the go for LM jettison. We armed the PYRO and fired the separation.

STAFFORD We also had the EMS on DELTA-V and NORMAL. At the time of LM jettison, we could physically feel a little negative acceleration.

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YOUNG Right.

STAFFORD It registered minus 0.2 foot per second that the separation imparted to the command module.

YOUNG It was really a jolt.

STAFFORD It was a lot bigger jolt than you have with a CSM/SM SEP.

YOUNG We backed off, and it backed off from us. In about 3 to 4 seconds, the sunlight came out from right behind the LM and blanked it out of our view.

STAFFORD There was a large cloud at separation. The cloud exploded all over the whole sky. Then, the sun was there and that was the last we saw of it.

YOUNG We had our helmets and our gloves on during that separation; we were completely suited and closed up in the suit loop during the separation.

CERNAN The 16-millimeter camera was running at 12 frames per second during that separation, so there is possibly documentation of about 10 seconds while the LM was being blown off with the ring until the sun blinded the window.

STAFFORD I don't know how much of it will show.

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YOUNG Then, we took our suits off and stowed them a little better this time which was a very slow process because we were really bushed. I had it that day; I ate supper and turned in. And, man, did we sleep.

CERNAN The ground told us, after separation, that the LM cabin (apparently upon separation) vented to a vacuum in something like 5 seconds. We don't know what happened; but our impression is that when we blew the ring, the hatch or the LM dump valve blew open. Some insulation from the tunnel area or something possibly had got stuck in the valve and had allowed it to vent.

YOUNG I think it was probably some structural failure in there, because to vent the forward hatch through that valve takes you quite a while. But, this thing was in pure vacuum in just a couple of seconds.

CERNAN Yes, it was 5 seconds. So, it was possibly something big that caused it to go down. From the standpoint of our configuring of the LM for the APS burn to depletion and from the standpoint of the S-band antenna commands getting continuous lockon, performed in excellent fashion, until we were completely through. In other words, what we had been able to set up in lunar orbit for the APS burn depletion was

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done successfully and adequately so that MSFN could monitor and get the complete set of information from the burn to depletion. Now, we go into the next day, John, with the landmark tracking, the vertical strip photography, and photography, and the entire works.

YOUNG

Okay. I'd like to say something about that entire day. That entire day, I had time to eat a couple of glasses of juice in the morning, no lunch, and a couple of pieces of food at night. That is all the time there was for eating. There wasn't any time during the rendezvous, and that is just the way it was. But I wasn't particularly hungry because we were so bloated.

One of the major problems that we encountered in the command module during the entire day, as far as operations were concerned, was moving around in the pressure suit with those hoses on. It was a continual struggle from the left seat to the lower equipment bay and also over to the right seat to perform periodic systems checks. It seemed like I was always fighting the hoses. Finally, I got used to it and found that it would be much easier if you just took things slow and easy. You'd get things done a lot faster than if you got all excited about tangling up in your hoses. You had to continually pay

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YOUNG
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attention to avoid being wrapped up in your hoses and getting all tangled up. It was our intention to lower the right X-X strut. In the simulator, we found that we could not operate in the spacecraft with the hoses on the right X-X strut attached because, with the spacecraft prepared for the contingency EVA, it took much too long to get in and out of the couch and go back and forth. But, in zero gravity, it was simple matter to slide in and out of the left couch and slowly push your way down to the lower equipment bay without disconnecting the X-X strut. I'd recommend that as little of the spacecraft be taken apart as possible. The preparation for the contingency EVA was accomplished in an estimated 10 minutes. It's a very simple matter to unstow and to un-install and stow the center couch and to make the associated changes, such as installing suit hose in it and making such changes to the hatch. It's all listed in our checklist. It would have taken us an additional 10 minutes or so to do the rest of the changes which consisted of completely venting the hatch and removing the pit pin to do the contingency EVA.

CERNAN

We might mention something here about LM restraint and LM hoses that we failed to mention in the past. We'll start with the LM Pilot's side and the Commander's side because they're

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(CONT'D)

pretty much the same, but maybe there were some differences. In the unsuited condition, no restraints are really necessary. The Velcro on the floor and on the sandals were enough to maintain the position you wanted to maintain. In a suited condition, about 90 percent of the time, the LM pilot used the outboard restraint only to restrain himself. This tended to pull him to the right and possibly a little bit forward, but in the unlocked position on this restraint for just zero-g operations (not landing operations), it was comfortable. It was adequate, and it certainly was a good restraint system. During the insertion of the APS burn, the commander recommended that we hook up on both sides, and we did. Because of the wallowing, we were glad we did.

STAFFORD

The commander found that it felt uncomfortable to have the restraint harness attached continually, so we did approximately what the Apollo 9 crew did in that we had a single restraint harness attached, usually to the inboard side of the suit. But the torque from the hoses produced a couple that would tend to float me up even with that arrangement. I was usually up on my toes, most of the time.

CERNAN

The hoses gave the LM pilot no problems when he was operating in the right-hand station with the outboard restraints. However, during the stowage for the APS burn to depletion, when

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it required moving around and free floating, the hoses continually torqued and put the LM pilot in positions that were not where he wanted to go. So, he was fighting the hoses as well as trying to restow the spacecraft. But, during the normal station operations on the right-hand side, they really weren't much of a bother.

YOUNG

I really think that this is an important point. We should come up with a hose that allows the crewman freedom of motion without torquing him. Some kind of a hose is needed that is flexible enough to allow you to move about without giving you unwarranted, undesired torques. I don't know how we're going to do that, but I think it's something we ought to look into.

CERNAN

From the standpoint of making a lunar landing from the restraint harness, I think that with both the inboard and the outboard restraints hooked up, there's adequate freedom of movement and certainly probably adequate strength for the lunar landing.

STAFFORD

Right, there's no problem there.

CERNAN

Okay. We slept like bricks that night, didn't we?

STAFFORD

We sure did.

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YOUNG I was exhausted, dehydrated, and everything else. Okay, the next day was a terrible day, but a lot easier than the rendezvous day.

STAFFORD We made an update, and we thought the method of determining our position with respect to the longitude of the lunar orbit with the 150 West mark was real good. Also, the lead-in for the times to go to different f stops was very good. We changed the f stops exactly as prescribed from the MSFN update. We made one pass on strip photography as outlined.

YOUNG Landing-site strip photography was made with the 16-millimeter and the 70-millimeter cameras from all three windows as best as we could. The Command Module Pilot actually switched seats and flew the spacecraft from both the center and the left seat in order to make all windows available for target of opportunity photography. On the first three landmark tracking passes, Gene was shooting targets of opportunity from the left and center hatches. On the fourth tracking revolution, he got in the left seat.

STAFFORD He shot from right and center to start with.

YOUNG He shot from right and center for three revolutions, and the left and center for the last revolution. On each night

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pass, we did a REFSMMAT realign, and they did it without night adaptation and third star checks. In every case, there was very little platform drift. That platform worked beautifully.

10.11 LANDMARK TRACKING

STAFFORD We all realized that probably one of the most important things to support the lunar landing mission was to really wire down the lunar potential with respect to the mathematical model and to make these landmark trackings as accurate as possible. For this, the CMP had spent a lot of time in the simulator. Also, between the CMP and CDR, we had worked out real close coordination techniques. I would visually pick up a target through the left rendezvous window and then lead in on the exact times when the CMP would pick it up. Once the first mark was made, I would time him in increments of 5 seconds, so he could evenly space his marks.

YOUNG The ground came up and told us we were marking 20, 25, and 30 seconds too soon, so we delayed our time of marking. It's my opinion that you cannot judge by looking at the geometry when you should start marking from your attitude. This is particularly true if you only have one man in there, unless you just do it on time. There's no way a guy can judge

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(CONT'D)

accurately when he should commence marking from the geometry of the situation. This is particularly so when he can't see the horizon before he starts, which was true in every case. If we are going to continue to do landmark tracking, the following changes are recommended. During the marking, when the flashing 51 takes marks, it is recommended that the shaft and trunnion angles be displayed in register 1 and register 2. It is also recommended that, when you are in AUTO optics and between the 90-degree and the 50-degree test, the trunnion angle be extended so that the optics move out and trunnion to the right position so it doesn't waste that time when it passes the 50-degree test of that 5 or 6 seconds that it takes to run the trunnion all the way out. Other than that, I think the landmark tracking worked adequately, but it was very frustrating. Particularly, when we were coming up late on the marks, and we missed several marks because of the delay involved in the trunnion running out to the 50-degree line when we were oriented at a somewhat different position. We just had to wait on the AUTO optics to get out to its full travel.

STAFFORD The total effort of tracking four landmarks over four consecutive revolutions and doing the IMU realign and star check was tremendous work load on the CMP. But we got all the data, and the results appeared to be excellent.

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YOUNG

Let me say something about the ability to mark. Sometimes, due to the location of subsolar point, the surface was just too bright to mark on through the sextant, so we had to use a telescope. This is true of F1 and sometimes of CP2, when we first started. The way that those marks were made should be recorded. It is believed that the first data point on CP1 was not the same place that was tracked on the following passes. The last 3 passes on CP1 were all on the same landmark, and they were done with a sextant. CP2 points were all done on the same point. The first two were done with the sextant; the third one was done with the sextant and the telescope. There were only four marks taken on the third one because we lost the target due to a sun washout. The fourth was done with the telescope, but they all are on the same mark. F1 was probably marked on the wrong place for the first mark, but it is not known for sure. The first markings were done with the sextant. The second, third, and fourth marks were all done on the same place on F1 and were done with a telescope. The major inaccuracies involved in AUTO optics tracking was noted on F1 where it is estimated that AUTO optics had to slew about 5 degrees to find the actual F1 target. In every case, the original location of the landmark was placed in the sextant. Site 130 was all done with the sextant, and I think they are all pretty evenly spaced.

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The bottom of 130 was not tracked. What was tracked in 130 was a small crater on the far side — inside 130 about an estimated three-quarters of the way to the bottom of 130. The location of each one of those landmarks will have to point out precisely from the photographs that we took on the sight. On CP2, we were tracking a crater which is an estimated 130 to 140 feet across. On 130, the sextant tracking, we kept the marks right in the middle of the crater. It was an estimated 140 feet across, assuming that 90 feet (when you are directly overhead) would fill the circle inside the optics reticle. Tracking was very easy. The real problem was tracking through the sextant near the subsolar point when the surface was just so bright that you couldn't define anything. Another problem was the times when that reddish color of the landmark line of sight interfered with the real line of sight. When that happened, it would clobber our vision.

STAFFORD

One thing that had gone into this total effort on landmark tracking was a lot of preflight planning. We would let Gene continue to photograph the moon; and as we went to the terminator, I would pitch fix to a predetermined inertial angle so John could do the alignment and star check. Then, I would call VERB 83, enter, and match this inertial angle with the orbital rate that we needed. I'd phase right into the ORB

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STAFFORD
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rate. We did a tremendous amount of maneuvering on that; but by going ahead on the planning and by being very precise with the maneuvers, we were able to do this entire tracking with very little fuel.

YOUNG

I would like to emphasize that this was a team effort --- the whole day was a complete team effort. Tom was directing me and pointing out where the landmarks were. I can't over-emphasize how valuable the strip maps were to lead us into these landmarks. It worked out really well, much better than we had hoped for, particularly in view of the fact that we were not watching the horizon. We were just going with the pitch angles given by the ground, and they worked out very well. It was a team effort that started way back in the Data Priority Meetings, and it certainly worked out well.

10.17 TELEVISION

STAFFORD

I think we actually cancelled a couple of television transmissions because we wanted to concentrate more on the landmark tracking. Basically, television was used throughout the mission on a noninterference basis.

YOUNG

I think that gets us through the four REV's of landmark tracking. Then, we had a 3-1/2 hour rest period. Did we sleep during that period, Tom?

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STAFFORD We slept solid for about 3-1/2 hours.

10.21 SEXTANT STAR CHECKS

YOUNG The sextant star checks for the TEI attitude was as follows. I'd like to emphasize that it became obvious about this time that special care must be taken with markings. It was evident that when you put the star in the center of the telescope and marked it in the center of the telescope (as opposed to saying it was off just a little bit, where you would get a star-angle difference of plus 1 or plus 2) that you would get zeros. I think that probably gave us the best platform alignments too. For those critical burns, we made sure that we had zeros for star-angle differences.

CERNAN I think that was evident in the fact that we didn't really require a midcourse alignment all the way home, until at the last. Then, that was only for a tuneup to reduce the g-load.

STAFFORD The climb out after TEI had been partially simulated before (at least a preview of what would occur there), due to some of the fidelity in the simulator at the Cape. It was from this that we anticipated some excellent film shots and also some TV shots. We went to a high-gain attitude angle which

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STAFFORD (CONT'D) would give us good high-gain contact with MSFN and which would also give us a view of the lunar surface and the whole Moon as we moved away.

YOUNG When we left the Moon, we must have had better than 100 feet per second in the RCS to get us back in the corridor, should any unforeseen events have occurred. It was a comforting feeling to have that reserve.

STAFFORD We left the Moon with what we had estimated to be nearly 60 percent of our fuel in the RCS.

10.22 PREPARATION FOR TEI

STAFFORD Again we rebriefed on TEI, we had a little skull session before every major event. We went to the TEI attitude about 30 minutes beforehand, so we could continually get more data on the Moon.

YOUNG We did oblique photography on landing site 3, and we were shooting black and white film. As we came into landing site 3 (about 4 or 5 minutes later), the black and white magazine ran out of film. We changed to color film. I don't remember which color it was, but we continued shooting the oblique photography over the landing site. At that time, the sun angle was pretty low, but the pictures showed up very well.

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We did photographs of opportunity which really weren't photographs of opportunity, because by this time, we'd almost photographed every photograph of opportunity that we could. Then, we tracked landing sites B-1 and landing site 150, and it is not known for sure whether 150 was actually tracked. But there's another three-crater grouping which is north of a ridge, north of the landing site. I'm not sure which of those three-crater groupings was tracked because the sun angle was very low, and the shadowy features made that crater very difficult to recognize. I'm sure glad that we had the OJT for landmark tracking; and I highly recommend that the G-guys (if they're going to have to track the landing site) be given the OJT. Furthermore, I highly recommend that we make every effort to pick clearly evident craters, patterns, and groupings, so that they can easily acquire these things. B-1 was a very difficult crater to acquire. If we'd picked landing site 133 instead of 130, we would probably have missed half of our shots of landing site 2. The three crater grouping of site 150 on landing site 3 is a good grouping, but it takes some study to make sure that you got the right three-crater grouping. I just didn't spend enough time on landing site 3. I'm convinced of that. I should have known ahead of time, but the low sun angle also made it difficult to recognize which three craters I should have tracked.

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10.23 SPS/TEI BURN AND ECO

STAFFORD The TEI burn went exactly as planned. The ignition was on time. We had some rates to start with, but within approximately 30 seconds the rate damped down. For the last few minutes of the burn, the pitch and yaw rates were absolutely zero, but roll would continually go back and forth in the deadband. Then we climbed out, which was recorded on television.

YOUNG I think the simulator should be corrected to show how this vehicle operates in SPS, the way it continually rolls back and forth across the deadband. It goes from one deadband to the other.

STAFFORD The residuals were absolutely fantastic. We had 0.3 feet per second X, which we reduced to 0.2, as by the predefined mission rules. The $V_g Y$ was 1.6 feet per second, and $V_g Z$ was minus 0.2 feet per second.

YOUNG DELTA- V_c was 19.9 which speaks very well of the EMS. We could have confidently done an EMS burn.

STAFFORD At the end of the TEI burn, we had fuel remaining of 9.2-percent oxidizer and 6.7-percent fuel.

CERNAN Throughout that whole burn, the PUG's was on the full increase side of the meter. The increase switch was put to FULL INCREASE after the second bank A valves were put in, so that

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CERNAN
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we would not get any start transient in case there might have been one with the flow valve movement. So, after we got a good solid secondary set of ball valves open, we went to FULL INCREASE, and it never did anything. The unbalance continued — the percentages continued to get further away.

STAFFORD

It was predetermined that probably one of the best beginning evaluations we would have would be the television system. Most people didn't realize that we were sending down sequenced signals. This is probably the highest resolution engineering device ever developed, 60 frames per second, 650 lines per frame. If we go back and reconstruct the tapes, we can probably get a better lead in as far as the obliques to the site and even the sequence camera. The true color will be evaluated in this, and the red, blue, and green color will be used on the Goldstone data as it was coming down in sequence.

YOUNG

The Moon is brown. I don't care what anybody says.

CERNAN

The more I think about it, the more I think that's right. I don't think we need to say anymore about it.

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11.0 TRANSEARTH COAST

YOUNG We set up passive thermal control, but this time we were rolling to the left instead of to the right on the first pass. For some reason, it's not known right now, maybe some wrong entries were made in the DAP, but we started with a bad angle. Some thruster firings and roll occurred and it coupled in yaw. We immediately went up against that 30-degree deadband after less than an hour and a half, so we stopped the whole thing and reinitialized it. The next three or four times that we set up passive thermal control, it worked just as preflight. It was normal and we varied our pitch from plus 90 to plus 270.

Let me say something about star visibility. Even with the sun coming through the hatch window, it was very easy to recognize large groups of constellations. When the spacecraft was oriented toward the north ecliptic, the stars that were visible were in the vicinity of the Sun. You could not detect such constellations as the Great Square, Pegasus, Perseus, Gemini, or the first part of the Big Dipper. However, Regulus, Leo, the Big Dipper, Arcturus, Jupiter, in the vicinity of the Moon, within about 15 or 20 degrees of the Moon, were washed out of the optics. Then, later, in the vicinity of the Earth the stars became apparent.

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~~CONFIDENTIAL~~YOUNG
(CONT'D)

The thing that got to you on the stars was the banding across the telescope of the optics. As soon as you approached the Moon this banding would start and completely wipe out your visibility for stars in the telescope, as far as being able to recognize constellations by themselves. However, in the vicinity of the Moon you could see Alphecca and Rasalhague. As soon as you got away from the Moon, Rasalhague was very visible, as well as Nunki, Scorpio and Dabih. Then in the vicinity of the Earth, within an estimated 30 or 40 degrees, all the stars were wiped out back through the Sun again. So there was a large number of places where you couldn't see any stars. However, had we gone into gimbal lock it would have been relatively easy to put the Sun in the hatch window and orient the platform with a P51.

STAFFORD

One thing we should bring out is we developed a new star chart for this mission, with the basic orientation being the plane of the ecliptic, which lies fairly close to the lunar equator. It worked real well for lunar orbit operations and also transearth. Whether you required north-set stars or southern-set stars you could look at the basic chart and tell exactly how, at any given time, to roll to where the stars would be and where the Earth, Moon, and Sun would be.

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11-3

YOUNG

One thing that impressed me about the stars was that, for example, in the Southern Cross, there are many bright stars; and many of the stars in the vicinity appear to be much brighter than the regular navigation stars. So you couldn't really always count on the brightness of the star to tell you whether you were going to pick a navigation star or not. Atria, for example, was a very dim star compared to a lot of seemingly brighter stars in that area, although once you got the hang of it, it was easy to pick it out. We used Atria on many realignments. Menkent, of course, being right in the middle of Centaurus, is just one of a group of very bright stars, and pretty difficult to pick out, but very easy with AUTO optics, of course. In AUTO optics, there's never any doubt about which star you have. Midcourse lunar landmarks, based upon the lunar landmarks sighting map with the two key craters of Messier A and Messier B with the big rays sticking out of them, stood out like a sore thumb. It was very easy to do star lunar landmark for navigation purposes, and I really recommend that star and star lunar landmark and star Earth landmark be considered as one of primary needs of NO-COMM navigation. There are areas that we noticed that were open all the time around the Earth, for example, that Saudi Arabia, Baja California, and parts of Africa near Dakar, the north coast of Africa, and certain other landmarks

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(CONT'D)

were available. It was an easy task, in AUTO optics, to put the landmark right in the middle - to put the star right in the center of the landmark and make the mark. There was no difficulty from our distance to see the small craters, Taruntius P, Taruntius H, Messier B, Sueha K, no difficulty to pick them out because they were keyed in the Messier craters, big-ray craters in the center of the Moon.

It was very easy to navigate. The star horizon measurements, that we made with the star near the terminator, were in each case very easy to do. There was no difficulty noted and, in fact, it was not difficult to do it completely in AUTO optics. The greatest difficulty with star horizon measurement was in finding the star in the vicinity of the Earth to do the optics calibration. In several cases, stars that we calibrated were 50 to 60 degrees away from the Earth, which is probably not very accurate from the standpoint of getting accurate landmark line of sight, star line of sight bias, and trunnion bias checks. If this is considered important, then we should develop an AUTO optics and capability of flying a spacecraft to the landmark line of sight with a star in the optics so that the crew doesn't have to spend a lot of time and a lot of fuel hunting around for a star that they can't find in the vicinity of the Earth. Because, within 30 to 40 degrees

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11-5

YOUNG
(CONT'D)

of the Earth, your eyes are wiped out with the telescope. We were told at preflight that the requirement to get the star in the vicinity of the body to be tracked was thermal. It was evident that the optics bias calibration was changing, almost with every set of star sights. Not significantly, but some. So we certainly recommend that if you're going to track stars in vicinities of bright bodies that there be an AUTO optics method of getting to those stars, because you certainly can't see them in the telescope.

STAFFORD

Another item that we thought was significant, and this has been mentioned on previous technical debriefings, is the fact that you should have S/C control authority to have freedom of the optics down the X-axis of the spacecraft with respect to the navigator.

YOUNG

It is certainly impossible to think in terms of flying without many, many hours of practice. I'm thinking in terms of which way you move the control stick to make the spacecraft go the way you want to. What you end up doing is making an impulse and seeing which way that moves the whole system, and if that wasn't the right way, then you are going to make two more pulses in the other direction, to correct one. This was even true of Earth horizon measurement.

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CERNAN You can't figure out which way you're pulling, yaw, or roll, or what you got. You want to talk about the P37's and our backing up the ground in midcourse calculation.

YOUNG We took our star-horizon measurements, after we completed the fourth set, and ran them through P37. We took the latest state-vector updates and ran through P37's. In each case, we were close enough for government work with the ground vector, which indicates to me that we have an onboard capability of doing this navigation back to the ground. I don't think we would have gotten into any trouble by flying the last midcourse with those last four sighting sequences. I felt reasonably confident that if we pressed on, we would have probably been in the ocean in some relative proximity to the pole. Our last midcourse correction was 0.7 feet per second and the ground's at that time was about 1.6.

STAFFORD So basically, we were within 0.9 feet per second of MSFN, using the basic MSFN vector updated by John's tracking. Using P37 and the onboard vector gave us a solution of 0.9 feet per second.

CERNAN As a matter of fact, when you integrated down to the best time to burn and the minimum fuel, the comparison with MSFN's time and minimum fuel was very close.

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11-7

YOUNG Of major interest was one midcourse correction that we made, which was done with the waste-dump system, and apparently corrected the flight path angle a tenth of a degree.

SPEAKER Why did we do that?

YOUNG I don't know, but it was about 0.001 feet per second, as I recall. And that was our capability. Midcourse correction number 6 was canceled. Midcourse correction number 7 was performed with 1.6 feet per second, performed on time and the burn to zero residuals.

11.39 FINAL ENTRY PREPARATIONS

YOUNG We had the ground give us an angle which we could orient to see stars at nighttime. We did a realign to the reentry REFSMMAT. When we woke up the morning of reentry, they gave us an angle which would avoid the gimbal lock, and which would allow us a good realign. Using AUTO optics, the stars were almost exactly within the center of the optics. We did two realign checks. We did one realign check after that, and got 5 balls for reentry at an hour and 35 minutes prior to entry. We're almost at entry now.

STAFFORD No command module RCS preheat was required. We monitored the command module RCS temperature throughout the mission,

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(CONT'D)

and it stayed well above the value that would be required to heat the coils.

YOUNG

Entry stowage was performed throughout the transearth coast. The major stowage that we did was the suits. The command module pilot's suit was stowed in the sleeping bag on the right side with the lithium hydroxide canister butt up against A6 and lashed down. The IMP and commander's suits were stowed under the center couch and lashed down as per the North American drawing for reentry stowage. The spacecraft stowage was a very simple thing to perform. It was not performed precisely as per checklist. Food boxes L-2 and L-3 were unfortunately still full of food, so there couldn't be any stowage performed in those boxes. The suit helmets were stowed in the right suit, and left suit and the center suit, up at the head of the spacecraft +Z, and the other helmet was stowed in B2 with waste material in it.

CERKAN

Which reminds me, the helmets were stowed on a suit, but they were on the hatch side of the spacecraft.

YOUNG

The couches could have stroked full length, it is estimated, without hitting anything on the floor.

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11-9

CERNAN And during our 6 to 7 g reentry, apparently our stowage was pretty good, because we had nothing coming out of the rafters, nothing rattled around, everything was pretty solid.

YOUNG One thing that did come down was the water gun. I was just going to comment on the complete stowage.

STAFFORD Again, we used the same technique on the transearth coast as we did on translunar. The day before reentry, we reviewed the whole reentry checklist. We reviewed the complete sequence that we would go through on reentry for about 3 hours. And I think this paid off very well. There were no surprises. We were well ahead on every item, and we were anticipating when the computer would change its displays, even during the aerodynamic phase.

YOUNG The entry checklist was gone through prior to reentry, and items which were not applicable, due to the fact that it was supercircular entry, or because of anomalies such as the primary water boiler, were crossed off and changed as per MSFN updates. Several changes were made to the reentry checklist in real time.

STAFFORD The spacecraft entered the shadow of the Earth within several seconds of when MSFN anticipated. Sunset, which was at 19:19:51, occurred within a couple of seconds.

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11.43 CM/SM SEPARATION

STAFFORD The CSM-SM sep was performed as prescribed. There were no anomalies. The command module was then flown in plus around to the entry attitude.

YOUNG Well, why don't we go through that whole check sequence? The primary purpose of all these alignment checks and horizon checks was to verify that you had the platform aligned properly. We did a 5-balls alignment on the platform. Then we maneuvered to the separation attitude, at which time sunset had occurred.

11.45 0.05g EMS AND CORRIDOR CHECK

YOUNG The 8 crew had tracked the horizon all the way around, to determine any gross horizon checks. Well, in our case, the horizon was dark. It is recommended, because things are happening so fast, that only one check be made, and preferably that check be made with the horizon on the window at the attitude it will be at sunset. That's an optimum time to do it. You can see the horizon very clearly there. It will give you one gross final check and if that platform drifts so much that you can't do an entry after that, you got a serious problem. I see no reason continually to track the horizon, which is dark anyway. Long before 0.05 g's,

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11-11

YOUNG
(CONT'D)

things are going to be white hot and you're not going to see anything anyhow. So I recommend that those continual horizon-tracking checks be eliminated as a point of no useful function.

STAFFORD

The time from before sunset to entry interface, when we make the check, is approximately 30 minutes. If the platform drifts badly in that time, it will also be obvious on the GDC correlation.

YOUNG

I'm not sure it would have been obvious with ours. We continually realigned the GDC to the IMU during the last portion of the tracking. The last one was a quick maneuver to the entry attitude, and a final alignment with the GDC to the IMU at the entry attitude. And if the SCS has to be used in a backup mode, it is recommended that the final GDC align be made at the last possible time to insure that you have a reasonable chance of doing a suitable roll entry.

STAFFORD

During the EMS tests, we determined that the scroll scribed initially making a mark. As it went to the final pattern, it did not.

YOUNG

It did not scribe properly and the ground recommended running it the other way for a half inch and then running it back

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(CONT'D)

to 37 K. This we did, and it worked and would have worked properly. We maneuvered to the separation attitude. When we separated I had left the switches in ENTRY and NORMAL and that triggered the 0.05 g switch, so the EMS started counting. The answer of course, given by the ground, which I should have known, was to run it down two patterns and start all over again, which we did.

We continually kept ahead of the entry checklist, and it paid off. When I made that mistake, by not being in the right position on that switch, that allowed us to correct for it without being behind the gun. It is certainly recommended that crews make every attempt to stay a little ahead of their checklist, except in those areas where you have to wait for a time sequence. You don't want to separate the spacecraft too early, obviously.

CERNAN

Just prior to separation, at 2 hours, we reserviced the primary EVAP for 3 minutes and activated it at an hour and 15 minutes before entry interface. It came on the line normally. At 50 minutes we brought the secondary EVAP on and it worked normally. There was a definite torquing seen, apparently from the evaporators. It brought the cabin temperature down to about 58 degrees, but it was not abnormally

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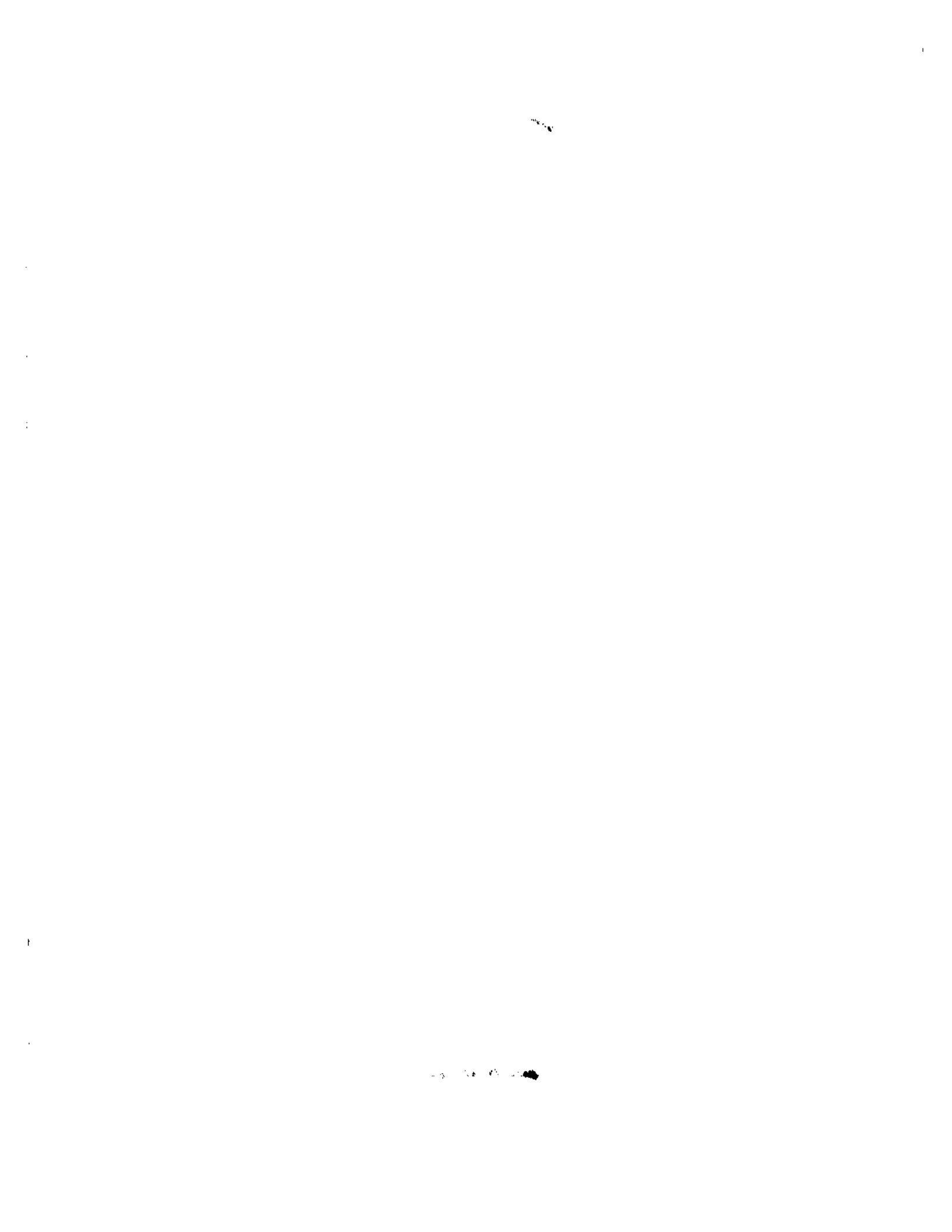
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11-13

CERNAN
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uncomfortable. The EVAP's worked throughout the remainder
of the reentry.

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12.0 ENTRY

CERNAN The EMS functioned perfectly. The CMC functioned perfectly. The spacecraft was flown in pulse and turned over to the CMC, with the switches in max rate and high deadband, at about 0.1 g. The spacecraft performed normally in CMC all the way to the parachutes.

The entry was characterized by a 6.8 estimated g pulse, which was of somewhat longer duration than expected, although it was perfectly nominal. The spacecraft was subcircular, as per the time given in the update. The steering appeared to be purely nominal. It looked like we got down as low as 2-1/2 to 3 g's on the g-meter before we passed subcircular. But the spacecraft was doing the things that it should have been doing. In no case was there any violation of any monitoring criteria causing a takeover. At 5.4 g's, the thing commanded a 90-degree roll, at 5 g's it was going for 180-degree roll, and the spacecraft performance in no case was sluggish in any respect. The machine was performing crisply. The RCS was really driving that machine, and one ring seemed to be perfectly adequate. There was no doubt that the machine was going to go subcircular and perform adequately the whole time it was doing the entry. It was a thing of beauty.

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STAFFORD When the downrange decreased to less than 10 miles, we went to bank angle to take out crossrange and modulate the lift. During this time, even though we were pulling g's, I was calling out crossrange and downrange and monitoring what the angles should be, even up to 5 and 6 g's. It was no problem calling out what the computer was doing. In the final display I hit verb to freeze it and it showed our total miss distance as approximately 0.9 nautical mile.

YOUNG We were talking to the ground all the way after blackout which was about 3 minutes and 29 seconds. We started calling the ground. I was transmitting in the blind, as best I could, what was going on. Our second g-pulse, estimated about 4 g's, was really something. To me it's a mystery how that CMC flies that spacecraft as well as it does. You couldn't fly the EMS in that manner and hope to end up in the same place that the CMC does. But it does it.

STAFFORD In the time sequence of events, drogue deploy was exactly on time. The drogues came out as a pink to an orange in sunlight. If we'd had a malfunction in the drogues, we could have seen these.

It was in blackness and the fireball, and then it was dark and then, when the drogues came out, they were in sunlight.

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12-3

CERNAN The drogues and the main, although it was dim sunlight, were very easily visible. I could watch every movement. I could see them deploy, and I could see the pilot's chute come. This time of day for reentry was just almost perfect because there is nothing you couldn't see in terms of drogues and main deployment. The visual impression of the reentry itself, unlike the multicolored Gemini's - fireball was sort of a white or gold hot fireball. It looked like a long, thin stream, the apex of which was a glowing ball which impressed me as being something like the Sun. Through all this gold-white fireball you could see out into the distance something like the Sun, like looking at the Sun through a haze of clouds.

YOUNG I wasn't looking at the light.

CERNAN And then, coming around the windows and, sort of as an envelope around this gold fireball, was a brilliant bright purple sheet. It was as though this whole orange or this gold, gold-white fireball was wrapped in purple and it stayed the same colors although the shades of purple varied from dim to light through the shock waves. It just basically stayed the same color all the way down.

YOUNG Okay. Let me tell you another mistake I made. At 50 K, I armed the pyros and forgot to go to boost entry until 24 K. Of course, that's about the time the cabin pressured 6 so it

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(CONT'D)

didn't make a hill of beans but we caught it; and, man, the air really came in in a hurry. The ELS logic was turned on at 30 K. No problem with that. One thing about the boost entry. At first I reached over and grabbed them and couldn't pull them back to the detent. I had forgotten that you got to push, you got to push forward on that thing to bring it down. It was caught in that detent; and, man, I thought I was going to break the handle off. But anyway, when I finally knew what I was doing wrong, I pushed outboard. I recommended that we brief all the crews to remember to push outboard on that thing to change the setting of that valve.

CERNAN

The best estimate of 90 000 feet based upon time from reentry reference time showed that the steam pressure started to peg about 15 seconds later but the steam pressure, once it started up slowly and methodically, went right up to the full increase position ... It went slower than in the simulator. The simulator just pops up, but this one started up and I'd say from boiling at about 0.15 to the time when it was full must have been 10 seconds. It just slowly started up but it was a definite movement. It was not an oscillatory movement. It just decided this was the time to go to full increase and it closed the valve about the same speed which you would close it manually. And I would say that in our case it would have been a pretty fair estimate. We would have probably hit the

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CERNAN
(CONT'D)

drogues maybe a thousand feet late, but based upon that reference time, it would have been a pretty fair estimate for drogues and mains.

YOUNG

Based on the fireball and how it was dying down, I'd estimate - just based on what we did in Gemini at about 130 K. I think I called out what I thought was 150 K based on the fireball at 120 K. I don't know if the ground heard me or not. When it stops burning you're starting to go through about 120.

CERNAN

I was checking this time against actual drogue times and the steam pressure would have put us a number of seconds behind but not too far behind to give us a problem. Visually the impression of the drogues were that they were really oscillating up there and I felt that spacecraft was being banged around on the drogues.

STAFFORD

But it still wasn't as much as on the Gemini drogues.

CERNAN

They don't stabilize - The mains came out - all three of them came out together.

YOUNG

Well, that might have been the period when we went through transonic. That's probably what caused all that shaking. It sure was a little rough there for a second or two.

CERNAN

The mains - when the mains came out, before they derceded, they were just a small little puckered up bundle of parachute

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(CONT'D)

and then they all dereefed simultaneously, and they all took their own quadrant, and we all got a full chute out of all three of them. I looked particularly because I could see some sparks starting - not a great number but a few of them - up towards the chutes. Visually, from where we were with the amount of sunlight we had, I couldn't see a thing in the chutes that indicated that there was a hole anywhere.

STAFFORD

I could see two chutes through the hatch window and all the chutes looked completely intact.

YOUNG

Okay. When we got on the mains there was a short delay while we were regrouping everything and the things dereefed and then we closed the cabin pressure relief valves and started the CM/RCS purge; and, man, it really gets rid of all that gas.

STAFFORD

The basic purge produced -

YOUNG

The biggest racket I've heard in a long time.

STAFFORD

Long yellow flames were visible but when it finally purged the lines - a lot of fire was seen.

YOUNG

The dump was pretty noisy and it died down toward the end like it went Bur-r-r-r-r-r.

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12-7

CERNAN But that purge must have put about a 5 foot, in length, and fanning out to about maybe 3 or 4 feet in diameter spray of gases and helium and fire and everything else out those thrusters.

YOUNG Yes. I saw a big bunch of yellow smoke going out through my side. Man, I know what that was. That was nitrogen tetroxide and it was heading north.

CERNAN At the completion -

YOUNG And a lot of it too.

CERNAN At the completion of the purge and the closing of the valves, we still had a fire on the right-hand side. A fire out of the thrusters over there that was big enough or hot enough to show flames leaping up past the right-hand window and there were definite flames and I'd say this lasted for at least 60 seconds before it went out.

STAFFORD Gene says, "Tom we got a fire out here." I said, "what are they going to do about it?"

YOUNG It went out when we hit the water.

CERNAN It went out long before we hit the water. It burned itself out probably after about a minute, or a minute and a half.

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CERNAN (CONT'D) But it was pretty impressive because the flames were leaping by the right-hand window.

YOUNG We had a fire on Gemini 10 too.

CERNAN We had a fire on 9 that lasted all the way to the water.

STAFFORD We could tell that we were right on top of the recovery force because I could look out the side windows from approximately 4500 feet down and we had a helicopter flying wing with us out of each window.

YOUNG We didn't see the aircraft carrier but it was quite clear that we were coming down near the water because you could see the water out of the side window.

STAFFORD You could see the water coming. It was a good reference for your altitude check.

YOUNG You could see the horizon, see the Sun coming up, see the choppers, and hear them.

STAFFORD We could hear those choppers from the inside.

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13.0 LANDING AND RECOVERY

CERNAN I thought the splashdown was pretty mild. We apparently hit straight flat.

YOUNG We hit flat.

CERNAN The chutes were jettisoned and they came right down on top of the spacecraft. And the carrier was immediately visible out of the side window.

13.1 TOUCHDOWN - IMPACT

YOUNG We practiced getting rid of the parachutes in a hurry many times. When we hit, the pyros were armed. We hit flat, it was a very soft landing. We didn't have much sea state. There weren't many waves, and the parachutes came down practically on top of the spacecraft. I think the parachutes were jettisoned before they hit the water.

13.2 SEQUENCE AND PROCEDURES FOR MAIN CHUTE RELEASE

STAFFORD As soon as we touched down, we were spring-loaded to go. Gene would close the breakers and call. Then I would pull the switch. It was a very mild splash compared to what my Gemini

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experience had been. Right away the parachutes were there, and shroud lines fell over on top of the spacecraft.

YOUNG There was no tendency for the spacecraft to go one way or the other. Tom immediately got out of the couch and went down to the LEB and that even made it more stable. Finally, all three of us got up and got out of the couch.

13.3 POSTLANDING CHECKLIST

STAFFORD The postlanding checklist was satisfactory. We went through the powerdown checklist.

YOUNG Yes, including those important switches on panel 250 that power down the whole vehicle. We opened every circuit breaker we could get our hands on and shut off every switch.

13.4 TEMPERATURE AND HUMIDITY

STAFFORD The temperature was mild. There was no excess heat.

13.5 COMMUNICATIONS

STAFFORD Communications were excellent with the recovery helicopters and also with the Princeton. The swimmers plugged in the line and it was overdriving a little bit. We could read the swimmers very well and everything went beautifully.

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13-3

~~13. VENTILATION~~

YOUNG We didn't use the postlanding ventilation system.

STAFFORD It was cool.

YOUNG The hatch was open within a matter of 10 or 15 minutes. It was open as soon as the collar was on. Swimmers were in the water right after the spacecraft splashed down.

STAFFORD We were out in the raft and the pickup was made 1, 2, 3, right in sequence.

SLAYTON It's all documented on TV anyway.

13.10 SEASICKNESS

STAFFORD There was no problem with respect to seasickness, lightheadedness, or dizziness. The recovery operation went smoothly and we were picked up.

YOUNG I dumped the dye marker in the water. I saw it go right over the side. It didn't deploy, but at least it made it possible for the swimmers to plug in.

13.13 COUCH POSITION

YOUNG The couches were left in a 180-degree position.

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13.14 INITIAL SITTING OR ~~STAN~~ DING

YOUNG There was no lightheadedness, dizziness, blurring, or dimming of vision.

STAFFORD No, I felt fine. I felt as good as when I left the Cape.

13.19 EGRESS

YOUNG We crawled out of the vehicle into the liferafts with no problems. We had our lifevests on, but did not deploy them. The crew was picked up in a basket. No one got dunked this time. The operation was phenomenally professional.

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14.0 COMMAND MODULE SYSTEMS OPERATION

14.1 GUIDANCE AND NAVIGATION

14.1.1 ISS Modes

STAFFORD The guidance and navigation system functioned perfectly.

YOUNG It displayed attitude errors lovely.

STAFFORD It was just beautiful.

YOUNG We didn't use the S-IVB takeover mode. Thrust vector control mode was beautiful. The temperature control was nominal.

14.1.2 Optical Subsystems

YOUNG We've already discussed optical systems operations. Let me say something about seeing stars with the LM on. I think you could see stars with the LM on if you pointed the whole stack, plus X axis, to the sunshine. We inadvertently did that for a TV pass. I was looking through the optics and I could make out constellations. I forget which constellations they were, but I could make them out. I recommend that, as opposed to going to a planet option. If you want a quick realignment just point the whole stack at the Sun, which would be an easy thing to do, and align the platform. As soon as you got night-adapted maybe you would have to pitch

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(CONT'D)

down a little plus X. The sextant mechanical drive worked beautifully. The sextant and scanning telescope were fine. The light transmission of the telescope was pretty low. This has already been noted. Once you're night-adapted all the stars that you could see at any time were there. In fact, you were looking at too many of them in a lot of cases. I had some difficulty in picking out the right stars. In the daytime you couldn't see any stars, but you could see the planets and the Earth/Moon/Sun combination. The sextant is so much smoother than the simulator, it's not even worth considering. Stability was beautiful. Zero optics mode worked great.

14.1.3 Computer Subsystem

YOUNG

Recommendations have already been made to modify the landmark tracking programs and the P23 programs. One to allow you to do AUTO optics calibration of the star and the other one, to display 1691 while you are in the landmark tracking option. This will drive the optics and trunnion out to the 50-degree mark prior to making the 50-degree angle track mark and save you 10 or 15 seconds. The R2 model takes a long time to run. VERB 83 takes a long time to run. It was noticed that the processing of optics and VHF marks was much faster than it was in the simulator. In the simulator

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14-3

YOUNG
(CONT'D)

you could only take two optics marks a minute; in the spacecraft you could take 3 to 4 optics marks a minute. We had a number of program alarms, due primarily to taking marks when flashing 51 wasn't called for in P23. We had alarms sometimes in P52, and also program alarms associated with VERB 41 NOUN 91. Those are all the program alarms that I remember. In every case that we had a program alarm the reason for that program alarm was obvious. Sometimes the AUTO optics did not track when the optics power switch was off. That was because I forgot to zero the optics, set the zero flag, and all those things. We had a 113 program alarm which indicated an inadvertent mark button. I don't remember doing that, but maybe we did. All the rest of the program alarms were well understood and were no cause for concern. They were just to remind you to do the right thing. The people at the Cape told me that the computer self-check does not really self-check the computers. I recommend it be deleted from the checklist.

CERNAN

I second that. When the computers function nominally, you've seen its reactions, you've seen its computations and integrations, and you've faith in it. You don't want to mess with the self-test.

YOUNG

We didn't have any gimbal lock. I guess this is the first

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YOUNG flight we didn't have gimbal lock.
(CONT'D)

STAFFORD First flight! We came close on one vehicle.

YOUNG In short, the G&N computer and ISS worked beautifully.

14.1.4 G&N Controls and Displays

YOUNG The entry monitor system worked great. You couldn't set it on zero and go to the EMS - the DELTA-V counter. You could not set that on zero and go without getting a jump. Sometimes you could but every other time it would jump to 10 or 25 feet. It didn't seem to make any difference. The DELTA-V check worked on every case as long as we were in DELTA-V and normal. When we set it up DELTA-V and STANDBY, it didn't work. The hand controllers are okay. We didn't turn off the G&N power switch.

14.1.5 Procedural Data

YOUNG The DSKY operation and verb-noun formats were okay.

14.2 STABILIZATION AND CONTROL SYSTEMS

14.2.1 Control

YOUNG Recommendations have been made about modifying the CMS to reflect the actual control dynamics of the command module during SPS burns. The rest of the control dynamics appear to be just like the CMS. All rates and operations were nominal.

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YOUNG MIN impulse is just like downtown.
(CONT'D)

14.2.2 Thrust Vector Control

YOUNG Thrust vector control and DELTA-V are okay. Orbit and de-orbit thrusting are nominal.

14.3 SERVICE PROPULSION SYSTEM

YOUNG Thrust vector alignment is no sweat. It was noted that during the engine thrust vector alignment the CMC would put the GPI's at a different place than indicated on the gage. We allowed for that by trimming them to the same position, with the thumb wheels on the GPI's, that the CMC would have put them. We felt we had a pretty good hack on the trim if we had to do a takeover. It was on the order of 0.2 degree.

CERNAN This didn't occur during burns but during the gimbal drive test. Were you aware of it during burns?

YOUNG Yes, I was watching it.

STAFFORD You could see the rates going up on it?

YOUNG Of course, I had the rates on 5 and 1 for SPS burns so I was watching it all. The thrust-on button we didn't use, but we were ready to. The PC indicator worked just like downtown. The PC indicator indicated 5 when it was reading zero. It

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started out indicating a low value for chamber pressure but as the mission went on, it came up. It indicated 102 and 103 psi for the LOI and TEI burns which is where it counted.

CERNAN

Let me go through the whole story on the PUGS. When we lifted off, the PUGS was reading 50 on the decrease side which is still in the green band. Our first burns were short. We didn't do anything to the PUGS because you wait for about 15 seconds until the things stabilize and settle down. For LOI, our first big burn, the PUGS oxidizer-increase/decrease indicator went from 50 decrease to about 150 decrease. At that time I went to the decrease position on the switch. The decrease indicator then slowed down to about 200, then started reversing itself. When it got to zero, the PUGS oxidizer valve was neutralized, put in a normal position. The burn continued and the increase/decrease indicator then started to go to the increase side. It started to go to the increase side and when it got to about 100 the switch was thrown to increase, but the increase or the unbalance continued. At the completion of the burn, it was somewhere between 300 and 400 - this is documented on tape. Just before the completion of the LOI burn, I went to the normal position on the oxidizer flow control valve. This made the unbalance to go even further off to somewhere

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close to 400 on the increase side. On subsequent burns, it was recommended that we go ahead and put the switch to the increase position again knowing full well that the oxidizer flow valve was not handling the unbalance properly. We went to the increase position after we got the second bank of ball valves in, so we would not start with a transient. After the second bank of ball valves were put in, the switch went to the increase position. During the TEI burn, the unbalance continued beyond 400 to off scale high and remained there throughout the burn. We ended up with about 9 percent of oxidizer and about 6 percent of fuel when we shut down the TEI burn. It was apparent to me that the PUGS was not functioning properly after the very first burn. The numbers have been documented and are available.

14.4 REACTION CONTROL SYSTEM

14.4.1 SM/RCS

YOUNG

We primarily operated the reaction control system in AUTO and pulse mode. Sometimes we went to acceleration command when we had the whole stack together. It was easy to control roll and pulse.

STAFFORD

We used the acceleration command mode to decrease the fuel usage to achieve certain rates over a series of pulses because

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STAFFORD (CONT'D) the I_{sp} is better. It looked like our total fuel usage worked out great, just like we planned.

YOUNG With the helmets and gloves on, you could not hear the jets. It didn't appear to me that you could hear continuous thrusting, but you could always hear the initial clunk when either the solenoids engaged or there's a hot explosion when these things fire. That was a valuable clue as to whether or not you got any output out of the burner. I think we ought to modify the CMS so it doesn't give this continuous sh-h-h and give it that one clunk and let it go at that.

14.4.2 Command Module RCS

YOUNG You could hear those fire continuously, and the pressure switch worked. You could hear the little clunk as it fired. You could hear the gurgle as the propellants went down to the various places. The CSM SEP switch works. It makes a big noise. You hear a pretty good sharp crack as a cue that things are going on back there. You could hear those thrusters firing. They're not as loud as we have them turned up in the command module right now.

CERNAN You can hear the transfer between service module and command module also.

YOUNG I couldn't hear the SPS fire either. I never heard that thing.

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CERNAN There's no doubt in your mind.

STAFFORD The acceleration is instantaneous.

YOUNG It's not as bad as that Agena was. Man, that Agena really whomped you all of a sudden. Maybe that's because we're sitting backwards.

14.5 ELECTRICAL POWER SYSTEM

14.5.1 Fuel Cells

CERNAN We never had any abnormal talkbacks on the pH indicators. We did have a fuel cell anomaly on fuel cell 1, on the third day in lunar orbit, sometime after probably 108 to 112 hours. The circuit breaker on the fuel cell number 1 pump package popped. We did not catch it because there were no anomalies on our gages at that time. All the temperatures were still within limits. It was caught by the ground. We went down there to reset this breaker. We tried resetting it. As soon as we did, it popped out and gave us a main bus undervolt light and an AC bus 1 light.

YOUNG I felt that breaker and it was warm.

CERNAN The breaker was warm. We immediately made the decision not to reset it. This meant that we lost the pump cooling package capability on fuel cell 1 - not necessarily the whole fuel cell.

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We ran it until the skin temperature got up to the mid-nominal range of operation, and decided that continued operation would just increase it. We took it off the line, and from then on we operated somewhere between 26 and 27-1/2 volts depending upon the load on the spacecraft. There was only one time when some cryo tank heaters cycled that we got a undervolt light on the main buses. After that period of time, we were very careful as to what we had powered up and what we did not have powered up. We turned things like potable water heater, optics power, and a number of other things that were not necessary off. We turned these things off just to keep our main bus voltage above 27. For the most part it stayed at 27 - 27-1/2 volts on two fuel cells. We had the capability of fuel cell 1 if we needed it, after it cooled down or with a continuous purge. A continuous hydrogen purge was limited by the duration of the mission, and by the amount of hydrogen. The further on we got into the mission, the better off we were for using that fuel cell. We did bring that particular fuel cell on for a couple of major events. One of them was the TEI burn. At that time the skin temperature had cooled down below the nominal. We brought the fuel cell on an hour and a half before the burn. By burn time, it had picked up 33 percent of the load and performed nominally. We had it on the line for a total of about 4 hours. We lifted

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off with the O₂ flow indicator on that same fuel cell failed. We knew it had failed off scale low. We had no indication of oxygen flow on that fuel cell. From that point on, we operated with two cells. We had another fuel cell anomaly on fuel cell 2. This anomaly occurred about 20 to 12 hours before TEI at the same time that we had fuel cell number 1 off the line, and the fuel cell number 1 light on. The condenser exhaust temperature on fuel cell 2 slowly started oscillating between the upper and lower limits of the caution and warning temperature parameters. It oscillated at about 2 cycles per minute, and about every 10th cycle it got low enough where it triggered the caution and warning master alarm at the lower limit. The first time we were alerted to this, was just as we went behind the Moon at about 10 or 12 hours before TEI. Fuel cell number 2 and a master alarm light came on to keep the fuel cell number 1 light company. We monitored and watched it pretty closely. The fuel cell output was holding up, the voltage was holding up, but the temperature on the condenser exhaust was cycling. When we were in sunlight for about 10 minutes and doing landmark tracking, the cycle slowed down and eventually damped out at the nominal temperature. When we were in the darkness for about 10 minutes, the cycle slowly started up, and it peaked out at probably around the early third of darkness. This continued on through darkness

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triggering a master alarm occasionally. This continued through and into TEI. After TEI, when we went into the PTC mode of operation on the coast back to Earth, the condenser exhaust temperature remained stabilized at the nominal temperature and we never saw this condition again. The thing that bothered us was that we had one fuel cell off the line because of the condenser exhaust pump problem in the pump package, and now we were possibly having a similar problem. We didn't know that this same cycle occurred on one of the fuel cells on Apollo 8 when they were in lunar orbit and we should have. Apparently there's some thermal conditions in the lunar orbit day/night cycle that certain fuel cells are sensitive to. We came home on two fuel cells. We brought fuel cell number 1 up once, maybe twice. It really wasn't needed, and we didn't have to power down. The transearth coast was nominal and the fuel cell voltage remained between 27 and 28 volts all the way home.

STAFFORD The only items that we powered down was to turn off the optics power switch, the GDC, and the potable water heater.

YOUNG And a radar transponder.

CERNAN Configuration of fuel cells, fuel cell number 2 on main bus A; fuel cell number 3 on main bus B; and those buses were not

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CERNAN
(CONT'D) interconnected. When we brought up fuel cell number 1, we interconnected it between both main buses, and this configuration worked very fine.

YOUNG I guess this is a pet peeve of mine, but this is kind of dangerous, the IMU power switch down there in the LEB being right next to the optics power switch.

STAFFORD Should have a guard over it.

YOUNG Should have a guard over it to prevent inadvertent switching. That whole LEB area is real dark. What you end up doing is you turn up all the lights in there, and you look at that switch very carefully before you turn it off. You can take the guard off the S-IVB IMU CMC switch and put it down there where it belongs.

STAFFORD Put it down there.

CERNAN You're right.

YOUNG If you ever had to do a S-IVB or a Saturn V takeover, and you have to raise the cotton-picking guard to get the switch to do it, you just bought yourself the 2 seconds that prevents you from making or not making it.

CERNAN Just prior to flight, it's a 5-minute job that the S-IVB IMU switch guard be removed.

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YOUNG We end up flying with the thing raised, the guard raised.

STAFFORD Well, we flew with it raised in case we had to throw the switch. Particularly in the MAX security when you'd switch over to the polynominal, or if you had a guidance diversion where you had to be on it real fast, the lighting, as John described, down in the lower equipment bay does make you think and look very close before you ever throw any switch there, because the optics switch is next to the IMU power switch.

YOUNG You ought to power down your optics just to keep them from being heated and running all the time. But you sure don't want to turn off the IMU inadvertently.

CERNAN We had nominal batteries. Battery C held just about 37 volts without a charge the whole mission; it was never used until reentry. We continually charged alternately battery A and battery B. They accepted the charge very well over 4-, 6-, and 8-hour periods. However, we never really saw 39-1/2 volts which is a criterion to terminate the charge. We got down as low as maybe a half an amp, more like about 3/4 amp, and we charged the batteries really on a basis of time or whether we were going in a sleep period. On a recommendation of the ground, we terminated the periodic charges. All the DC

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monitor groups - AC monitor groups, all worked very well.

It was very evident, just like the simulator, you can tell exactly when the gimbal motors are coming on, and a positive indication through the H_2 and O_2 flow indications on the fuel cells and through the ammeter position on the monitor group. You can see those gimbals not only come on, but you can see them move.

The inverters work beautifully. We never had to go to the third inverter. Main bus ties worked beautifully; you can, of course, monitor through your DC voltmeter whether you really had the battery buses tied to the main buses. That was done everytime we turned the main bus ties on, and we got a verification of that before we started the gimbal motors.

Non-essential bus switch, no problems, not even used. G&N power switch was just left alone. Cryogenics system worked real fine. It appeared to me that the O_2 heaters, AUTO heaters, kept the O_2 tank pressures down around the bottom of the nominally green area. We very seldom saw medium to high pressures in the O_2 tanks. They were always on the bottom side. We never got any caution and warning lights on those two particular tanks. We did get a cryo caution warning light about 2 or 3 times on low hydrogen pressure either in tank 1 or tank 2. The heater cycles were effectively set up

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prior to sleep periods, on ground recommendations as to whether they be AUTO, OFF, or ON.

Towards the end of the mission, on the seventh day, one of our hydrogen AUTO heaters stuck in the ON position. Because of the continued temperature increase, we just played that from the OFF to the ON position without any trouble. It was on the seventh day of the flight. The fan switches worked real fine. The cryo's were circulated prior to sleep periods and prior to burns. We were in this two-fuel-cell condition around the Moon. We certainly wanted to conserve our power and our low-voltage capability. Instead of using the heaters for cryo pressures, we used the fans which we were told required a lot less power to operate. It was evident on our voltmeter that when we cycled the fan instead of the heater, instead of getting a half volt drop we barely could even see the fan come on. I think possibly the fuel cell anomalies are of different nature, although they resulted in roughly the same condition. The second fuel cell, if it had actually failed in a pump package area, would have resulted in the same condition as we had had on the first one.

14.6 ENVIRONMENTAL CONTROL SYSTEM

YOUNG

The environmental control system worked normally throughout the mission. We used the REPRESS package. It's not a

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rapid REPRESS package, for things such as LM REPRESS.

The major discrepancy we had in the environmental control system was the clogging of the LM tunnel-vent system. We couldn't vent the LM tunnel vent.

The regulator valves worked okay. Emergency cabin regulator worked okay. The cabin atmosphere, in general, was noted to be very comfortable. Humidity collecting in sufficient amounts to probably cause problems were noted during two SPS burns, TEI and LOI. After we got rid of the lunar module, we had water condense on the hatch. And it was noted that up near the hatch seal ring that water turned to ice. It was 20 degrees cooler in the tunnel on the return trip, at least 20 degrees cooler. It was recommended that part of the presleep and postsleep checklist include wiping down the tunnel hatch during transfer of clothes, and that prior to any burns the tunnel hatch be wiped down, and prior to reentry that the tunnel hatch be wiped down to prevent accumulation of water on the center seat crewman.

There were numerous floating particles. The inflow valve had to be repeatedly cleaned due to the fiberglass insulation floating around the cockpit. The inflow valve and also the little screens that we put over the exhaust hoses. The intake hoses on the environmental control system hoses had to be cleaned.

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CERNAN Odors. The odor scrubbing of the cabin was satisfactory.

STAFFORD Satisfactory.

YOUNG It was noticed in the first part of the mission that towards the end of the canister operation, I seemed to notice a more objectionable odor. Then we changed our canister and it cleared right up. I didn't notice it during the last part of the mission.

Inducement to cough. There was some coughing involved because of the fiberglass. It was irritating to the skin and some eye irritation, particularly to the LMP and the CDR.

Cabin circulation was adequate. The hoses where unsuited placed around the spacecraft and - and on the transearth coast - they were taped together, pointing in opposite directions. The exhaust hose was pointing one direction and the - the intake hose was pointing in another direction. It provided adequate circulation, and kept the cabin well scrubbed.

Cabin fans were not used. They served no useful purpose on this mission.

Water supply tank. The water potable tank service was full of bubbly water. The potable tank inlet valve was open, the water was still bubbly. The chlorine injection was nominal in every respect.

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STAFFORD Except the first direction. We questioned putting chlorine in the tank and not having the valve open. We were directed, on the advice of the medical group, to inject another ampule of chlorine.

YOUNG By putting in another ampule of chlorine, and we were told to keep the potable tank inlet valve closed, and as a result we ended up with a line full of chlorine, which made it very objectionable to drink and caused a great deal of discomfort to the crewmen.

Food preparation - a complete fiasco.

CERNAN Towards the end of the seventh day the water gun apparently put out drinking water at an extremely reduced pressure for a period of a couple of hours. Then, after more water was taken out of the system, the pressure came back up to normal.

YOUNG No explanation for that.

CERNAN There were no kinks in the hoses or anything. It was all investigated. The valve was on. It just was reduced pressure water, and then after more water was taken out, it returned to normal.

YOUNG Food preparation was normal.

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CERNAN

The whole water glycol system performed as it was built to perform. The pressures were nominal, the temperatures were nominal. The radiators were nominal, everything performed just as expected.

YOUNG

The same can be said of the suit circuit. There were several cases where O₂ FLOW HIGH lights occurred due to several reasons. The main one was I was either in a suit with the inflow valve closed or the fiberglass insulation had clogged up the inflow valve, which resulted in O₂ FLOW HIGH. But, both the reasons for these O₂ FLOW HIGH lights were very apparent, the decision was made to press on and ignore them. In every case, where we found out what the problem was, things returned to normal.

We had an O₂ FLOW HIGH light when we first started the mission. Remember that? For a long period of time. I think it was due to the fact that we were recharging the REPRESS package in the ECS package. It seems like it just sort of went away. When we closed the vent valve at 8 hours we never did see it after that, much.

The gaging system was nominal. The waste management system, the fecal disposal system, the roll-on cuffs, the fecal disposal system is a complete mess. But what can you say about it? It operates just the way we thought it would operate. I don't know how you can make it operate any better.

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CERNAN It's a poor system but there's nothing in front of us.

14.7 TELECOMMUNICATIONS

CERNAN Telecommunications was nominal. Individual audio center controls operated properly. The VHF was poor compared to the S-band. We really operated on S-band effectively for the whole mission.

YOUNG Explain the anomaly about the VHF.

CERNAN It might have been the antenna pattern, it might have been corona, it's hard to say what it was when we were operating with the IM on VHF. But other than that, the VHF performed nominally. Apparently the recovery beacon was heard - was tracked. Operation of the S-band high gain antenna - the antenna operated very well, including in the REACQ mode which we used quite a bit going to and from and in the lunar orbit. Beam width switch, actually you could acquire very readily in the medium beam width position. You get AUTO block, and then to peak up the signal strength a tad, you could go to narrow band. But actually you could operate on medium beam width most of the time if you really had to. We just went to narrow, peaked up the signal in the AUTO track, and held it. Could not hear or feel the CDS band antenna bang around. We used the CMC DSKY to obtain antenna-pointing angles much of

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the time, and they worked out perfectly. We got the rest of the angles from the ground when we maneuvered to a particular position to get TV TRIACQ, or burn attitude, or what-have-you. S-band TV apparently worked well. The DSE tape apparently did not fail and worked throughout the flight. No comments on the ranging, oscillator, power amplifier, etc. Everything we needed worked as prescribed. Tape recorder, power switches, everything worked right. The voice-recorder indicator worked right to the best of our knowledge, because we saw it gray a good period of the time, especially on the back side of the Moon. Tape recorder switching for the most part was done by the ground. OMNI/HIGH GAIN switching was done for the most part via the ground. The PTT switches worked.

YOUNG

When you guys were in the LM, I played with the VHF squelch all the way off. No squelch, and we had ranges out to about 300 miles except when you were pointed the other way. I'm sure that was an antenna pattern problem.

CERNAN

That probably an antenna pattern problem from the LM, because I really didn't do much with the VHF antenna switching.

YOUNG

Yes.

CERNAN

The VOX circuitry was used very limitedly. When it was used, during some of the TV commentaries, it worked.

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YOUNG Yes.

CERNAN COMM worked as prescribed.

YOUNG The S-band COMM is the greatest thing going. It sounds like you're sitting right there on the ground with somebody, when you're around the Moon.

CERNAN The only problem at lunar distances that we ran into is due to the time delay between the CAP COMM and the spacecraft, you tend to cut each other out and interrupt each other.

STAFFORD We ought to adhere to the discipline that you end every transmission with over.

YOUNG We ran the entire mission, once we found out things were all right, with the S-band squelch ENABLE. You still know when you lose COMM, you hear the crackling in your earphones. It's quite evident when you go around the hill - around the Moon - it's gone. I see no reason for ever having that switch in other than ENABLE position. It keeps all the noise out of your earphones, and it doesn't degrade COMM in any manner that we can see.

14.8 MECHANICAL

YOUNG The tunnel, the drogue, the probe, the lighting operated nominally with the exception as previously noted. Three,

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four and 10 were one-shot cock latches. Latch number one had to use auxiliary override to cock it. The probe and drogue operated as per checklist.

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15.0 LUNAR MODULE SYSTEMS OPERATIONS

15.1 GUIDANCE AND NAVIGATION

15.1.1 PGNCS

CERNAN The IMU - was powered up - was aligned in the docked configuration. It performed as expected. We saw very little drift between it and the AGS for 30 - 40 - 60 minutes after AGS update.

STAFFORD There were no anomalies there at all on the PGNCS.

CERNAN We saw differences in time delays on VERB 82's and VERB 83's particularly. At some times VERB 83 would take forever to come up, like 3 minutes and maybe even 4 minutes.

STAFFORD Sometimes it would come up in 35 seconds - the minimum time. Other times it was in excess of 4 minutes.

CERNAN At times it was too long and we needed the computer back more than we needed the VERB 83 information. We'd put in a VERB 96, stop integration, and proceed on with the use of the computer, which worked perfectly fine.

STAFFORD This was also noted in the command module.

YOUNG That's right.

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STAFFORD The same thing in the command module, it appeared that VERB 83 required longer than VERB 82. VERB 82 had some delays, but VERB 83 was definitely longer than VERB 82.

CERNAN Okay, in the optical subsystem there were anomalies, and we got good alignments out of it. There are a few small things that need be mentioned. The AOT was within the reticle area of the AOT, and there were 3 or 4 hairs in there. There were no cracks of any sort. They looked like hairs that were within the field of view. They were not close enough to the center to make any difference or bother any of the alignments. The center of the AOT, particularly in a plus Y direction was an area that transmitted - probably about 30 or 40 percent of the light that the rest of the AOT transmitted. This made it very difficult to align and mark on stars close to the center of the reticle. The star brightness would dim very slowly. There were certain positions within a radius of 5 or 6 star diameters around the center of the crosshairs in which the star would actually disappear entirely. This was a little bit aggravating, because this was a problem we had in the simulator, which was not supposedly a problem in the spacecraft. On the minus Y and the bottom side of the reticle, this was not so pronounced. However, it was throughout the directional area, right around the center of

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the crosshairs. The dimmer control worked electrically okay, but mechanically, you could dim it from no reticle at all to a very, very dim condition, and then the rheostat or the thumbwheel would rotate forward as if it were out. There was an over-center spring which would cause it to go to a very bright position; and then, it went from very bright to extremely bright. So you almost had to accept it in a very dim position to mark on stars or physically hold it with your hand in that mechanical dynamic area where it wouldn't want to stay. The latter was very difficult when you needed that particular hand and those fingers actually to do the marking. The field of view was adequate. I mentioned the light transmittance in that central area. Other than that, it was very good. There were other problems. The interface with the computer was excellent. The alignments came out very well, based on our third star check. We put the star right smack in the center of the reticle within a limit of the DAP deadband we had in. I guess that brings us to rendezvous radar.

STAFFORD

The rendezvous radar test that we performed was nominal - just as prescribed. The radar worked exactly as prescribed, and as in the simulator. We could track the side lobe patterns, and we never had difficulty locking onto a side

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STAFFORD lobe. We locked on out to MAX range, and had it for a period of time. And over to the command module maneuver to an attitude for a backup burn, and due to the transponder pattern, we slowly lost lock. However, the total correlation between voltage of AGC versus range was as the preflight data predicted, and very helpful. Under landing radar, the landing radar self-test went exactly as prescribed. The landing radar was turned on earlier than prescribed in the flight plan. The attitude approach was for a local horizontal of plus 10 degrees, and as soon as we went to the attitude, we had an indication right away that the landing radar had locked on to the surface.

CERNAN The LGC self-test was done pre-separation. It passed with flying colors. Everything was nominal, just as the checklist predicted. The LGC worked well in every program, every prethrust and thrust program we used. The alignment programs worked well. We had no unexplainable master alarms that I can recall. The control of the vehicle was as prescribed. All of our ground updates required that we go into update link. Then go into POO, which we did every time. We kept all the flagwords set, and had no problem with update link through the S-band. We had no restarts, and I can say that the computer worked exactly as we had hoped it would.

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STAFFORD The FDAI worked as prescribed. The only display which was not G&N was a rate gyro display, and the calibration of the FDAI, not being completely zeroed, a part of it comes under the rate gyros, which were not associated with the G&N. It has been discussed before that the G&N and all the displays were good.

CERNAN Procedural data. We found out that the DSKY works very well with the Commander's right hand, and the LMP's left hand. And that's the way we used it, we passed it back and forth to each other. There were no problems in its coordination. And, I guess that this takes us to the AGS.

15.1.2 AGS

AGS alignments were made frequently throughout the flight predictedly the way they were called for in the LM rendezvous flight plan sequence. Updating in the AGS occurred just as we had planned it, and there was only one time where the AGS was attempted to be initialized with the high bit rate switch in HIGH, and, lo and behold, it didn't initialize. Otherwise the state vector was initialized properly. There was only one anomaly in the update alignment sequence, and that was prior to undocking when the AGS were aligned to the PGNS. VERB 83 was checked against range, range rate, and thete. Theta was found to be in disagreement with the

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PGNCS and the AGS by as much as 30 degrees. The sequence of update and alignment was made three separate times prior to undocking, and the 30-degree bias between the two in theta was seen every time. After we separated, the AGS was looked at again, and I don't really recall whether this was before or after the next update, after separation. From then on, VERB 83 theta, range, and range rate, and the AGS range, range rate, and theta all agreed very, very closely. For the AGS calibration the initial numbers were recorded, but due to the roll thruster limitations of the command module, and because of the pressurized tunnel, we were not able to hold the proper angles in minimum deadband required to do the AGS calibrations. So no accelerometer or gyro calibration was completed.

There were no radar updates to put into the LM for CSI and CDH; because of the radar filter problem, there were no radar inputs put into the AGS for TPI because of the time element involved. This was all preplanned. There was no deviation from the preflight checklist or preflight rendezvous procedures. However, the AGS computations at TPI based upon the state vector obtained from the LGC was within 0.2 of a foot per second agreement in total velocity required. It was within 10 to 20 seconds agreement on the time for execution at TPI based upon the same theta of 26.6 degrees. From the

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CERNAN
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standpoint of the AGS, time held the whole time. It never varied. Address 407, which freezes the reference frame, which in Earth orbit on LM 3 continued to be recycled to the 10 thousand - through small accelerations - was monitored prior to every burn. It stayed at zero as expected in lunar orbit. The keyboard and the displays worked better than the simulator as far as being able to push buttons easily and get your readout. Powerup was nominal, and as far as I am concerned, the AGS monitored every burn. I really believe that every big engine burn could have been done on the AGS with residuals being small enough to complete a very nominal rendezvous.

STAFFORD

The AGS as a control system performed per specification. When the descent stage was attached for certain attitude maneuvers I would use AGS and pulse. However, once staging occurred, I only used PGNCS and pulse. AGS and pulse had too much authority for the lightweight vehicle. The AGS attitude-hold mode performed satisfactorily for both the staged and unstaged vehicle. We did use AGS for the computer function for radar acquisition and that worked out very well.

CERNAN

Yes, address 400 plus 20 000 for target acquisition, and 400 plus 10 000 for burn attitudes, agreed very closely with the PGNCS. They were used particularly for manual target

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(CONT'D)

acquisition while the PGNS was being reprogrammed, not reprogrammed, but recalled for P20.

STAFFORD

The staging anomaly in which the parallax in the viewing of the switch position has been previously described (when I switched to the mode). But in pulse, I'd switched to the mode control position and the vehicle started dynamics after staging was initiated; then, with the light vehicle, it started off at that time. I rechecked a series of switch positions real fast, and then it went to DIRECT to damp the rates and start to maneuver around to the insertion attitude. The AGS ATTITUDE HOLD mode was used for the CDH burn to accomplish a detailed test objective and is a very tight control mode and performs satisfactorily.

15.2 PROPULSION SYSTEM

15.2.1 Descent

The descent engine burn was made in a satisfactory manner. For the first DOI burn the ullage came on as initiated by the PGNS, the engine throttle lit up; however, the thrust chamber pressure appeared to be more than 10 percent, I'd estimate approximately 15 percent. Then I throttled up rapidly to 40 percent for the profile of DOI, and there was no rough combustion or chugging in the engine at all. The shutdown

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STAFFORD
(CONT'D)

occurred right on time and the residuals were noted in the flight plan data. During the DOI burn, guidance was absolutely nominal with no deviations at all.

CERNAN

The engine could not be seen nor could it be heard.

STAFFORD

We could feel the acceleration.

CERNAN

The feel of acceleration and watching the computer.

STAFFORD

During the phasing burn, the ullage was started again by the computer; the engine ignited to exactly 10 percent and continued on. A few seconds after ignition, the descent propellant quantity light came on followed by the master caution light simultaneously. This was immediately pushed out, and the burn was guided very straight. This was followed by the DECA gimbal light coming on. I rechecked it rapidly, and the attitude error needles and the rates were zero for all purposes. There were no attitude error deviations, so the engine gimbal enable switch was not placed off as had been previously briefed as a procedure.

CERNAN

The descent quantity light apparently went out then and it came on again.

STAFFORD

After the computer throttled the engine up to 100 percent after 26 seconds of thrust, the descent propellant g quantity

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(CONT'D)

light came on again with an accompanied master caution light which was pushed. At that time, the engine shut down, and the residuals were very nominal.

15.2.2 Ascent

Under the ascent engine. The ascent engine insertion burn was made with the PGNCs. The ullage was started by the computer. Right ignition, the engine instantaneously came to thrust, and the acceleration was obvious. During the burn, you could hear thrusters firing, and the engine had both yaw and pitch. The vehicle had yaw and pitch oscillations that we had expected from reviewing the data from the LM 3 ascent burn to depletion. Again, it was a different type of operation than we experienced before in any of our burns. However, we anticipated that this would occur. We had the restraint harness locked, and the type of oscillation was similar to a dutch roll in an aircraft. I estimate that we would occasionally reach up to 5 deg/sec in pitch and yaw rate.

CERNAN

It was a definite discernible wallow.

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STAFFORD It was a wallow, and we could see the attitude error needles varying. At shutdown, the guidance was perfect and the residuals were nominal.

YOUNG Did the simulator do it like that?

STAFFORD No.

YOUNG No?

STAFFORD At least what we had seen on the simulator was just a straight variation, but there was no attitude error needle variation like we experienced in the burn. Again, this should be programmed in the simulator; so when the crew makes an ascent engine burn, they can expect to see the attitude error needles vary as the vehicle goes to the pitch and yaw maneuvers.

CERNAN We had no caution or warning lights associated with this burn at all. Both computers counted down, and the burn was really a very nominal burn.

Instrumentation. Other than the descent quantity light, gaging, displays, cautions, and warnings were all nominal -- nothing new or unexpected from the ones already mentioned.

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15.3 REACTION CONTROL SYSTEM

CERNAN

The reaction control system performed nominally in all respects. Worth mentioning is the fact that the 100-pound thrusters on the thin hollow shell of the LM are not only noticeable but are extremely noisy and clangy. If you put a wash tub on your head and someone banged it with a rubber mallet, that's the way the thrusters sounded. If you looked out the window, you could see the thrusters fire with a long orange plume. Concerning control motor response, the PGNCs, with a light vehicle ascent stage only, is about three or four times the authority you need for such things as Z-axis tracking, P20, and P52 rendezvous. One pulse would send you in one direction, and another pulse would reverse the direction, and no stop in between. I'd say about three or four times the authority that you really needed.

All the other phases of the other phases of the system, including the translation control and all the subsystems associated with it — the pressurization, the gaging, the probe warning, and everything else — went as per activation checkout operations.

During part of the cold fire PGNCs checkout, we did not get the DSKY numbers we expected to see with the rotational hand

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CERNAN
(CONT'D)

controller. These numbers were seen in real time by the ground. We were given a GO on a basis of the numbers that were read out, although they were not the numbers we had seen continually in the simulator.

15.4 ELECTRICAL POWER SYSTEM

CERNAN

I can't speak too highly for the electrical power system. The batteries were up to full charge when we got in. All the ascent/descent checkouts performed well. We started out with the buses somewhere around 30 or 31 volts. We got down to about 27 volts on the low taps, switched to high taps, and stayed well into the 29- to 30-volt region the whole flight. The ascent batteries were brought on as per checklist to warm it up. They took the load at staging without any problem at all. The monitor systems for the ascent/descent pyros, ammeter/voltmeter all worked well. All the status flags worked. We had not one electrical or EPS subsystem malfunction or anomaly in the LM that I can recall. Explosive devices, all the pressurizations, deployments of landing gear, staging, and every vital function that was called for worked. We checked out each system individually by deploying the landing gear on one system and pressurizing the DPS on another. Apparently, we got a clean separation of the ascent and descent

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(CONT'D)

stages as seen by photography and by the Command Module Pilot. We had a good landing gear lock as seen again through photography and by verification by the Command Module Pilot. We had a good power system.

The lighting in the LM was much better than I expected it to be because, for the first time, we had within the LM natural light which we never have in a simulator. In the simulator, we're in darkness all the time in effect, and the lighting is generally not very good; but a lot of our operation, 60 percent of the operation around the moon in the LM, is done in daylight and the lighting is excellent. At night time, we had adequate lighting. I had really no complaints at all about the lighting — the integral lighting or the flood-lighting — for nighttime operation. I saw absolutely no reflection, daytime or nighttime, in the window that bothered me at any time. There was some reflection in the camera during the taking of pictures, but very little. I was very much amazed that we did not get a great deal of reflection, but there was none at all noticeable.

Exterior light - we never really used our docking light. Our docking target was extremely visible to the Command Module Pilot.

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15-15

YOUNG How about the one on the CSM. Did you see that?

STAFFORD It was bright.

YOUNG I didn't have it turned on. I forgot to turn it on. I had it all hooked up and forgot to turn it on.

CERNAN Once we turned the flashing light on the LM, we never turned it off because, after the first P52, I found that there was no interference and no flashing light could be seen in the AOT. For the benefit of the Command Module Pilot tracking, we left it on through all our P52's.

No problem with alignments. At night time, we could not even see it flash through the window. We didn't know whether it was on except by verification from the Command Module Pilot.

YOUNG It was visible in excess of 300 miles; that great.

15.5 ENVIRONMENTAL CONTROL SYSTEM

15.1.1 Oxygen and Cabin Pressure

CERNAN Oxygen supplies, transducers, and regulators all were operating normally. We were in and out of helmets and gloves. Most of the time we were in helmets and gloves for the major burns, for docking and undocking, and for staging. The cabin held the seal very well. We could not discern any leak rate. We

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did a normal switchover at staging for the ascent oxygen and water systems. Everything worked just as expected.

15.5.2 Cabin Atmosphere

CERNAN

Cabin atmosphere was adequate, other than the fact that during the whole day a great deal of the insulation was blowing in there from the command module hatch from the previous day. This seemed to settle out pretty much. After our first descent engine burn, we didn't see too much of it.

STAFFORD

I was coughing and wheezing a little bit when I first got in there, and I'd take some water and wash it down. But no problem after that. I think it all did settle down pretty much after that first descent burn.

CERNAN

Okay. The cabin atmosphere circulation was adequate. We had the cabin fan on for a period of about 30 minute. We both agreed that it didn't do anything for our comfort as far as cooling was concerned. The noise level, although not extremely high or extremely objectionable, was there without producing any significant circulation or cooling; so we turned the fan back off and operated probably 90 percent of the LM mission with both cabin fans off.

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15-17

CERNAN
(CONT'D)

The LM was comfortably acceptable. We didn't really do a great deal of moving around. We certainly were not cool or cold. Everything was set on a MAX cool condition configuration. It was adequate and I guess we weren't really hot and weren't really cold. We weren't even really cool, but it was acceptable. The humidity apparently was very much under control. We had noticed no carbon dioxide in the atmosphere that we could detect. The indicator was well below the caution area for carbon dioxide level. However, the ground says that they had detected an increase in carbon dioxide in the cabin, so we brought the canister back for analysis.

YOUNG I understand it was up to 6-1/2 or so.

CERNAN We never saw that in the cabin.

STAFFORD But they requested we bring the canister back. The canister was brought back and is being analyzed.

YOUNG I guess it's that Mylar insulation.

STAFFORD Probably reduced the flow of air.

CERNAN Noise of the cabin fans was the majority of the noise in the LM. Also, a great deal of noise comes externally from the

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CERNAN
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thrusters. As LM 3 reported, when you reposition the repress valve, it's a horrendous bang that can be heard all the way up in the command module. We anticipated this and tried to warn each other when we were going to move this valve. This was very infrequent. The noise level without cabin fans in the LM is produced wholly and solely by the glycol pumps. We ran only one primary pump at a time. The pump winds up and screams as if the bearings are going to go out any minute. It's not an extremely high-pitch scream; it is a very loud solid-volume scream, like that of a wheel that needs a great deal of oil. That's the one noise producer in the LM. The Commander wore the fitted earplugs with the Snoopy helmet, and this significantly reduced the volume requirements on his audio panel. The LM pilot did not wear the ear pieces with his Snoopy helmet. Had adequate COMM and was in a nominal 6 to 7 position on most volume controls. He had the capability of going higher. The volume was certainly adequate to hear everything that was going on. When you sleep on the right-hand side of the command module, the pump noise get lost in the environment. When you're sleeping on the left-hand side, it's right there. We had no caution and warnings on the panels.

YOUNG

Tom is probably deaf in that frequency range.

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15.5.2 Cabin Atmospheres

CERNAN On the cabin atmosphere systems, there are no further problems. Once we got rid of most of the insulation from the hatch, there was little or no irritation.

15.5.3 Water Supply

CERNAN When we went into the LM on the first evening before the rendezvous, the LM water had definite volumes of gas in it. This gas was found to sustain itself throughout the whole rendezvous day. There were less bubbles when we left the LM than when we arrived. The gas was still in the water. The water tasted fine, but it was gassy. There is nothing further on the water because everything else worked great. We didn't use any of the waste management systems.

15.5.4 Water Glycol

CERNAN When we first activated the water glycol, we did so without activating the primary EVAP flow 1. This was done according to the checklist as planned. The water glycol temperature at the point in the checklist where we activated the EVAP flow was up around 80 or 90 degrees. The glycol temperature light was ON. There was no problem. The only thing I'm commenting on is that it took about 10 or 15 minutes for the temperature to stabilize at its peak, even after it went into EVAP flow.

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It takes another 20 or 30 minutes to get down below a caution and warning range where the glycol temperature went out. It is not an immediate process when you start pumping water through that water boiler. It's a slow, thermal, inertia process before you get down within the normal range of the glycol temperature. I guess I mentioned the pumps and their noise. Both primary pumps and secondary pumps were all checked out. Pressures were nominal. The whole system was checked out as per activation checkout list and flight plan. The AUTO transfer circuit worked during the checkout. It was not used during the flight. Here's another system that performed just as we had hoped it would.

YOUNG

The glycol pump in the command module was noisy. Tom could sleep by it, but it kept me awake. I don't know if that's a thing to gripe about, but it really bugged me.

STAFFORD

I think this is a real problem in an individual's sleep habits.

YOUNG

When I went over to the other side, I didn't have any trouble.

CERNAN

From the LMP's point of view (he slept on both sides), I've got to agree with John. I could sleep a lot better on the right-hand side. When I slept on the left-hand side, I felt that the pump was running right behind that bulkhead.

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15.5.5 Suit Circuit

CERNAN Suit circuit, circulation, and flow was what we expected it to be. We had a low flow rate. We have already commented on the temperature and comfort. The noise level certainly increased when you put your helmet on. You had a lot of air flowing through the helmet. At one time, the LM Pilot tried to get a little bit more cooling on his face. After I put my helmet on, I went to the EV position on my suit diverter valve. Although it was cooler, the noise level was so high that I felt that it was not worth trying to operate it in that condition.

STAFFORD I tried that one time, too, and I had a high noise level.

CERNAN The rest of the information is in 5.0.

STAFFORD The water accumulators worked as prescribed. The suit loop did not feel moist at all. We will comment again on our analysis that we weren't warm, but we were just at the lower edge of the comfort level. This has been remedied on LM 5 and subsequent spacecraft.

CERNAN The suit flow valve did not reposition at any time other than when we did it ourselves manually to connect or disconnect from the hoses. The cabin gas return valve worked.

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15.6 TELECOMMUNICATIONS

15.6.1 Monitoring

CERNAN We solved the anomaly which we already talked about on VHF-VHF A simplex and eventually VHF A duplex ranging mode. We solved that anomaly with the CSM after undocking. VHF communications were basically pretty good. There were times when we lost contact, but I think that was probably because of antenna switching problems. I believe the volume level and the level of clarity were fairly good.

YOUNG The VHF sounded loud and clear in the command module from the LM except during two periods of time. One time was just prior to phasing for about 10 or 15 minutes while you were down low in the phasing attitude. I think it was an antenna problem. The other time was prior to the insertion burn when the command module was pointed in the opposite direction from the lunar module. I think that was an antenna problem also. There was no way to get around it. The one objectionable thing about the COMM was the repeating of your own voice transmission. That was probably on S-band because of some relay setup.

CERNAN From the LM point of view — on the VHF — we operated in VHF ranging after the DOI burn throughout the completion of the

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CERNAN
(CONT'D)

rendezvous. There were times when VHF ranging was lost because of attitudes and burn constraints. This VHF ranging on LM 4 puts the two LM Pilots in a hot mike mode of operations which was apparently not objectionable to the Command Module Pilot. It also turned out that when we went to reacquire VHF ranging — as long as we did not say any words — we were in a hot mike operation. The Command Module Pilot was listening to the background noise of the LM, but it did not interfere with VHF lockon. We had good VHF lockon every time we attempted to go to that mode. Every time we did reacquire VHF lockon, the LM could hear a low-frequency buzz for a period of about 5 or 10 seconds. This buzz occurred at the beginning of the lockon, during lockon, or at the end of it. We could hear this buzz and knew the lockon procedure was going on. We didn't talk during that time.

YOUNG

We had two or three cases where the thing was reading half range. It was obvious, because we couldn't have closed to half range. We had a couple of cases where it didn't lockon at long ranges. When it was reading zero, we lost communications with each other. Those are the obvious cases. Readings at close ranges were like 0.07, 0.06, then it would jump 0.07, 0.06, 0.05, back to 0.06, 0.07, 0.05. It was sort of shaky

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YOUNG
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when you got close in, but out far that thing was riveted in there just like EMS.

STAFFORD

We correlated the VHF ranging with the raw rendezvous data to the computer. The correlation was there, and it was usually within 60 to 120 feet.

15.6.2 S-Band High-Gain Antenna

CERNAN

Clarity of voice transmission coming and going on the S-band high-gain was excellent. On the OMNI, it was good, too. When operating in an OMNI mode, we couldn't get the circuit margins that were required. We had to go to the down-voice backup BIOMED switch which gave us hot S-band COMM to the ground. Since we had been switching between high-gain, we wanted to maintain high-gain any time we could acquire it and the OMNI antennas. We had to go to OMNI every time we made any attitude excursion that might lose high-gain track to save the antenna from banging into its stops. We went to OMNI during P52's and during attitudes which were burn attitudes that would not allow us to maintain S-band track. We frequently went from the hot mike condition to the push-to-talk position. We did this so frequently that much of the time we weren't sure which one we were in. All we were sure of is

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CERNAN
(CONT'D)

that we had COMM. That OMNI mode worked, voice-wise, probably too well.

STAFFORD

Many times when we thought we had our intercommunications turned OFF, we would be in a hot mike situation, and it wasn't obvious to the crew. You can't ascertain this. Let me bring this out. We weren't briefed on this mode of operation until the week before flight. We had not practiced like this at all in the simulator. By then, all of our simulation was over.

CERNAN

We didn't know until the last week prior to flight that this downvoice backup mode would give us a hot mike S-band. We did not know that the VHF ranging mode would give us a hot mike in VHF. Those two things were known facts long before that last week before the flight.

STAFFORD

It wasn't amplified as such in the AOH. It wasn't simulated that way in the simulator or with the integrated simulations with the command module and mission control. We had one run just with John, but the simulator wasn't set up in the operational mode like the spacecraft.

CERNAN

I was probably the greatest preflight skeptic of the S-band high-gain antenna. During postflight, I will eat crow and be the greatest praiser of it. The S-band antenna locked on when

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(CONT'D)

you got it anywhere within reasonable angles, and it locked on very readily. The signal strength came up slow, but positive. You could manually tune it from low signal strength levels to high signal strength levels. It would take AUTO track anywhere above 34 to 36. You could go from slew to AUTO track, and it would AUTO track itself right into a MAX signal strength of about 4.2 on the meter. This operation was really fine. One anomaly we saw in the altitude chamber is that when the S-band antenna moves, it sounds like the bearings are grinding. It just grinds and grinds and grinds. I was a little bit surprised because subsequent tests in the altitude runs on IM 4 didn't have this noise. They said there would be no noise. However, there was a lot of noise.

STAFFORD You could hear it during the initial activation and checkout in the command module. You could hear it grinding away. The vibration would shake the total stack.

YOUNG That's right. It set up the maximum resonance frequency with the total stack.

CERNAN Prior to any anticipated high-gain loss — to be sure that the S-band antenna would not track in the stops (which meant prior to LOS, prior to P52's, and prior to any special attitudes) —

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CERNAN
(CONT'D)

we took the S-band antenna and slew it to a pitch of 90 degrees and a yaw of zero degrees. This was basically a neutral position. Then we went to the OMNI condition for the remainder of COMM during that period of the flight. There was a time or two when we forgot to do this. When that happened, it did bang into the stops. When it banged into the stops, it blew the B-band antenna circuit breaker, and you immediately lost any S-band movement with the high gain. You lost the meter and the capability to slew it. This happened two, maybe three times. The circuit breaker was reset. We immediately regained slew control, and the antenna worked nominally the rest of the time. Hitting the stops apparently did not hurt it. It did pop the circuit breaker everytime it hit the gimbal stop. The final item on the S-band is that on the right before rendezvous we did our S-band DTO's and got excellent results. In most cases, these results are obviously more readily attainable on a basis of what MSFN was able to determine about their TM capabilities as well as voice. We checked out VOX, PTT, and ICS PTT during these DTO's. They all worked. The anomalies of the COMM system were such that in some areas where signal strength was expected to be higher it was not as good as was expected. In some areas where they expected to get little or no signal strength (such as the FM modes), the signal strength

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(CONT'D)

and the voice were excellent. I believe there are some modes we could have operated in on this flight — some OMNI antenna modes — that would have eliminated the hot S-band mike to the ground; but that's water over the dam at this point. Another item in COMM is on the night the DTO's were being checked out, we initially did not get voice transmission from the spacecraft to the ground. That was because the down-voice backup switch is a three-position switch. In this spacecraft, it happened to be a very stiff switch. When the LM Pilot thought it was in the down-voice backup, it's physical position was off for the first segment of the DTO test procedures.

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16.0 MISCELLANEOUS SYSTEMS, FLIGHT EQUIPMENT, AND GFE

16.1 CABIN LIGHTING SYSTEMS AND CONTROLS

CERNAN LM cabin lighting was a lot better than either one of us expected, mainly because when you are operating in daytime you've got more than adequate light. When we were operating in the night nighttime, the integral and the flood lights were more than adequate — far better than we've ever seen in the simulator. The one thing that impressed us both, which was thought to be a pretty big problem in the LM both in daytime and nighttime operations, was reflections off the window against the white suit. I don't think I ever recall in real time seeing reflections — certainly none that bothered me. Of course, a lot of my work was inside the cabin. The only time we saw any reflection is what is recorded on the 16-mm camera. Other than that, lighting and controls were in good shape.

16.3 EVENT TIMERS AND CONTROLS

YOUNG The LM event timers worked very well. We never had one bit of problem with them. On two different occasions, the CM digital event timer was set accurately and changed time. In

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(CONT'D)

one case, it incremented several minutes, unknown to the crew; and in the other case, it incremented in terms of 10 seconds. The event timer in the command module is difficult to set up. It has four switches. It is not reliable. It should be able to count down to a time and then start counting up like the digital event timer in Gemini. In other words, count down to zero and then start counting up in terms of minutes. It will not do this. As far as I am concerned, the digital event timer in the command module is a tremendous step backward. We had a much better digital event timer in Gemini.

CERNAN

It is visible to only two crewmen which sometimes is a tremendous detriment. The third crewman should also have a handle on what that time countdown clock says.

YOUNG

That's right, and the digital event timer in the lower equipment bay is used frugally. It's practically worthless.

STAFFORD

The digital event timer on the lunar module worked satisfactorily. I always set the event timer up to the same switch motions as to the one in the command module.

YOUNG

The major deficiency with the digital event timer is you can't trust it. When you're counting down to a burn, you

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16-3

YOUNG
(CONT'D)

can't be strapped to something that is going to jump minutes and seconds on you particularly when you are not realizing it. You just can't trust it.

16.4 CREW COMPARTMENT CONFIGURATION

We've already made recommendations concerning the things that ought to be fixed such as the proper restraint of items in zero gravity, extensive use of bungees, and increasing the Velcro allowed for retention of equipment.

CERNAN

Because our work on this mission required continual operation and very little lax time, we did not have extra loose gear that we didn't know what to do with. We didn't really have to live in the LM; we had to operate in it which might be different from follow-on missions. As a result, temporary stowage was not really a problem. We used the clips on the sunshade and on the DSKY and DEDA panels for checklists. They appear to be adequate for all of our data, and there were no other real true compartment configuration problems. There were a lot of unstowed areas in LM-4 that are certainly going to be filled up for LM-5. But the way we had it stowed, moving the ISA around and restowing it for the ascent burn and depletion all worked out satisfactory.

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16.5 MIRRORS

CERNAN
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The mirror in the LM was really not planned to be used unless it had to be. As a result, we didn't unstow it. Mirrors in the command module are of marginal use. You don't really need them to look over your shoulder like you did in Gemini, however they are certainly good for other little household items like shaving.

YOUNG

There's one use for the mirror in the command module and that's when you have one man flying the command module by himself. If he can position a mirror properly while he is in the lower equipment bay, it merely takes a glance to see whether he has any spacecraft rates. I think that it is pretty important to be able to do that. Also he can set up the pitchdown rate for the landmark tracking when he is by himself, just by looking at the mirror. He doesn't have to go back and glance at the display. However, I recommend that when one man is operating by himself, he take the time to float back up there in zero gravity rather than depend on a backwards display.

16.6 CLOTHING

The best thing we can say about the PGA is take it off after launch and only wear it when you have to.

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STAFFORD The constant-wear garments appear satisfactory.

YOUNG We only had two changes of constant-wear garments, but that's enough. But the thing that is wrong with the constant-wear garment is if you have to make a head run while you are in a pressure suit, or don't have time to take your constant-wear garment off to go to the bathroom, the slit in the back is still not big enough. It wasn't big enough on Gemini 3, it's not big enough on Apollo 10, and probably won't be big enough on subsequent missions.

CERNAN I just had to rip mine.

YOUNG I ripped mine. Those of us who left the constant-wear garment on ended up ripping the back out of them.

CERNAN The LCG was put on in the command module the night before we planned on going into the LM to save time. It is a fairly slow job to change underwear, and the BIOMED transducers and leads, to effectively get a new set of undergarments on. Especially when it is the LCG that has been packed in a vacuum package.

The LCG was warm. I slept in it the night before we went into the LM for the rendezvous and it was comfortable. As a matter of fact, it was a little warmer than the constant

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(CONT'D)

wear garments. This made it comfortable because the command module is a little cool at times with the sun shades up. I wore it under my suit which was fitted for the LCG. It was a little tighter but comfortable.

I had no problems except the one that I have been trying to get fixed for 6 months. The tubes in the LCG go down to about two or three inches above the wrist. From there on down we've got about another 1-1/2 inches of loose nylon and loose lining material which does nothing but get caught between the suit and the gloves when you try to put the glove on. I asked that this be taken care of on my LCG before flight. It went down to the last week and finally there was paper work okayed to seam it up.

The garment should be cut off down below the tubes, hemmed properly and neatly — not folded under so that you've got loose material that's going to get caught in your gloves when you want to put your gloves on rapidly. We put our gloves on and took them off maybe 10 or 12 times in the LM. About half of those times I had liquid-cooled garment-lining material stuck in the mechanism.

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YOUNG The flight coveralls were terribly frayed before the mission was over. The booties were especially frayed. There were long strands coming out of the arms.

CERNAN The LM pilot had his two toes sticking out of one bootie.

STAFFORD Right.

YOUNG We need more pockets on the flight coveralls. Why don't we go back to regular flight suits?

STAFFORD We need zippers instead of the Velcro.

YOUNG That's right-the Velcro won't hold anything in there.

CERNAN The pockets are big, flexible, and loose and when you put something in the pocket and put that Velcro flap over it, it eventually starts floating out.

YOUNG That's right. As soon as you bump into anything and snag that pocket, out it comes. I must have lost tool E 25 times out of my Velcro pocket.

CERNAN We need pockets that were similar to the type you have on a regular flight suit - slash pocket with a zipper and a little arm pocket with a zipper so that you could put personal things

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(CONT'D)

in them. You could put chewing gum or your ear molds when you weren't using them, or other small little things that you need like every pilot does. You wouldn't lose these things. You wouldn't have to dig down in the bottom of your temporary stowage bag to find them. They always end up coming floating out in front of someone's face anyway. The utility of the present flight coveralls, pocket-wise, is far below average. All three of us feel very strongly about that.

YOUNG Yes, I think it's a useless garment.

CERNAN The two-piece is alright, but the pockets need to be more operational. We need just an average everyday flight suit with slash pockets and zippers.

YOUNG Yes, I think so, too. And I think a single-piece flight coverall garment would certainly be adequate. The only reason for having two pieces is for the biomedical gear, and you don't really need that. All you've got to do is cut a hole in the thing. I think all three of us used both kinds of COMM adapters. We found that the smaller GFE COMM adapter was more satisfactory.

STAFFORD Far more satisfactory.

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YOUNG It was less bulky. However, it's quite apparent that nobody's paid a darn bit of attention about how long to make these things. They certainly were not optimum. There was plenty of wire, but still, when you got all this thing put together, there was a lot of excess wire length down inside that gear. Instead of being a nice package, which it certainly could easily be, it was too long. I don't know who designed these things, but there was absolutely no attention paid to how long the cord ought to be that hooks the thing together. Instead of fitting flat across your chest, it wound itself all over your chest.

CERNAN There's a gross difference, though, on the size of those things.

YOUNG That's right.

CERNAN The government-furnished adapter is really pretty good when you compare it in size.

CERNAN Beta cloth. Most of the Beta cloth fraying we saw was in the flight coveralls. We had so many things being collected by the screens on the hoses, insulation debris from the hatch and what have you, that it was difficult to tell whether we were getting pure Beta cloth or not. We did have a great

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~~CONFIDENTIAL~~CERNAN
(CONT'D)

deal of fraying from those flight coveralls, and that could very easily be mixed up with Beta cloth fraying from some of the other material. I think Tom Stafford wore the Snoopy helmet the whole time, John Young wore the Snoopy helmet about 90 percent of the time, and Gene Cernan wore the Snoopy helmet about 50 percent of the time. Cernan didn't have anything against the Snoopy helmet. It was comfortable, it fit well, and I could hear well. After a period of time in flight, I felt like I wanted to take it off my head — let it feel a little freer. I wore the lightweight headset around the neck. When I wore it around my neck and adjusted it properly, the light weight headset was very comfortable. I didn't really have any problems with it. The COMM didn't really appear to be a problem, although much of the time, when you move around before you talk, you have to reposition the mike. I could fly that mission again with either one. Of course, I put the Snoopy helmet on for all the critical work and certainly for reentry. But for the transearth coast, I wore the light-weight headset. It's just a dealer's choice in my case.

STAFFORD I liked the Snoopy helmet real well and wore it the full time.

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YOUNG I thought the Snoopy helmets were great — once I finally got one fitted. This took the better part of two flights to get done, and it wasn't accomplished until about 3 weeks before we flew.

STAFFORD The urine collection device needs some improvement, but there was no constraint on the lunar landing mission.

YOUNG Boy, I'd sure like to design a relief tube. If they'd let us design one and try it, I bet we can use it just like a relief tube. We ought to be allowed to try it. I don't think it's necessary for the urine collection device that we've got to have a bladder.

STAFFORD We need a better throttling valve. I always went directly overboard, but the vacuum could grab ahold of you.

CERNAN I went directly overboard, but I always built up a little head of steam first. I never used the bladder.

YOUNG The procedure that we came up with was to put a small head of urine into the valve, turn the valve on (having evacuated the dump line), fill up the dump line, then open the dump valve. I never used the bag on the urine system, so I think it could be deleted.

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CERNAN That last procedure was modified just a little bit in many cases. I just built up a little head and opened the whole valve immediately. It went right overboard. There were only one or two crucial moments where I thought I wasn't going to get back out of that cuff.

YOUNG Even though it might appear to be a dangerous way to operate, it certainly didn't seem to present any problem. I don't think any device as big as that is required. I think we can use a properly designed small simple device like a relief tube.

Instead of allowing the contractor to design a monstrosity, we should come up with a small device and carry it along as an experiment. Try it out. I certainly hope that we can get away from the annoyance of this — the dribbles and the discomfort involved in urination. It takes too infernally long to urinate. For example, in the middle of the rendezvous, to have to stop for 15 minutes to urinate is just ridiculous.

CERNAN The urine collection device in the LM was obviously through the UCTA in the suit. It was not used by either pilot.

YOUNG Do you want to say something about the stowage areas?

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STAFFORD I thought the stowage areas for the command module compartments were completely adequate. We need more retention items out on the main display console and in the lower equipment bay.

YOUNG In my opinion, the CM stowage areas themselves are adequate, but the method of stowing is questionable. We use these snap straps to tie everything down with. If you have numerous articles tied under a strap, as we had on our flight, you open one strap and four items flow out. All this could be prevented if, instead of using straps, we use bungees with positive tension under them. Then all you do is raise up the bungee and pick out the item you want. The rest of it stays restrained. It's a darned nuisance when you have five or ten items floating out in the spacecraft. The use of bungee cords in various places would greatly aid the crew in keeping things in the vicinity of where they intend to operate with them. There's no sense in having equipment floating all over the spacecraft. The optics eye pieces floated loose. I think those things ought to be mechanically bonded to the equipment. There's no reason why the optics eyepiece should float out when you bump it with your elbow. That's the kind of change that they could do for Apollo 11. It wouldn't

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(CONT'D)

interfer with the spacecraft operation, because those boxes are out of there three quarters of the time anyway.

CERNAN

That's right.

YOUNG

It would absolutely have no effect on Apollo 11.

CERNAN

We feel strong about this. They certainly ought to be implemented on Apollo 11.

YOUNG

Whatever kind of material those inserts are made out of, the government has allowed itself to be sold a bill of goods. We've got entirely too many inserts for the amount of equipment that we're carrying. We never did any such thing in the Gemini program. Why we're not smart enough to come up with some mechanical insert device that'll allow you to retain things in there without having a lot of wasted space, I don't know. I think that we could carry 2 to 3 times the equipment that we've got in there, if we had a proper insert designed. For example, film. We could have carried extra film packs - several times over what we carried. The insert takes up most of the box.

CERNAN

The insert, is hard to get out of the box. Once you get it out of the box, it's difficult to get the film, or whatever

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16-15

CERNAN else you're trying to get, out of it. It's been designed to just push out, but it's not quite that easy. You ought to be able to go in there and pick out a pack.

One of the best ways to stow film is in a little bandolier type bag like we carried the LM film in. We carried some command module film that way. You just slip the bag out of this compartment, pull your film pack out or pull the whole bag out, Velcro it around the wall and use it.

YOUNG It's clear to me that the inserts are designed to protect the equipment against the 78 g crash or some kind of launch abort situation. I think that's absurd. I don't care what happens to the equipment. All you want to do is keep it from coming out of the box.

STAFFORD Yes, absolutely.

CERNAN You want to talk about any of the stowage on the LM? What about the purse fitting?

STAFFORD The purse is a wonderful device, but the fitting kept floating up out of its detent. Even though I'm sure it would fit adequately in one g, there should be another check made for the tolerances. The purse was probably one of the handiest temporary storage devices I've ever seen. We used this to

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transfer a lot of gear back and forth from the command module to the LM.

CERNAN

The ISA over the PLSS was also a very handy stowage item, especially for the LM pilot. He could reach over there with one arm. I stowed a lot of my film over there that I wanted quick access to. We could put any number of things in those pockets with it only partially zipped up, and they'd hold. We had a little Velcro on the feed port cover and the helmets for temporary stowage retention. This was not for retention during loads such as burns, but was for temporary stowage retention. It worked well. We were able to keep our helmets in one place. We stowed one on the engine helmet cover. The other one, mine, I stowed on a piece of Velcro on a bulkhead by the ECS.

All these thousands of little brown straps that we've got in the LM — that we strap together to hold things down and to hold things together — I'm not sure where the usefulness is ever going to be. I've never really felt that they had a great purpose. Some of them can be used to stow the helmet. I opened a compartment one time, and all these little brown straps started working their way out like a bunch of worms from outer space. The minute I saw them coming, I started

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pushing them back in. As I pushed one end in, there'd be a couple more come out the other end. I finally had to use both hands, push them both in, slap the Velco cover on them, and put a big skull and crossbones on the door. I told Tom Stafford never to open that compartment at any risk. So, I guess they're available if you want to use them, but they scare me a little bit.

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16.7 BIOMED HARNESS

YOUNG

I felt the AC DC connector and it was a little warmer than body temperature — not much — and did not cause any discomfort. It's possible that the biomedical harness, being up against the stomach, may have contributed to this feeling of fullness in the stomach area that we all experienced throughout the mission. I'm not certain about this, but it might have been a contributing factor.

There was some itching produced by the sensors — particularly the upper one on the chest. I was tempted to scratch that thing more often than not. I question the need to wear both sets of leads to get data. Maybe one set of leads would be adequate. I recommend that we eliminate as much of that biomedical equipment as we can.

CERNAN

The BIOMED sensors started bothering me about the third day — the two sensors on the top. I lived with them throughout the LM rendezvous. They were still bothering me, but they didn't quite get to the point where I was ready to rip them off. They were itching, and pulling the skin quite a bit. I came very close to pulling those sensors off. A lot of the time we were forced to operate without BIOMED on continuously

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CERNAN
(CONT'D)

anyway. So it's a good question as to whether or not we really need it all the time. I don't mind the sensors on if the people feel they have to have the data, but if two would do it I see no reason to have four.

16.8 PRESSURE GARMETS AND CONNECTING EQUIPMENT

YOUNG

During the rendezvous day cooling was adequate, but movement around the command module was a continual fight against the hoses. I finally adapted and learned not to fight it. We need a more flexible hose with possibly a universal type joint on it to allow movement. During critical operations, for example, when preparing for a burn, if you were running behind your timeline and were in a hurry to get from the lower equipment bay to the seat, you'd end up wasting more time than you gained due to the hoses torquing you around when you got in the seat. You'd have to reposition the hoses. It was a continual and frustrating fight against the hoses, which contributed to most of the exercise during the day.

16.9 CREW COUCHES

STAFFORD

I thought the crew couches were really good. I had no complaints at all about the way they fold up.

YOUNG

The shoulder harnesses were tied back around the couch arm

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(CONT'D)

rests. The center crew couch was unstowed and restowed in a matter of minutes — I'd estimate less than 5 minutes. There was no problem associated with stowing the crew couch. The one thing that made couch stowage a little difficult was the hatch bag hung down underneath the right hand couch. The bag prevented the couch from being pulled up as tight to get it out of the way so you could have access to the stowage boxes underneath the left couch. I recommend we eliminate the hatch bag. The couch was no problem in zero g compared to all the trouble that it gives you in one g.

16.10 RESTRAINTS

STAFFORD The restraining harness in the lunar module was adequate. We had it tied down and locked for the ascent engine burn. I had one strap locked for the descent engine burn. It was adequate. For just normal standing position, I found that it was uncomfortable to have it locked full time with one strap. The hoses torqued me up so that I was continually standing on my toes. It was not an uncomfortable position, but it did make me have a head position that would give you parallax with respect to certain switches. It presented a different view from what was seen in the simulator, where we had one g pulling down on us. Your eye position was maybe 3 or 4

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STAFFORD
(CONT'D)

inches different. If the Velcro had higher shear strength, I would have had no problem at all. I'd have been held down.

YOUNG

In the command module we used the lap belt during transposition and docking and during those periods when we were involved in making burns to prevent doing anything inadvertent and to keep our position relative to the controller pretty much the same. The lap belt worked satisfactorily whether you were down in the couch looking at you instrumentation or up further looking out during the docking. Did you use the hand holds?

CERNAN

I put my feet in them a lot of times to do exercises. The MDC was used as temporary stowage. We wedged flight plans and check lists. We used clips to clip food bags to it. Really inadequate — a second choice — but it was all we had.

YOUNG

I think if it could be replaced by a bungee strap, it'd be a lot better device for that purpose.

CERNAN

I did use that one particular strap under the MDC when we strapped in a launch to pull myself down into the seat.

YOUNG

In the command module all the restraint sandals do is pull

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YOUNG
(CONT'D)

the Velcro off the bulkhead down in the LEB when you've got your feet down there. We pulled a number of patches off.

STAFFORD

We pulled two patches of Velcro off the lower equipment bay.

CERNAN

The LM pilot was the only one actually operating in the LM unsuited. The restraint sandal Velcro really served to help you move around and restrain yourself when you were in the flight coveralls. In the suit, you've got that big boot. You tend to bend your ankle or move -- thus putting forces on that you don't realize. The whole boot just rips the Velcro off the floor. You don't even really know you were held to the floor with the Velcro. I think it does little or no good with the suit. Although they are not a good restraining system they keep you from floating and moving all around the LM. They keep your feet fairly flush on the floor which I found to be a tremendous asset in the unsuited LM checkout period.

YOUNG

As far as I'm concerned, the Velcro on the floor and on the sandals is nice, but it is certainly not necessary. The G&N handhold provide you all the stability that you need to take sightings and marks. I certainly think they are useful. They help you orient yourself with respect to your MARK button

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YOUNG
(CONT'D)

and with respect to your hand controller. For initial orientation down in the LEB, the small amount of Velcro that we have on the sandals and on the floor is probably useful. It gives you some sense of orientation. But as the mission progressed, I was making star sightings with my feet off the floor half the time and just holding onto the hand holds. It was no problem to stabilize yourself with your eye against the telescope and your hands on the G&N handholds.

STAFFORD

I thought the sleep restraints were satisfactory.

YOUNG

I didn't use the sleep restraints but one time. The rest of the time I floated around in that bag. I think the sleeping bags were excellent and kept you warm. The CM would start to cool down at night and 3 sleeping bags were a good way to go. I'm glad the Apollo 9 crew told us to carry three.

CERNAN

When I sleep in zero g I have to restrain my head. I either have to sleep with my arms wrapped around it, or when I slept in a sleeping bag, I had to be inside that sleeping bag from toe to head. I'd put my head down in the sleeping bag, which was comfortable sleeping, except then the sleeping bag was too short. So I ended up sleeping a lot of times like a baby in the womb. I had to bend my legs so I could get positive retention of my head.

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YOUNG I wondered what you were doing.

CERNAN I had to keep my head up in the corner, because if I let my head out of that sleeping bag, and it floated around zero g, I couldn't sleep. So I had to restrain my head. So for a person with this problem, the sleeping bag is a little short.

STAFFORD I didn't experience any problem: I slept like a rock.

YOUNG When I went to sleep there was nothing.

CERNAN I had that same problem in Gemini. I had to wedge my head up into the corner. If I could keep my head from moving, I'd sleep like a log.

YOUNG I was floating all over the spacecraft, but it's the only way to sleep. That's really fun.

CERNAN You might mention our preparation for EVA.

YOUNG Okay, we allowed about 15 minutes in the flight plan to prepare for contingency EVA, which was certainly adequate. Couch stowage was the major item in contingency EVA prep but presented no problem whatsoever. I did not flatten out or tie the bag to the floor and do the other items that we would have to do to get ready for a contingency EVA, such as completely

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YOUNG
(CONT'D)

depressurize the cabin and vent the hatch. Actually, it would have taken less than 5 minutes to prepare for it. The training we went through was certainly adequate to get us ready for this type of situation. In my opinion, by doing the operation in one g many times, you are adequately prepared to do it in zero g as far as the internal preparation of the command/service module is concerned.

STAFFORD

The same is true with respect to the lunar module.

SLAYTON

But you're saying you don't see any requirement to train in zero g airplanes.

YOUNG

Not for preparation of the command and service module, internal to vehicle, because there is enough restraint inherent in the vehicle. The dimensions are so restrained that you might as well be in one g to do it.

CERNAN

As far as the actual transfer is concerned, we don't have any more data now than we had before we flew; but we felt very strongly, based on our other EVA experience (which all three of us have been involved in), that for transfer with that type of handrail for the contingency situation, the airplane would not be beneficial because of its short period of zero g. Furthermore, a transfer on a handrail like that is certainly

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easy enough to do the first time; and I don't believe any water training is really necessary. One of the questions that came up before flight about the water training was the problem of vehicle misalignment. That misalignment and disorientation of the vehicle both internally and externally, doesn't make any difference when you go through the tunnel. Externally, it's not going to make any difference because you are just going to walk up a handrail to the hatch.

YOUNG

After 3 days of zero g, you acclimatize yourself to the situation. It becomes quite apparent that rapid movements cause more problems. Every time we threw something in a hurry and hurriedly reached out to grab it, it went all over the spacecraft like a rifle shot, and the same applied to the human body.

CERNAN

Time is so costly and there are so many things that you have to train for and plan for that you cannot afford to spend too much time on the things that are not going to happen. You've got to be familiar with your capabilities and with the procedures you are going to have to go through, but you cannot afford to spend the time on something that is not going to happen, because you don't have that kind of time.

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STAFFORD I thought that we were adequately trained to take care of any EVA situation.

16.11 FLIGHT DATA FILE

YOUNG I think our flight data files were certainly adequate for the command/service module. We did not carry any duplicated material with the exception of three sections. I think that the requirement for each crewmember to carry a complete checklist is nonexistent. We had enough equipment on hand to tell us exactly what to do in every case with the exception of AOS procedure that we frequently used, which was the new PTC mode that was figured out in real time. I would like to say about the flight data file that it sometimes required two and three different pieces of equipment to operate. For example, if you are going to do landmark tracking on rendezvous day, you're going to have to have your flight plan, your rendezvous procedures, and your lunar landmark tracking maps to lead you to the landmark. There is no way to adequately retain three different pieces of data at one time. I recommend that we prepare some simple method of attaching this type of data so that it's not only accessible but also readable and right where you need it so that you don't have to use your hands. In Gemini we used clips, and it can also be done with bungees.

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CERNAN In our estimation, we carried the minimum amount of flight data that would do the job. It paid off, because we didn't have three copies of everything which meant that when you took some notes, recorded some data, or took some special procedure that you wanted to put in the LMP or the CMP checklist, you knew exactly which book it was in. The checklists were very seldom in the pocket; they were always being used, were stowed in R12, or were stowed temporarily behind some of the handholds.

YOUNG You are talking about a one-man operation in the command module and we're talking about extended periods of time in the future -- up to days, in fact. This one man will have to be ready to operate with no less than five different pieces of flight data -- the lunar landmark tracking map, the flight plan, which could be part of his rendezvous plan, the update log, and his flight plan into which he could put his updates (and he should do that) to eliminate an extra piece of equipment. He is also going to have to have his CMP checklist for those GNC procedures that he can't memorize and the LMP checklist for situations where he is going to have to pull the ECS redundant component checks and nominal system checks,

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YOUNG
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as well as off-nominal situations. I recommend that he carry the CMP, and LMP checklists in his pocket and then have some method of attaching those others to the spacecraft.

CERNAN

The part of our flight data file we didn't mention, which is probably as important and certainly as useful as any, was the sets of flight data cards that we used throughout the flight for almost every phase — burns, entry, launch, TLI, TEI, the whole works. We had numerous cards, and it appeared to be inconvenient; but we got a stowage situation straightened out so that, for example, at TEI we were down to five cards — a DAP card, an SPS burn card, two entry cards and an earth-landing card — to do the rest of the mission. That certainly didn't prove to be any problem. We started out with about 20 or 30 cards, and they certainly appeared to be cumbersome. They were small and they had each phase for a single-man operation; you can't afford to be thumbing through a checklist. In other words, it would be very difficult for one man, who is going to have a service propulsion system burn, to thumb through the checklist and read through a complete procedure. We certainly proved, by the use of the SPS burn card for every burn, that it wasn't necessary to have that big, sticky procedure.

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STAFFORD The way it was sequenced, the CMP would have the launch checklist in his suit pocket. The CDR had all the TLI cards in his pocket; and as soon as the individual event was completed, they were put in stowage and never looked at the rest of the mission. The evasive maneuvers from SPS midcourse, LOI 1, LOI 2, and TEI were all made with the SPS card. That was on the center of the panel.

YOUNG While operating around the Moon, we put a card over the engine firing light. The card listed film settings which continued to vary during the flight. Let me say something else about the flight data file. We had a lot of decals around the spacecraft, which would be very useful for one-man operation.

STAFFORD In other words, instead of a checklist book, there were decals on the bulkhead.

YOUNG We had decals for the cabin depress and the cabin repress procedures, the hatch opening and the hatch closing procedures, and the suit integrity check procedures. We also had lunar module and command module pressurization procedures and the circuit breaker decals indicating what circuit breakers were on panels 250, 226 and 255. We had a complete abbreviated stowage list decal underneath the G&N system.

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YOUNG
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These proved useful during the flight and were referred to on several occasions when there was some doubt. It looks as though they would be very useful if we had to do a continuous EVA. The LM/CM pressurization decal, of course, was referred to on several occasions. I recommend the decals for all future vehicles; they can save the crewmembers a lot of development work.

16.12 INFLIGHT TOOL SET

YOUNG The only tool used in the inflight tool set was tool E.

16.13 DATA COLLECTION

CERNAN Most of the data collection was collected in the flight plan or in the particular checklist that we were working with. The whole command module operation, P52 information, landmark tracking information, and updates were copied in the flight plan. The results of our SPS burn were also put in the flight plan so that they were available to pass to the ground. It was a convenient place to store the information. In the LM, we did the same sort of thing only in the rendezvous book. We recorded data chronologically in the book we were working through so it would be recorded for posterity.

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16.14 THERMAL CONTROL OF SPACECRAFT

YOUNG

The translunar and transfer PTC mode, 0.3 deg/sec set up from initially zero rates with a 30-degree deadband, worked adequately, and it is recommended that it be used for all future flights. The second of the thermal control modes in lunar orbit, which involved a different attitude than what we went to initially, appeared to be adequate for thermal control of the vehicle in lunar orbit. It is recommended that those two PTC modes be used on future flights.

We found out that if you put the window covers on, the spacecraft tended to cool down rapidly as compared to when we had the sun coming through the window during the PTC mode. When we felt cool we would turn the hatch windows toward the sun, and it produced immediate heat. It was evident that there were places in the cabin that were warmer or cooler than what the temperature meter indicated. It tended to be warmer up around the hatch area where the windows were and tended to be cooler in the tunnel where the ice was. However, this didn't seem to affect our operation.

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16.15 CAMERA EQUIPMENT

STAFFORD Throughout the entire flight, we continued to have jams on the Hasselblad camera backs. This would entail taking the camera back, turning from the white to the red to the white indicators again, and losing the target you were shooting at the time because of the velocity that you had (either rotation or orbital velocity) and also because of losing that much film.

CERNAN We'll start - we'll continue on with the 70-mm Hasselblad, then into the 16-mm. We knew from training of the problem when you put a fresh 70 mm back on a camera. You may have to crank the first two, three, or four frames around manually and then show that white indication showing in the window. Then it will snap and supposedly will snap throughout the entire roll of film. We encountered that in training, and we were aware of it. I don't think we should have to put up with that in flight. I think those backs should be tried and snapped through any number of frames that is required so that this does not happen. Wherever it did happen, it happened on about 50 percent of the 70-mm frames. When you're in the process of taking pictures, sometimes the time is very important, and you throw a new back on there and don't want

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to try manually to crank it around so that you can get the picture started, this is especially true at times when you're in helmet and gloves and you cannot crank it around. That's item number 1. Item number 2 is something we didn't see with our training packs. In the case of two or three packs, you could eventually start snapping pictures and you would take 6, 8, 10, or maybe 20 pictures and the back would jam again. You would have to crank around three or four frames manually. Then you would take another half dozen pictures, and it would jam again. Then you'd manually crank around a couple of frames, and it would jam again. We saw this on two or three packs. I believe that we eventually snapped or took all of our 70-mm film that we had. The problem is that you can never tell when these little inconveniences are going to occur and in our case, dog-gone-it, they occurred at the most critical times — times when you were down around 10 miles or 9 miles from the lunar surface and you needed those pictures or times when you were looking at targets of opportunity and they were only out the window for a minute or a few seconds.

The 70-mm camera in the LM was used primarily by the Commander. In addition to these other problems that we just mentioned, all of a sudden, approaching the landing site or very shortly

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thereafter just above the landing site, the camera failed to operate at all. At that time, we didn't have a chance to tear it apart. Subsequently, in the command module on the way home during the coast phase, the camera was effectively torn apart, the backs were taken off again, the lens was taken off, and some troubleshooting was done. It was found that the only way we could get the camera to snap was to crank the gear around manually. That was very obvious in the base of the camera — one full crank, snap it, and then it was obvious that the crank or the gear did not re crank itself to pick up another picture. That camera was considered lost throughout the rest of the flight. The other 70-mm camera did work well except for the problems we mentioned with the backs. The lenses interchange pretty readily. Do we have any other dope to pass on about the 70-mm camera?

YOUNG

I tell you it was really frustrating when you would see a target of opportunity like that hill on the mountain of crater 310 (which is surely one of the most beautiful pieces of geology on the back side of the Moon) and not be able to get a picture of it. That was pretty bad.

CERNAN

The 16-mm camera in the LM worked fine. The new lens we took, which has the rabbit ears and the detents for the

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F-stop settings, was excellent. We'll talk about the other lenses in the command module in a minute, but the detents for the F-stops were very good. However, the one problem that was encountered (and again it seems that these problems are encountered in critical times) was that a number of times when we went to put a new 16-mm film pack in the camera, it was not immediately compatible with the camera. That is, the electrical pin that has to be made when you slap that magazine in the camera was not always in alignment with the pack. Sometimes the pack had to be just shifted in shear on the camera. Sometimes the knurled nut that tightens down the head had to be loosened because, when you made it too tight, the electrical connection was broken and you had to find some place where the electrical connection would continually made so that you could continually run the camera. Again in critical time periods, you didn't have the time to trouble shoot; so the first thing you did was to put it in, to make sure it was in properly, and to fasten it down. If it didn't work — maybe if you just took it out and tried it again quickly — you took that pack, put it back in your pocket, grabbed for another one, and shoved it in; and the chances were that it would work. In our case, it did. This was occurring on the LM during the low-pass side, for example.

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However, in the command module (after we got back after the LM rendezvous day where we used the command module movie camera quite a bit), we then saw this same problem occur with the command module camera where certain packs were not necessarily compatible with the camera. Eventually, the command module camera failed to operate entirely. It just stopped at about the 6th day, I believe. Luckily, we had brought the LM 16-mm camera back and interchanged 16-mm cameras. There was one anomaly that was mentioned to the ground. Apparently, it was okay because the 16-mm film shows the masking problem to be okay; but I've been led to believe that every time you put a different lens on a camera, the camera has to be masked properly for light leak so that that lens will fit properly to the particular camera. We had to come back with the configuration of using the LM 16-mm camera with the command module lenses because we would not fit the right-angle mirror on the LM 18-mm lens. We finally got a configuration we had to go to, and fortunately for us, it did work. The one big problem with the 16-mm camera is that the magazines are not just a one-shot affair. When you put them in the camera, the gear interchanges -- engages. You can see that, but it is the electrical contact that does not engage. All the film packs are not readily

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accessible, or readily compatible, with the particular camera. Again, this seems to happen when you want to use it most.

YOUNG

Okay. On several occasions, the new 70-mm lenses with the detents were certainly helpful; but I believe they also have a tab which it is possible to hit with your elbow. I really recommend that we make those detents a little more positive. In other words, make them require a somewhat higher friction to engage. On a couple of occasions, I picked up a 70-mm camera, and it was obvious that we had inadvertently changed the F-stop or the distance. We had gone from infinity to some other place because the detent was not positive and, unknown to us, we had accidentally hit that tab. I recommended that we increase the friction to get the 70-mm camera in and out of the detents ... quite easy to do with that tab on there, and I surely recommend it because that could cost a couple of films and certainly make you miss targets of opportunity. I'm certain that's going to be a factor when a crew-member starts operating on the lunar surface with this equipment pressurized. He should have that thing set up, and it should be very difficult for him to change those stops once he's got them set, or else he'll do it in that pressure suit without even knowing it.

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CERNAN I also recommend that the 16-mm lens that we used in the LM which had the detents be made compatible with the ring-angle mirrors so they can be used in the command module, because the lenses that were used in the command module had to be taped continually so that, every time you changed hands or moved the camera around for another person to use, you wouldn't change the F-stop setting. This happens continually unless you tape that lens. There are no detents at all on the command module lenses. I recommend we go to the LM type lenses for the command module. That's good stuff.

YOUNG Are we beating a dead horse?

CERNAN We were, but let me say one thing. I think all the 16-mm packs, after they are loaded, should be put in a camera that is going to be used. It should be ensured that the packs are electrically compatible with the normal installation methods and do not have to be forced, sheared, tightened, and loosened to make that camera run.

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17.0 VISUAL SIGHTINGS

17.1 COUNTDOWN

STAFFORD I could see nothing of any unusual significance. We anticipated the sunlight in the left rendezvous window for the CDR and had the boost protective cover window taped over it. Even with it taped over, it was a little bright there with the sun hitting on that aluminized Mylar tape. The sun never interfered with instrument sightings.

CERNAN Towards the end of S-1C boost, aerodynamic heating apparently produced smoke that could be seen between the boost protective cover and the hatch window.

YOUNG At lift-off, I noticed a little increase in light, which I think was probably because of the engines lighting off.

17.2 POWERED FLIGHT

STAFFORD I was watching the instruments going through the structural pogo's. I didn't look outside during this period.

YOUNG There was a big flash at S-1C ECO.

STAFFORD There was. You could see it.

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CERNAN You could also see some debris.

STAFFORD Okay, I was looking straight ahead at the instruments, so I didn't see anything. Okay, at S-II ECO, I thought I saw a flash.

STAFFORD But again, I was looking at the instruments more than anything. At S-IVB ECO again, I was looking straight ahead at the instruments and the DSKY.

CERNAN I didn't see anything then.

17.3 EARTH ORBIT

STAFFORD I didn't see manmade objects during Earth orbit. Geological landmarks - we always recognized Africa and the Atlas Mountains as all three of us have been there before.

17.4 TRANSLUNAR AND TRANSEARTH FLIGHT

STAFFORD During translunar and transearth flight the only thing we saw near us was the S-IVB. We could see up to 4000 miles at certain times.

YOUNG Yes. When we separated from the S-IVB, there was a lot of debris. In fact you could see it in the sextant

STAFFORD This should show on the TV, the sequence film, and the still photos.

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YOUNG When we turned around there was still a lot of debris.

17.5 LUNAR ORBIT

CERNAN Lunar landmarks - we ought to probably comment about the solar corona. I guess the solar corona could be seen 8 to 10 minutes before sunrise.

STAFFORD I hacked it one time at 12 minutes.

CERNAN Twelve minutes before sunrise it got to be a very dull parabolic glow. It was very concentrated in a very small area of the horizon, unlike sunrises and sunsets on the earth which spread across the horizon.

STAFFORD Right. And it had about the same texture as the Milky Way.

YOUNG Yes.

STAFFORD A very light Milky Way that increased to a heavy Milky Way and then just straight shafting.

It was a pure nearly white light, and you could see shafts going out of it, but it had about the texture of a Milky Way.

CERNAN That's right, and then it slowly got brighter. Then it got more pronounced right on the horizon where the white band would appear, but again in a very small area maybe about 12, 15, or 20 degrees of the horizon.

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STAFFORD I got a chance to time it when we were doing the landmark tracking. I timed it with my watch. I could see it for a period of at least 12 minutes prior to sunrise and also at sunset. We'd go to a different attitude where John could do the P52 to realign the platform. I tracked it down for about that long.

CERNAN You could watch it get brighter, but you could not predict exactly when sunrise or sunset was going to occur. When it happened, it was instantaneous. When you watched sunrise, you saw the solar corona get slowly brighter. You were positive that you were not close to sunrise. All of a sudden "bam" - the Sun was there and you were blinded.

STAFFORD Within one second.

CERNAN You couldn't watch sunset because you couldn't look at the Sun. Sunset would occur just "bang". Then you had the solar corona and you could watch it slowly disappear.

17.6 ENTRY

STAFFORD On entry - I watched through the hatch window as John went around to the entry attitude - I could see the earth airglow. As we were coming in, it was just before sunrise. We had a blue airglow out there.

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YOUNG Beautiful - yes.

STAFFORD It's a beautiful airglow with some pinks up above it.

YOUNG Yes, and that's why we recommended we only do the horizon check one time that day, not at that point in the mission, and not track the horizon on around.

STAFFORD Ionization is recorded on the film. It became white hot when we first hit the atmosphere, just like we'd gone into daylight.

YOUNG It was so hot out there you couldn't see anything. It was white.

CERNAN It was white hot. As you looked out into the apex of this ionization layer you could see a brilliancy which could almost be mistaken for the Sun following you right down. Then, once you really started getting deeper into the ionization level, this whole white was surrounded on periphery by a big, bright, solid purplish glow that came out over the side windows and stretched out behind the spacecraft.

STAFFORD The drogue chutes came out in early morning sunlight. They were orange in color.

CERNAN They were very easily seen at this time of day.

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STAFFORD The main chutes came out, and they were red and white.

YOUNG During landing and recovery, the only thing that I saw that surprised me was the amount of gas going out of those thrusters. We dumped a lot of oxidizer right into the chutes.

STAFFORD Main chute was recovered. The apex cover was recovered.

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18.0 PREMISSION PLANNING

18.1 MISSION PLAN

- CERNAN The mission plan was basically conceived during March and April of 1967. We had not basically deviated from the trajectory or test objectives that were known then. What was added later was landmark tracking. But the intricate details in the data priority meetings did not really finalize all the individual items until about February to March, 1969.
- YOUNG We were having data priority meetings until a month before we flew.
- STAFFORD We were trying to get everything locked in concrete as early as possible, but because of previous missions and the priority allocated, we couldn't get it done until this time. Also, we wanted to coordinate every detail we had with the Apollo 11 mission.
- YOUNG And COMM DTO's changed up until launch. I wish we were able to freeze those a little better.

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18.2 FLIGHT PLAN

STAFFORD We had a good hack on the flight plan once we made the decision to go on the 18th. Several of us worked out a preliminary attitude profile on the lunar orbit phase within a week after the management decision was made on the 18th.

YOUNG It was a working flight plan and most of our information was kept in the flight plan. It really worked well for us.

STAFFORD The flight plan was the basic thing we'd use and we had the cards to supplement it.

18.2 SPACECRAFT CHANGES

STAFFORD There were not many spacecraft changes made because of previous flights that effected our operation directly. The main thing that perturbed us was the fact that there were certain modes of operation that we'd never used in simulations. How the LM COMM systems would work was not brought to our attention until four days before flight.

CERNAN Up to about a week before flight, there was never really anything set in concrete as to what people really wanted to learn, and how people really wanted to conduct the DTO's. The people who originated them apparently didn't know enough about the LM/CSM COMM system to know how they operated, or

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how to write the DTO's. The various Directors in the Center never had gotten together. It was finally left up to the flight crew to say, "Listen, how do you want us to do it?" It was finally then left up to the flight crew, and by that I include certainly the support crew and the backup crew that were working with us. This went right up until about a week before the flight. One more recommendation from the people who supposedly originated these things, would have, as far as we were concerned, left them totally out of the flight plan. There was no organization and no thought behind these DTO's. The flight crew had to get together, gather the information, put it together, and then finally get down even to the nitty gritty situations of how the switches are set up, and when in the flight plan it's going to be done.

YOUNG Yes, we don't recommend that method of operation a couple of weeks before flight.

STAFFORD It shouldn't be the flight crew that has to get these items squared away.

18.3 SPACECRAFT CHANGES

YOUNG There weren't any spacecraft changes, but the things that made the crew nervous were the spacecraft modifications and

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repairs that were conducted due to equipment failure. I guess we're always going to have these. But I think in future spacecraft they ought to look at making vehicles more able to conduct complete tests after hypergolics are loaded and to changing equipment out without having to pull panels which invalidate large series of other tests that have been run, and which can't be rerun after panels are pulled.

18.4 MISSION RULES

STAFFORD I thought that the mission flight director did an outstanding job with respect to simplifying the mission rules and getting it down. Again, there were changes all the way through, but by and large, I don't think any of us had any complaints about the mission rules. We got on them early, and they were squared away, and any changes were coordinated rapidly.

YOUNG I think one of the basic design philosophies that came out of this flight was to keep the LM active wherever possible. That was a very sensible mission rule. Even with guidance failures in the lunar module, you still had a control system operative.

CERNAN It appears to me that not only do we tend sometimes to lack in coordination between particular directorates, but that

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within the directorates themselves, people don't understand today that we've got two vehicles. You cannot do something to the procedures, the flight plan or the techniques of flying one vehicle without affecting the other. This is one of the big problems we ran into. Effectivity of LM procedural changes to the command module are gross. These obviously were never investigated until we ran into them ourselves, either on paper or in the simulator. The one thing we've got to look forward to in all of our future missions is that there are two vehicles, and these two vehicles have to operate in a coordinated fashion. It's not simple to make changes, especially late changes.

YOUNG Let me ask a question in that regard. Did we check VHF A and B the day before?

CERNAN No, we didn't do any VHF check the day before. I think VHF checks ought to be done on the first day.

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19.0 MISSION CONTROL

STAFFORD I thought the GO/NO-GO's were sent up in a timely manner.

YOUNG Good thing they sent them to us because we were going.
We were using negative reporting. If we didn't hear a
NO-GO we were going.

STAFFORD Mission Control did an outstanding job. The only thing I
have any complaints about was the goof up concerning
chlorination of the water during the first night. It was
chlorinated before we launched, and it came down that
the doctors insisted that we put another load of chlorine
on it.

YOUNG We told them the position of our potable water intake valve.
They said leave it closed. I didn't have the schematic out
to back me up, so I took their word for it. I wish I
hadn't.

CERNAN That should have been thought out premission.

STAFFORD Yes. The ones we launched with were probably right.

YOUNG Yes, that's right. I didn't think we were going to chlorinate

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the water. After we closed that valve, I figured we'd drink that water, then open the valve and then start the chlorination process. There's no way to circulate it once you get the valve closed. Fuel cell water pushes that stuff in there. I knew that. I just wasn't thinking, that's all. I should have really quizzed them on it.

STAFFORD Well, we didn't want to get in a flap with them to start with on that first night.

YOUNG That's right.

STAFFORD We questioned them on it twice, and I ended up drinking all the chlorine. I do have a cast iron stomach.

CERNAN I've got an orange bag full of it that I left in the LM.

STAFFORD I drank it. It didn't hurt me - just browned me off.

CERNAN It burned a little bit when you urinated, but other than that it was alright.

YOUNG I drank a good deal of it because I drank that second batch of juice right after they told us not to drink the water. We'd already finished drinking two carloads of it. It tasted terrible.

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CERNAN We were all of the opinion that when you mix chlorine and hydrogen in water you get a dilute form of hydrochloric acid.

YOUNG I think that's been shown not to be the case.

STAFFORD I think Mission Control should certainly be commended. In simulations we'd worked out with them attitudes and request for attitudes and high-gain lock to go to a platform align where no gimbal lock would be involved. Their whole organization should be commended for the way that they handled that and the way it worked out.

YOUNG The one thing that kind of made me a little nervous was that it seems like for each REFSMMAT change, along with it should go an attitude for the crew to look at stars as well as an attitude which will allow you to avoid gimbal lock when you're torquing the platform through those very large angles. We were quite nervous there a couple of times. It looked like the way the platform was torquing, it was going to drive it into gimbal lock. Tom was standing by to take over.

STAFFORD I went to the ACCEL command in all three axes to take over and avoid gimbal lock.

CERNAN Maybe these fears were unfounded, but we certainly didn't know it at the time. I think that problem needs some study.

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STAFFORD The message is that you always have to anticipate ahead of time.

19.3 CONSUMABLES

STAFFORD We were kept well informed with respect to the consumables. We had no questions. One time before DLI, when our oxidizer fuel pressure went to zero, we questioned Mission Control. Through their telemetry sources, they came back and said that the oxidizer pressure was GO for the DPS burn. It was satisfactory. Then during the second DPS burn, we had the master warning light along with the DPS quantity come on twice. We were not concerned about it. We just pushed it out. The thrust chamber pressure was satisfactory, and we pressed on to the burn.

19.5 FLIGHT PLAN CHANGES

STAFFORD I think that this was fairly well coordinated and not patched up to any excess. Everybody did a good job on the flight plan preflight. The real-time changes were really insignificant — just minor things that fitted in good.

19.5 REAL-TIME CHANGES

STAFFORD The only real-time changes we had of any significance were the changes to the entry checklist procedures because of the

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fuel cell problem and the water boiler. They involved no
problem whatsoever.

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20.0 TRAINING

20.1 CMS

STAFFORD We made an analysis when we were the backup crew on Apollo 7 that the real key to operation on the lunar missions is an integrated simulation between the command module and the lunar module. The earlier that a crew achieves this, the more satisfactory it would be. A few runs could be made independently using a point target with the vectors from a point source. It's a completely different world when you're working real time with two-vehicle voice communications in the transfer of data between all three sources: the command module, the lunar module, and the Mission Control Center. We pushed to have the simulators in Houston integrated, and we did achieve four to five runs before we went to the Cape. It sure pointed out some problem areas. We got on them right away and got them solved. We also achieved several integrated runs with MCC and the CMS in Houston. We were never able to achieve an LM/CMS run while we were on the Houston simulators, however, part of this is because of the late arrival of trajectories in the total configuration.

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CERNAN

Running rendezvous closed loop with one simulator and not tying into any other simulator (integrated) became, after a period of time, to be almost negative training. You don't ever really get a feel for what the guy in the other spacecraft is doing and what his problems are or what his time line is like until you start operating integrated. We made a point that, after we once had the integrated capability down at the Cape, we would never do any rendezvous in the LM that was not integrated with the CSM. We felt that we knew the rendezvous and the techniques well enough that at this point it was worthwhile only when we could run integrated. I think almost all of our LM time, including the activation and checkout phase, which was another high coordination requirement area, was integrated, except when we ran independent malfunction procedure or other small items. There were a lot of single operations where the LM was not involved. We ran the command module by itself a lot for entries launch aborts, TEI's, TLI burns and what have you. But from the LM point of view, we did very, very little nonintegrated work once we obtained this capability at the Cape. This is something we highly recommend.

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STAFFORD The basic thing is that both the Houston simulators and the Cape simulators have the same capability with respect to integration and with the Mission Control Center. The star MEP's worked as soon as we got the proper trajectory ephemeris. Early in January we had determined the exact stars we would use in the mission. That was Acrux and Antares for our alignment, and this was actually done in flight. We knew the star patterns. The Houston and the Cape simulators were outstanding with respect to the star fields. Trips are not required at all to the planetariums.

YOUNG The one thing we couldn't simulate in the command module simulator, which we anticipated might give us a little problem, was landmark tracking. Actually, in flight, it proved to be very difficult to determine, for example, when you should stop and start marking accurately to determine the geometry. I just think that's inherent in the problem. I certainly don't begrudge not being able to have had that capability in the simulator. If we could ever get it, it would be useful, particularly when you're talking about one man tracking the landing site with the lunar module attached. The visual simulation for docking and undocking, I consider acceptable in all respects. I don't think it is necessary to make the trip

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up to Langley to operate that piece of machinery (RDS). When the visual simulations on CMS 3 were properly calibrated and the visual system was set up accurately, it was just like the real thing.

20.2 LMS

STAFFORD

On the lunar module simulator, as we neared the end of training, the visual model of the command module was outstanding. Only a minimum number of runs need be made in the TDS because of the limited control modes in the TDS. You do not have all the control mode capabilities because of the slop and lag. The LMS at the Cape was just in beautiful shape. A few runs need to be made on the TDS to get yourself acclimated to the actual look at the vehicle. Again, I think that I spent a total of 5 or 6 hours, and this is definitely adequate for any lunar mission. The rest of the time, your best visual indications for total dynamics (pitch, yaw, and roll) are on the LMS. The vehicle dynamics for docking are better in the LMS than they are on the TDS.

SPEAKER

Are they right?

STAFFORD

They are. It's a little more sporty in the pulse mode when you go to attitude hold.

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20.5 DCPS

STAFFORD The DCPS is a wonderful device. We worked out the backup guidance techniques for boost and entry and also the guidance techniques for backup of the TLI burn in case of a platform failure on the Saturn IVB. I recommend that all the crews have about the same amount of training that I got on the DCPS. I think I had about 25 hours on the DCPS. Going through boost phase was like I've been there so many times before, that there wasn't much to it.

YOUNG Booster steering is an integrated operation of the CMP and CDR and they must work together doing that kind of operation.

STAFFORD In the DCPS, John and I went together, and just like any other critical thing, we always made a point of working together as a team.

On the LMPS, again, if the LMS is available, the LMPS should have a low priority. For initial training, if there is no other simulator available, the LMPS is fine.

20.6 LMPS

CERNAN The LMPS primarily was used by the LMP very much the way the DCPS was primarily used by the Commander and CMP. There were about 12 to 15 hours prior to LMS availability that the LMPS

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was used to get the rendezvous technique down, to get the backup chart techniques down, and to get familiar with the software and the programs that would be involved in our particular flight. I thought it was very valuable, and I stressed that effort be made to get it up and operating, and I'm glad I did. Once the LMS became available, with this background you were able to readily utilize the LMS's capability and more complete facilities than you would if you had to start from scratch on the LMS. So I thought LMPS was good in bringing you up to speed originally. I don't think it's good for continuous training once the LMS is available.

20.7 CMPS

STAFFORD In the CMPS, John?

YOUNG We didn't have a CMPS. I sure wish we had had it for basic procedures when we first started, but we didn't have the math flow either.

20.8 CENTRIFUGE

STAFFORD The last time I was on a centrifuge was prior to Gemini 3, and I don't think my training suffered a bit.

YOUNG No, I thought the centrifuge was valuable from the standpoint of flying the EMS closed loop and flying the g meter closed

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loop. We were worried about the failure of the PGNCs, and on the wheel I had every confidence that I could have flown that whole reentry with just the g meter. Also, I had considerable confidence after I got on there that if all three of those pieces of equipment quit — with just a roll angle, we could have made it back somewhere without any problem.

STAFFORD Again, I don't think any long period of time or effort should be spent on it.

YOUNG No, I think one run per crew is all you need, and you probably ought to have it just to remind yourself of what those things feel like.

STAFFORD Are you saying that for one crew member?

YOUNG Yes, I don't think you ought to stick all three guys in there.

STAFFORD I had no problem with talking and seeing exactly what was going on and analyzing at 7 g's.

20.9 EDS

STAFFORD I think the EDS is a requirement for a few minor runs.

20.10 RDS

YOUNG As I said before, I think the RDS is useful in pointing out the proper dynamics. However, when the CMS is kept in the

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right configuration and the boys get the models and the dynamics of the simulator working properly, the CMS is certainly adequate training for docking.

20.11 NR EVALUATOR AND GAEC FMES

STAFFORD When the program was first cranked up and due to the non-availability of a high fidelity CMS and LMS, the North American Evaluator and the Grumman FMES were available to start the basic procedures in the coordination between the Mission Control Center and the crew. However, since the program has matured, I see no further requirement for the North American Evaluator or the Grumman FMES.

CERNAN We, as a crew, never did fly the FMES.

STAFFORD No. We flew the North American Evaluator early as backup to Apollo 7 when the CMS was not working.

YOUNG I flew it for landmark tracking because I thought you couldn't get it anywhere else, and it was helpful to me as a confidence builder that I could repeatedly track the same landmark every time. But there again, the simulation doesn't have the fidelity to show you proper geology to landmark tracking, so I don't feel it's a requirement.

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20.13 SPACECRAFT FIRE TRAINING

STAFFORD I think if you experienced fire training one time, that is adequate. We had it as a backup crew for Apollo 7, and that was all we needed.

20.14 PLANETARIUM

STAFFORD I think with the high fidelity that we have on both the CMS and the LMS, no further planetarium training is required with respect to the flightcrew themselves. For early indoctrination, for newly assigned astronauts, there is certainly a requirement to get the basic star patterns. Once you are assigned to a prime or a backup crew or even to a support crew, the planetarium is not required.

CERNAN We've been looking at stars for 5 years. That is what helps.

20.15 MIT

STAFFORD I think it's a requirement to have a concentrated MIT briefing at Houston early in the game and not waste your time going to MIT. This kind of falls in the same category as the North American Evaluator. When the Apollo system was just starting to mature and not much information and documentation were available, it was a requirement to go there. I could see no further requirement to go to MIT unless there was a certain type of use on the simulator.

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YOUNG The MIT guys wanted me to come up there to check their horizon. The definition - I think we can get by putting the same type of slide in the CMS. In fact, I recommend that we fix the CMS so we can put the landmark line of sight slide in there that defines a horizon and you can practice with that one. That's what you probably should be practicing with. When you are close in, if you want to practice star horizon sighting, give the guy a picture of what the world really looks like from an MIT slide and let him use that. It certainly wouldn't be any problem to implement it.

20.16 SYSTEMS BRIEFINGS

STAFFORD All the briefings on the launch vehicle consists of one day and this is completely adequate. I thought what we had on this spacecraft was adequate — 1 approximately 5 days on the command module and 5 to 6 days on the lunar module. Early in the program, the one thing the flightcrew has to watch for is to make sure you don't get bogged down in minor details of the subsystem which you have no capability to analyze in real time or the function is not available with respect to the controls and displays.

CERNAN One comment about the spacecraft briefings is that the final systems briefings are very short, to the point, and pertain

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CERNAN
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only to your spacecraft. In our case, 106 in LM 4, they were good. They brought us up to date on the peculiarities of our spacecraft. The only problem is they brought out things, items, particularly in the case of LM 4 pertaining to COMM that had been known for months and that we had never known about. It was not until the final systems briefings a week before the flight that we began to discover that there were some idiosyncracies about the COMM which affected our operation which we had not been using in the simulator, nor which we had incorporated in our procedures.

YOUNG

During the final command module systems briefings, there were two questions that were asked about the command module. One question was how do the readings off the rendezvous radar transponder compare with the flight readings which should have been identical. It took us more than a week after that to get these data straightened out. I got answers from two different sources which disagreed on which positions were wired up and what the readings should have been. The other question was that we were getting some information during the briefing that led us to believe that our spacecraft gages were not reading what the telemetry parameters were reading. In fact, there were some wide variations. We asked to see a

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YOUNG
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list of how the spacecraft gage readings compared with what the telemetry was reading. We never got that dope — never. That's the kind of thing a test pilot should have in the back of his mind. I am not saying he needs to dwell on it, but with the problems we had on rendezvous transponders, it would have been nice to know what our readings really were.

20.17 EVA, WITH ZERO-G AND ONE-G WALKTHROUGHS

STAFFORD

The most valuable thing that we got out of the training was the one-g walkthroughs. This was invaluable, with respect to the probe, and the drogue, the tunnel work, and the contingency EVA training. I think we had just the right amount of it.

20.18 MOCKUPS AND STOWAGE TRAINING EQUIPMENT

STAFFORD

These improved greatly in the last 3 months prior to our mission. The mockups we had available here in Houston were outstanding.

YOUNG

It was only on our last training session on the probe that we had an actual flight-type probe. The rest of the time, we had been using one which had some little change in it every time we saw it. Based on the D data and on the things that people like Jake Smith, who knew the probe inside and out,

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YOUNG
(CONT'D)

told us, I certainly thought we were adequately trained in the mockup with the probe, the drogue, and the hatch operation.

20.19 PHOTOGRAPHY AND CAMERA TRAINING EQUIPMENT

CERNAN

We talked about photography and cameras, but the training equipment was readily accessible and available to us, and we had no problems there. I'm glad it was, because we learned some of the intricacies of camera failures from it.

20.20 SEXTANT TRAINING EQUIPMENT

YOUNG

I think the simulator is adequate for sextant training. However, it can't be emphasized too much that the simulator doesn't produce accurately the smoothness and the ease with which you can track objects in space. Actually, that can be a help, because if you can do it in the simulator and get accurate numbers, you certainly can do it in the spacecraft.

20.21 GENERAL SUPPORT

STAFFORD

General support procedures continued to be a problem. We tried to get everything ironed and locked in; but again, because of the factor of 2-month launch centers, the total system does not have enough people or something was basically wrong in the correlation of the data from previous flights.

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We got data priority meetings out of the way and squared away early. Again, there was always a tendency to have data priority meetings late in the game; but these were turned off, and I don't think we missed anything from it.

CERNAN

We had great numbers of changes made in our transposition and docking procedures and our probe, hatch, and tunnel operations based on the D data. These were done pretty late, a month or less prior to flight; and I wish we had had a chance to turn around that information a little faster. However, because of the closeness of the centers, we just couldn't do it. Also, it wasn't apparent to us just what information that we ought to use out of D until we really got the final checklist, which was about a month prior to the flight.

20.22 PLANNING OF TRAINING AND TRAINING PROGRAM

STAFFORD

I felt that the training program was an outstanding area. The total planning of the training program and the coordination with the crew training coordinator was carried out to the nth degree. We had everything planned well in advance. We knew exactly where to go, and what to do.

CERNAN

I'd like to mention two items along that line. Number one, it was good because we always had a feel for what the days

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ahead had in store for us in terms of training. Of course, sometimes these had to be changed, but we had at least a feel for what we were looking forward to and what we were going to have to be. Number 2, when we had an exercise that included a lot of other people, suits, simulators, or support people, the crew did not have to follow up to make sure these people were there and readily available. They always seemed to be well informed and well prepared of the time, the place, and the requirement for gear that they had to supply us at that time. I thought that was excellent, because I'd seen in the past where crews could be ready, but nothing else and no one was ready. People got caught by surprise because they didn't know a certain exercise was going to be conducted at that time. We didn't have any of that.

STAFFORD

I thought that the coordination of the training was done to the nth degree. It couldn't have been better.

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21.0 HUMAN FACTORS

STAFFORD Preventive medical procedures were adequate. Premedical care was fine. We very seldom saw the doctors and, when we did, we got the adequate number of vitamin pills to take care of colds. To meet this type of launch center and have adequate training, you really milked every last minute out there. At present under our schedule, there is not adequate time for exercise, rest, and sleep until about the last 3 weeks. The medical briefing was prepared down to where it was short and informative and should not extend past the period of time we had.

YOUNG I think to add the medical debriefing to the last week or so, with all those problems we had, was pretty traumatic. We got called in at the last moment for a briefing on the best way to prevent getting motion sickness while you are in orbit. There is a lot of psychological business associated with motion sickness. That kind of a briefing in which, in my opinion, they meant well was full of erroneous information presented to the flightcrew. If we had followed that kind of exercise pattern, I think we would have been in worse shape than we were. I think that kind of thing that late in the game, unless it's well thought out and has some common sense associated with it, shouldn't be given to the flightcrew.

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That was a terrible thing; they gave us all that stuff on top of the other problems that we were having at that time with the spacecraft.

STAFFORD

There's been a great effort made to increase the palatability of the food, and the only thing that really perturbed us was the fact that there was gas in the water.

YOUNG

I'm not sure that the gas in the water was the whole story. I felt full the entire flight, and I really don't know if we were drinking that much gas in the water. In some cases, before I would eat I wouldn't feel like I was hungry. We didn't eat a lot of food.

STAFFORD

I think that because of the reduced activity, even though we did a lot of light symmetrics on board, the total BTU output in zero g is reduced from one g.

CERNAN

Item 2A says compare the hunger sensations in flight versus 2 weeks preflight. When you are hungry, it doesn't make any difference whether it's in flight, postflight or preflight. When you are hungry, you have desire to eat and you produce the hunger by burning up calories; burning up BTU's. When you are not hungry, you don't particularly want to eat. As a result, I think all three of us ate a greatly reduced

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CERNAN
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portion of food every day. It was obvious by the amount of food we brought back, but as far as I'm concerned, this in no way affects the medical capability or the operational capability. It's the fact that you haven't done any work to move around, haven't done work to sleep, haven't done any work to punch any buttons, haven't walked anywhere; you have done very little exercise. Only enough to make your muscles feel a little bit relaxed. You eat when you're hungry, and when you are not hungry, you don't eat. It's just that simple.

STAFFORD With respect to the gas, I know that of every bag of juice that I prepared, I could make a quantitative evaluation that approximately 20 to 25 percent of the total volume had bubbles.

YOUNG That's right, and if it was a hot meal, it was 50 percent.

STAFFORD Which was probably steam.

YOUNG Yes.

STAFFORD We tried to filter this through our teeth.

YOUNG It didn't work. You can't get rid of the bubbles.

STAFFORD You can't get rid of them.

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SLAYTON Did this give you a problem rehydrating the stuff? I assume it would. You wouldn't get enough water in there.

STAFFORD Well, we kept pumping the bag until it was full.

SLAYTON I see. You did get it all rehydrated.

STAFFORD We got it rehydrated, and the taste wasn't too bad except for certain items.

YOUNG You actually end up with a bag of air and water; and what you would do is take your pencil, punch it in the end of it, let the air out, and then put some more air and water in it.

CERNAN One of those things about eating and making meals taste good is associated with the crew compartment temporary stowage capability. You couldn't really take a whole meal and prepare all three or four or five article. Once you prepared them, you had no place to put them. So what you do is prepare some orange juice, and you drink it. Then you would roll up your garbage and put it away. Then you would take out the applesauce. Or you would take out the beef stew and heat it. You never had a chance to eat and drink at the same time like you do at a meal. This is a little different way of eating and a lot less desirable.

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STAFFORD I think one thing, getting back into this, is the area Velcro. Often it was convenient for the Commander to prepare all three meals. But in the time I had three or four of the bags completely filled, I'd have them on the table by the lower equipment bay that had all the Velcro patches. But the shear strength was so low in the Velcro that one minor bump would knock food bags that we couldn't hold down all over the place.

YOUNG I think a good place to put a bunch of bungee cords is down there on top of that table. Just throw them over and slip the food packs right under them.

CERNAN Concerning packaging meals, I said when you are hungry you want to eat. When you are partially hungry, you want to pick out the good things out of the meal that sound good to you at that time to eat. When they are packaged, you have no idea, expect to go into another book, another checklist to find out what is in meal C, day 5. That's another article that you've got to take out, put something else down, pick it up, and look at it. What you want to do, if you're going to package food as meals, is put what is in that meal somewhere readily readable on that package. You want to know what's in there. We were cutting meals apart to find things we would like, because we didn't know what was in them.

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When meals are packaged, they are packaged in such an integral fashion that you can't get one article out. They're wrapped around each other in bags and packs, so that when you break open a meal, the whole works has to come out. You can't just pull one orange juice out or one bacon cube or package of bacon cubes. You've got to uncrap the whole thing because they are interwound within each other when they are packed. You immediately have 5 or 6 articles, including the wet wipe and the gum, which can be thrown out of the spacecraft. Getting rid of them was recommended a long time ago. You have all these articles now and you can't pull one article out of that package.

STAFFORD Okay, anything else on food?

CERNAN Would you have preferred that food items not be packaged in meal units?

STAFFORD I think we had a pretty good balance of what we needed.

CERNAN I think they could be packaged in meal units if you knew what was in the meal unit.

YOUNG If you don't package them as meal units, someday in which they are all crushed together. We had juices all packaged together,

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YOUNG
(CONT'D)

and there again we were leafing through the juices to pull one out that we would like to drink.

CERNAN

And the juices. If you have 5 juices, they were wrapped all together. So to get one out, you had to take five out. You couldn't just take one of them out.

YOUNG

You had five juice packages pulled out, and there you were.

CERNAN

But, I think we ought to stick to the meal packaging. You ought to label what's in there and try to package them so that they are not interdependent on each other to get out. The portions are more than adequate. We had enough food to stay out there 30 days.

YOUNG

At the rate we were eating, we did.

CERNAN

I think we all liked the new foods (the spoon-bowl, packaged items) with a special emphasis on the turkey and gravy. The ham was good. But the beef is so dry it might just as well be packaged as bite-sized beef and bite-sized potatoes.

STAFFORD

Here's the discrepancy. We had some sample wet packs of beef that we tried in Houston before we went and it was good. But the beef we got there was not like a complete roast beef slice that was nice and juicy. They were hard, dry pieces of beef.

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STAFFORD The turkey we had in flight was like the turkey in preflight.
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That ham was the same. The beef was considerably less.

CERNAN I wish we had had more turkey. We were matching for the
turkey. It was really good.

YOUNG And also the beef and ham.

STAFFORD The turkey was absolutely delicious.

CERNAN I thought we all liked the intermediate moisture fruits. We
all snacked on them.

STAFFORD We ate peaches and apricots. They were delicious.

YOUNG I don't recommend the rye bread.

CERNAN The sandwich spread and bread was not the big hit we thought
it was going to be. We tried it early in the mission, and
then tried it again on the way home. It was all right.

YOUNG Gus didn't like it either.

CERNAN We didn't particularly like it, I guess.

YOUNG No, I didn't. The rye bread had a peculiar smell to it once
we got it out of its wrapping.

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CERNAN Some of the reconstituted foods that were in the spoon-bowl package configuration were good. And they were readily accessible to eat with a spoon. I think we all had a number of those throughout the flight. They were actually pretty good, and they were easy to eat because the consistency of the food was such that it would stick to the spoon.

21.2.9 Deviations from Programed Menu and
Scheduled Eating Periods

CERNAN When we were hungry we ate. When we were not, we didn't. This was also very closely associated with the activities of the day. It's not like sitting down and having everything in front of you and eating and drinking. It's a long, complicated process to sit down and have a meal.

YOUNG Yes, during rendezvous day, we had a little time for breakfast and plenty of time for supper. However, we all missed lunch and didn't have time to do anything but drink water during that period. There just wasn't any time in the plan to eat lunch.

STAFFORD We were going over the top of the big football. I had it on automatic Z-axis track to get data with respect to the program number data points and P20. Gene was doing the work on

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the right side using the AGS. I just whipped out two fast-backs and prepared them. On a regular g mission, you've got to eat before you get off the surface because you don't have time from insertion on through the rest of the phase in a rendezvous.

CERNAN

Food preparation is not that difficult a task. It's such a tedious job that you really have to make up your mind you're hungry enough to want to eat before you want to go through the process of preparing the food.

YOUNG

You could very easily speed quite a bit of time trying to get the nozzle of the drinking gun into the top of the package. Boy, that thing was tight in a lot of cases, and even though you cut it, you'd have to stick scissors or something down in there to get into it.

STAFFORD

On the question of the drinking gun — I think what we have derived as a continuous flow water gun is far superior to the individual squirt from a counter gun. This should be continued.

CERNAN

I think we used the drinking gun for almost all of our cold water reconstitution. Almost the only time we used the food service center was for hot water.

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21.3 WORK-REST/SLEEP

STAFFORD Regarding difficulty in going to sleep, the CDR had no difficulty going to sleep at any time.

YOUNG I didn't either, except that the one night I tried to sleep next to the glycol pump. I immediately shifted my position and went to sleep somewhere else.

CERNAN The LMP didn't have any particular difficulty. I guess anxiety during one or two nights prior to reentry made sleep a little bit more difficult. But I think we've certainly got an adequate sleep station — both above or in the couches — and we all slept real well. The only disturbance during sleep that I found — and it was only on one night because the ground handled it very well every other time — was the S-band antenna switching over on the OMNI's the last night before reentry. They were apparently catching a switch just after the crackling buzz started — even with the squelch enable on — and that was pretty disturbing. But on previous nights that sound was not heard, so they had been switching antennas just a little bit earlier than the sound would occur.

STAFFORD No programed exercise was planned on this mission. The CDR did isometrics each day on the way out. Once you got in the

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lunar orbit, the activity there was enough exercise itself. We used the inflight exerciser on the way. We found that if you really put out very much effort that you became sweaty and heated up considerably because of the lack of cooling at the 5 psi atmosphere. However, the exerciser onboard is completely adequate.

Regarding inflight oral hygiene, there was no mouth discomfort. Brushing was no problem. The dental floss was good. I didn't use any toothpaste. I just used water and a toothbrush.

CERNAN

The LMP used the toothpaste and a little water. No problem. I just swallowed the toothpaste. It left your mouth with a pretty good feeling and a pretty good taste.

STAFFORD

Regarding sunglasses or other eye protective devices — I used the sunglasses every day and found that they're really required, as your eyes became fatigued from the brightness of the Sun. The CMP had a special device to use with respect to the sextant.

CERNAN

The sunglasses are adequate for handling the brightness inside the spacecraft. However, they sure don't help you if you're looking anywhere near the proximity of the Sun externally because it's so bright that I'm not sure there's anything that will help you.

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YOUNG It was really difficult for the CMP to adapt to sunlight while spending so much time trying to be night adapted for the tracking process. So it was a problem. I think you just want to avoid the sunlight if you're going to be a CMP.

STAFFORD Unusual or unexpected visual phenomena or problems experienced.

CERNAN I didn't see any.

STAFFORD The medical kit in the command module and the lunar module are certainly adequate.

CERNAN We took Lomotil, which is a diarrhea preventive for gas on the stomach hopefully to get rid of some of the bubbles, and not for diarrhea control.

STAFFORD To reduce the bubbles.

CERNAN Maybe this isn't the right thing to take for gas on the stomach. Maybe there's something like Tums for the tummy that would be better than Lomotil for gas on the stomach, because of the effects of Lomotil on your bowels. I don't know. I just present that question.

STAFFORD Okay. The next item is housekeeping. There are items of housekeeping of the restraints, bungees, and various positive retention devices that we've already outlined.

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I think every mission objective we had was concluding comments met. They added some in flight, and those were all met.

YOUNG

No, we missed one. We didn't do the landmark tracking because we couldn't vent the tunnel — with the LM mark.

STAFFORD

We did it in the docked configuration on the first day. In the real time we couldn't do it because we couldn't vent the tunnel, and we couldn't make the maneuver. We got a landmark tracking configuration with the docked LM on the first day of LOI.

YOUNG

And that's going to be a toughie, too.

STAFFORD

And the other ones — DTO's were added real time in flight. The ones we accepted were done.

Medical requirements: I think that the physicals have been reduced down to where they're getting somewhat realistic with respect to the total number of flight items drawn and the length and duration of the physicals. Once it's determined what the total physical workload is for a lunar surface EVA, the bicycle and pump your heart rate up to 180 doesn't seem very sound to me.

CERNAN

What John's driving at is, you've been looking at a heart rate of 40 or 50 for 8 solid days and you jump off on a ship. All

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CERNAN
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of a sudden, you pump yourself up to 180, and it doesn't feel very good. It doesn't even sound very good.

STAFFORD

As soon as the lunar mission is completed, this activity should be terminated.

YOUNG

I question the wisdom of doing that. It's bad enough when we're feeling good down on the ground to run up to 180 for 15 minutes on a bicycle.

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22.0 CONCLUDING COMMENTS

This portion of the crew debriefing covers the immediate action items to be initiated for the Apollo 11 mission. The order of preference will be command module action items, lunar module action items, and miscellaneous.

22.1 COMMAND MODULE

YOJNG One of the basic problems we had during the command module active rendezvous was the fact that there is no way to retain data necessary to conduct a rendezvous. The following data are required in one-man rendezvous procedures: the flight plan, the rendezvous procedures book, and the update book. There is no positive retention of any flight-type data in the command module. It is recommended that we come up with a system of conveniently located bungee cords to strap this equipment down in the lower equipment bay convenient to the optics and telescope, underneath the main display console and next to the left couch. If these significant and necessary items float away from you during zero-gravity operations, you're going to be wasting a lot of time getting them back.

STAFFORD With respect to the main display for three-man operation, we found ourselves continually losing time in trying to locate

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items that we had previously put on the Velcro. The Velcro that meets the present flammability criterion does not have enough tensile strength; and even small items of low inertia or mass, like cards, would continually float off the Velcro. We were finding ourselves taking more time to do an individual line item than was required because of the inability of the Velcro to restrain items.

Permaclips like we had in Gemini or, particularly, bungees would be best. A series of these all over the main display console, where you can easily secure items, we consider as nearly a must for efficient crew operation.

YOUNG

Another area that a bungee could be very effective is on the X-X struts in the lower equipment bay and by the hatch.

CERNAN

Once you let go of a food package, a camera, or an eyepiece, it may be gone forever. Once something gets lost in the command module, it takes three men about 15 to 30 minutes to find it. We found this an agonizing problem. It was a living-condition problem, and it's a problem that these permanent-type clips and bungees would solve. It would make command module living a lot more adequate.

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YOUNG The basic problem is that once you get something out, something else comes with it; and there is no place to put it, to stow it, or to hang it. It just sort of wanders around, and it's very inconvenient. There should be some place next to stowage boxes where you can stow a piece of equipment, once you take it out of its box, and hang it there until you need to use it.

STAFFORD A good place for this is on the inside of the doors in the R areas.

YOUNG Right.

STAFFORD You could have a little clip on the inside of the door or a bungee on the inside of the door.

CERNAN I think the three of us could identify strategic places to put something like 20 bungees throughout the spacecraft. It's ridiculous to have to take food bags and stow them in the inlet duct of the postlanding vent system. That's where we had to stow the food bags. We crumpled them up and stuffed them in there.

The only suitable place to keep the flight plan where two or three of us could see it at the same time, other than in our hands, was in the rail over the caution and warning

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system. That's bad. We tried to keep the caution and warning system uncovered. It's impossible at times. We do need a place to keep these things.

CERNAN

The Velcro, at least in my opinion, is inadequate. Let's not talk about quality; let's talk about quantity for a minute. On the cameras, we have only one small patch, maybe a half inch or an inch square. Thus, when you're trying to do something, you have to look over your shoulder and definitely see where you're placing this article. You're trying to place it on a patch that happens to be one inch square or less. What we need is sheath of Velcro, particularly over the back of the right-hand and possibly the left-hand couches. This is a great stowage place for cameras and other equipment. The other Velcro problems are the food bags and the gloves. If you want to hang them up somewhere temporarily, it's not compatible with the Velcro on the spacecraft. It does not hold securely enough to maintain things from floating around.

YOUNG

Additional Velcro is required behind your head. Frequently we knocked off the cameras without knowing it by moving our heads and causing the Velcro attachment to fail and shear. Then when you looked for the camera, it would be somewhere where you couldn't find it.

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CERNAN The way it is now, with a patch meeting a patch, it's a Velcro alignment problem. You've got to align the piece of Velcro on the object you're trying to stow on another piece of Velcro. What you really want to do is just be able to reach over your head and slap it back there.

YOUNG I'm not so sure something like a metal spring that you just pick up and slap the item under wouldn't be better.

STAFFORD A bungee type thing?

CERNAN That might be true. I don't know, although this is a nice Velcro area here if you Velcro it totally.

STAFFORD I don't think, because of flammability, we can have a total mat. At least, we need an increased area. Also one of the great items that we saw as a deficiency was the retention strength of the Velcro. It's unsatisfactory.

YOUNG The optics eyepieces fell off on two different occasions. Both of the sextant eyepieces unscrewed in zero gravity and floated off. We had to spend about 10 minutes looking for it prior to a very crucial P52 requirement prior to a burn. The telescope eyepiece was bumped loose and fell off halfway through the mission, and we spent some time looking for that.

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Those items should be mechanically retained on the equipment because of their crucial nature.

The radar transponder switch was placed in the heater position approximately 20 minutes to test the radar prior to going to operate. It was run through its test. It was not moved after that time. Apparently during separation, it self-gyrotorqued to an intermediate position. Recycling the switch caused it to work. I would suspect this is because that switch is probably moved very infrequently during testing so that it never really gets any cycles on it to amount to anything.

CERNAN

I have two items to cover on system. Number one is the PUGS. On the first burn, the PUGS apparently started out working. The details of the increase/decrease is on tape, but basically it went to decrease some 200 pounds. The switch was put to DECREASE. As it was approaching zero, it was put to zero; however, the oxidizer went to INCREASE. Subsequently on the following burn, it went full INCREASE and stayed there. The switch had been put there. We ended up with an oxidizer unbalance of full INCREASE. I'm not sure what this did to our resultant quantity. We had something like 9-percent oxidizer and 6-percent fuel, which could be critical if we

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needed the rest of that propellant. The result of the PUGS operations is going to have to come out of the ground test data. As far as I'm concerned, the PUGS did not work. It was used as briefed upon landing for 15 seconds before ever putting it on the line, watching the transient. I saw it go through the tank changeover in the 57-percent region, and it did exactly what I expected. It plotted 4 minus, 4 plus, 4 minus, and percent banged around a little bit. It settled down after 50 percent and continued to go to the full increase, and we had an unbalance. As far as I'm concerned, it didn't operate properly.

We apparently lost the hydrogen pump package in fuel cell number 1 which caused us to lose our condenser exhausters. The circuit breaker popped on fuel cell number 1. When we reset it, it popped again and gave us a main bus undervolt light and an AC volt light, an AC bus light, a main bus light, and an AC bus light. The fuel cell was still usable for short periods of time until it heated up or with continuous hydrogen purges. The other anomaly which has to be resolved is concerning fuel cell 2. After we were in lunar orbit a couple of days, about 12 hours before TEI, we saw the condenser exhaust temperature go beyond the caution and warning limits -- full high to full low at about 2 cycles to 3 cycles

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per minute. Now, about once every 10 times that it hit the bottom side, the caution and warning and the fuel cell number 2 lights would come on. The question that has to be resolved is why did we see these oscillations? Why did this oscillation damp on the sunless side of the moon? Why did it increase after about 15 minutes in the darkness? Why was the same oscillation observed on Apollo 8? We saw it on one fuel cell, so it apparently has something to do with the thermal environment around the moon. We didn't see it on our third fuel cell. It was perfectly normal. This is a very unnerving situation, especially when you have one fuel cell out to start with. I think this has to be resolved. This started about 10 or 15 minutes after we got into the night side.

STAFFORD After LOS.

CERNAN When we got into the day side, it had about the same thermal time lag. In about 10 minutes or 15 minutes, it damped out and then would start again. This cycling action continued on the condenser exhaust temperature until we did TEI. When we went into passive thermal control on the way home, we never saw the oscillation again; but the thing that bothers me, it apparently was not unique to spacecraft 106. I had word that

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it was seen on spacecraft 103, so it could be the lunar thermal environment that does it. We have to find out why.

YOUNG

I don't know if this needs to be corrected; but our GDC, in my opinion, as far as being used for a guidance system is concerned, was completely invalid. If we had tumbled the platform, we could not have used the GDC to get a quick platform alignment unless we had tumbled the platform within about 15 minutes of our GDC alignment. We had a lot of drift in yaw and some drift in roll. Pitch was pretty good, but as a guidance system, I don't think it was worth a tinker's hoot.

STAFFORD

Let me amplify that. We checked it in the spacecraft during preflight testing on the pad the day of launch, and it looked good. We could ascertain in flight that the performance of the system degraded. Again, when we were trying to fly as accurately as you could to correlate the total effort required on the landmark tracking, the pitch was fairly accurate, but the yaw and roll were unacceptable for short-time phase ... drift. I'd estimate that the drift rates in zero g, as far as we could analyze it. It would go up to at least 25 hours.

YOUNG

It was completely unacceptable for any rendezvous situation and barely marginable for any large SPS burns.

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STAFFORD The TEI burn would have been nearly impossible. If we'd have had to make the TEI burn, we would not have accepted the fast return home, because of the inaccuracy. We would have taken the slow return home, and there we'd had to use the midcourses to start with. That would have been our decision on board, because of the GDC --- if we'd lost the basic uplink data.

YOUNG If that's the guidance system, make mine vanilla. With the insulation removed from the hatch as we had it, we recommend that wiping down the hatch be included as part of the daily inspection routine because it's going to be covered with water, especially when the CSM is operating alone in the PTC mode. I don't think this was a problem, but I think the loose water should be kept - -

STAFFORD There are no electrical connections up in the hatch.

YOUNG Only the tunnel vent lights are up in the hatch and they are shielded. I think that water should be wiped, especially prior to SPS burns and during reentry.

STAFFORD It rained during reentry, prior to reentry, prior to sleep, and after wake up. You're going to get a large accumulation of water on the hatch when you're asleep.

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CERNAN Here are two other real quick pseudo-anomalies. On the last day before reentry we had a hydrogen CRYO tank heater fail in the AUTO position. This is no problem. We had to do some manual cycling. The other anomaly was that the primary evaporator failed. It dried out during the launch phase. We tried to reservice it in orbit, and it dried out again. We never used the primary evaporator from that time on until reentry. We did not need it, or try to use it in lunar orbit. From a temperature point of view the radiators handled the job superbly. We serviced it for 3 instead of 2 minutes prior to reentry, and brought it on the line. It worked like a charm all the way through reentry.

STAFFORD I'm glad it did, too.

YOUNG One of the unresolved problems is why we couldn't get VHF. When we first turned it on, we couldn't get VHF A and B to check out. This may be a CSM problem; it could be a LM problem. When we finally got it on, it worked great.

CERNAN After separation, we had VHF B simplex. The problem appeared to be in the VHF A transmit mode. The command module was unable to read the LM. The VHF A transmit mode is obviously used in VHF A simplex and in VHF A duplex, the ranging mode with which we are most concerned, with. But as soon as we

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undocked, the VHF A simplex and duplex modes and ranging modes worked perfectly.

YOUNG

When the DELTA-V counter on the EMS was placed to DELTA-V and normally at zero, it would jump to 10.8 plus or minus or some odd number. It is recommended that it be fixed so that it doesn't do this. It makes it impossible to use from zero. The EMS DELTA-V counter is a very vital piece of equipment for applying and monitoring burns of small velocity to the rear.

The AOT was really sort of dirty. On the AOT within the star line-of-sight region, there were 3 or 4 hairs that were clearly visible anywhere from a quarter of the way out from the center, to all the way out to the end. One thing that disturbed me greatly was that within about 10 percent of the crosshair center, the light transmission was severely reduced. It was reduced as much as 60 or 70 percent in the plus Y axis. Around the other 3 axes, it was down about 50 percent. I didn't understand why, but when you went through a certain area on a plus Y axis you'd literally lose the whole star. I was led to believe that this was a simulator problem not the real world. But you didn't lose it instantaneously; it just faded out as if there were a haze area or a possibly dirty area near the crosshairs.

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YOUNG
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The rheostat-dimmer switch on the AOT went from no light to a very, very dim light, most of the time it was not adequate to really mark a star. The problem did not appear to be an electrical problem: it was a physical problem. The rheostat control knob would fall forward physically when you came up from the dim position toward the bright position. When you hit the point about half way between, the knob would just roll forward on its own. So, it was a mechanical problem. In spite of this, actually the alignments went very well. The accuracy of the alignments, the star check, and other aspects were very, very good.

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22.2 LUNAR MODULE

STAFFORD An item that has been highlighted before from the Apollo 9 mission with respect to fuel cost and crew attention was relative to zeroing of the rate needles. We were told pre-flight that the LM-4 error needles are the most accurate that had been calibrated, and they were zero. I determined first, on station keeping with the command module, that when I looked at the error needles to go to zero, I was continually drifting off. The test was very easy in the simulator. However, in real flight, I was continuing to drift off when I had VERB 83 called. During this time I could see that when I had zero rates indicated on the rate error needles, I actually had rates. At the time we were too busy to calibrate them. Just before docking, when I finally went to the AGS attitude hold and deadband MIN, where we had no movement, we determined that a zero, true-vehicle rate indicated 2.2 degrees to 2.5 degrees per second right deflection in yaw, 0.3 degree per second down in pitch, and 0.2 degree to 0.3 degree per second in roll. When we tried to fly the attitudes to zero, we continually had a rate going which immediately would build up into a total displacement. This would require that you continue to monitor the vehicle attitude and use fuel to fly back.

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STAFFORD
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I pointed out before, the five degrees per second, and 25 degrees per second scale is unacceptable. Basically required is what we have in the command module: 1 degree per second and 5 degrees per second. But even with the 5 degrees per second those needles were not zeroed. This caused me to use more fuel than I'd been used to using in the simulator, and it required far more attention be given to the vehicle.

The other item that I noticed that was different which required a cost in fuel was the response of the ascent stage. Again, we had a fuel loading of 50 percent fuel on the ascent stage, but the Z-axis track - we're using the Z axis track with the primary guidance and navigation system, required far more fuel usage than we've ever seen in the simulator. In the simulator, we would see an occasional thruster fire. During actual flight, when we had Z-axis track engaged during rendezvous, we would have thrusters firing every five to 10 seconds in a series of 3 or 4, and it would go from one deadband to another. I found that I could beat the Z-axis track with respect to fuel. We had no radar bias by occasionally making one pulse. Now it was one pulse in PGNCS. You can never kill the rate. It's always an overshoot. You can go within certain limits, say plus and minus 5 degrees, and if the radar angle bias is low, total fuel usage can be reduced during tracking and rendezvous.

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CERNAN This was very obvious when using a PGNCs mode of operation with AOT alignments. You could never literally slow down a star in the fashion you would like to slow it down for the alignments. You can still make the alignments - no problem - but it's not like controlling with a heavy descent stage. During the phasing burn, we had the descent quantity light come on twice with the MASTER ALARM.

STAFFORD This was during the phasing burn, and needless to say, we had just made our pass at 50 000 feet and had started into darkness. But we pressed right on.

Also associated with the phasing burn, after the burn was initiated (and we'll have to look at the tapes for the exact time) we had another MASTER ALARM with the DCA gimbal warning light coming on.

CERNAN The AGS performed very well in all respects with the exception of one unexplained anomaly. Prior to undocking the 304 address, the angle theta did not agree with the PGNCs. It was incremented by some 20 degrees to 30 degrees. As soon as we undocked and did another alignment, this angle bias, or angle difference, disappeared and ended up as zero. From then on, alignments and updates were excellent: no problems at all. However, after the alignment and the update, 3 separate times prior to undocking, we still had this angle difference.

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STAFFORD Concerning VERB 83, to determine R-dot and theta, I would say approximately 50 to 60 percent of the time the solution would be displayed in 30 seconds to 35 seconds. At other times, it would go as high as 4 minutes.

CERNAN At many of those times, we needed the computer badly, so we went through a VERB 96, used the computer, and worried about getting back to VERB 83 when we needed it. The other LGC - radar unexpected anomaly was the first update we received in P20, in almost every case. It was seen many times after VERB 93 initialization, after about 4 marks and was way high like a 5 digit number on a range and range-rate correction. In every case we hit a VERB 32 to reject it, and then the next update came right on in. So it was the first update after the initialization.

STAFFORD I'm certainly glad that we were watching real time and saw the data from the ascent burn to depletion on LM-3, because we had rates up to 5 degrees per second on the ascent stage. It appeared to us that the vehicle was going through plus or minus 5 degrees per second oscillation. However, the guidance shutoff was fantastic. But we anticipated this. We had both of the retention straps to our suits tight and locked. You need them. The descent was so stable and everything that we didn't have everything down for that.

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- CERNAN The only descriptive word I can think of is wallow, because it seemed like it wallowed; but at the end of the burn.
- STAFFORD It's like a pretty healthy dutch roll in an aircraft or something like --
- CERNAN The reaction control system worked fine, other than the PGNCS control and the light ascent stage and the PGNCS pulse. It ought to be noted that every time one of those ascent reaction control engines fires, it's like the whole inside wall of the spacecraft is blowing out on you. It's like you're inside of a big garbage can and someone's beating over your head with a mallet.
- STAFFORD If you want to make the simulator realistic, they should simulate occasionally a little pop, pop. More like a KA-BOOM, BOOM when they're fired.
- CERNAN A clanging, a clanging - -
- STAFFORD I noticed it more during the ascent stage. You can see the structure vibrate - -
- CERNAN The LM was noisy like we expected. We kept one cabin fan on for a while. It didn't really tend to improve the cooling, so we turned it back off for noise control. Tom, would you say that you were not hot, but you were not cool?

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STAFFORD I was not hot, but I was not cool like in the command module. Again, like we squawked in the altitude chamber, the cooling capacity of the LM is not as great as the command module. I was not uncomfortable, but I could tell that I wasn't in real praise of high activity. Again, the present system was very marginal. It's being improved on LM 5 with the liquid-cooled garment facility.

On the cabin fan again, we could see no noticeable increase in cooling because of it. The amount of noise that the device makes is fantastic, so we only had it on for a short period.

CERNAN Your major continuous noise is the glycol pump. It winds up. It has bearings that are noisy. It's a noisy, noisy pump. The other noise level — and you can hear it continually while it's operating, not only while you position it — is the S-band antenna. You can hear that thing track continually. It sounds like someone is rubbing across the side of the spacecraft with a washboard. It's just that continuous grinding and grinding and grinding back and forth. When we first got in the LM, the water had bubbles in it. It had air in it the first night. The next morning, it had more bubbles in it. We hadn't consumed a great deal of water, but when we left the LM, I would say that it still had some bubbles in it but not many.

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STAFFORD We probably drank most of the major bubbles out of it. There is no reason why this mass of water can't be completely de-aerated and free of bubbles.

YOUNG You know, George told me they didn't deaerate the water that they serviced us in the command module.

CERNAN I believe that the S-band high-gain antenna — the lock-on and capability of operating it — was 100 percent better than expected. I won't go into the details on it. It did work adequately. The COMM was good. It was easy to lock on, it was easy to position, and it tracked well. The OMNI's apparently did not work as well, and as a backup mode, we used the OMNI backup configuration which gave us a hot S-band mike to the ground. The normal voice mode of operation checked out the night before and worked adequately, but it was a preference of the ground to go to the voice backup mode of operation.

22.3 MISCELLANEOUS

STAFFORD One thing, again for information to pass on to the Apollo 11 crew, the S-band antenna really growls. In fact, John could hear it growl up in the command module. When we were checking it out, it was shaking both vehicles.

YOUNG It's really an eye opener. You don't have to go back over it again.

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22.3 MISCELLANEOUS

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YOUNG It's really an eye opener. You don't have to go back over it again.

STAFFORD We found during training that continually the Hasselblad camera would not actuate when we pushed the trigger. We checked with the people in the Support Division, they said you would have to use a little roll knob and advance the film one time. Well, for real important targets, you can't take time to do this. On all the magazines — black and white color, every one — we had to stop and occasionally turn one or two film slides through to get it to work.

CERNAN This was not only on the first picture off of that reel; it was sometimes in the middle of the reel. All of a sudden, it would stop; and you'd have to advance it manually to get the red dot out and the white dot back in to start taking pictures again. When you have a glove on, as in some instances, you can't do it.

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STAFFORD They may be trying to put too much film in the magazine. We don't know, but it is certainly unsatisfactory. We had the Hasselblad fail — which is under analysis.

CERNAN The sequence camera film packs are not necessarily compatible directly with every camera. They work, but they should be able to put that magazine in the camera and have electrical contact made immediately (as soon as you lock the magazine in) and have the camera run. In many of our packs, the magazine had to be manipulated, split around, forced in, or any number of things to make that electrical contact so that the camera would run. In a real-time operational situation, when you need the pictures, this is unacceptable. We also had, on the way home, a failure of the CSM 16-mm camera; and I don't know yet what it was or why. It just failed to run, period. In the LM, we had an 18-mm lens that had detents for the f stops, which was fine. You could set it, and it would stay in a detent. In the command module, we had lenses that had no detents. They had very little friction, and continually as has happened in the past, some of those f stops slid around; and you'd have to check it every time prior to using the camera. As a result, what we ended up doing, which is ridiculous, is having to tape the camera every time we wanted to set an f stop so it wouldn't slide away from us.

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YOUNG That's really bad.

STAFFORD I think we are in an area that needs considerable attention. We need to ensure that we have a review cycle so that all the onboard data are finalized, if possible, 3 to 4 weeks prior to flight. To come down to the last week and still be changing data and data cards is unacceptable. All the approach plates into the landing sites, the onboard data, and the rendezvous procedures should be in the final flight books so we can review them 3 to 4 weeks before flight. The present system, where they come up only 1 week to 5 days before the flight, is unacceptable.

CERNAN Unacceptable, unnecessary, irresponsible, and ridiculous. This is true of the contractors, people such as MIT, and in house such as E and D, ASPO. Fortunately, they get reviewed by FOD because we're working with those people on SIMS, etc. It appears to me that everyone gives themselves a deadline of about 3 days before the flight. This is unacceptable.

STAFFORD I think one thing that contributes to this is the present 2 months launch center. This will be alleviated; but for the 11 crew, this is an item of great concern.

CERNAN The other thing about onboard data is the problem that there is no central point within the center to filter the information.

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We get one recommendation from Grumman, and the next day we turn right around and get another recommendation on the same switch setting or the same chronological position in the procedures to make this switch setting. We get one recommendation from the contractor on one day, and a day later we get a 180-degree reversal from NASA MSC, or NASA KSC, or one of the other contractors as to the position of the switch.

You've got to have agreement before it comes to the crew.

We'll accept a recommendation that is correct. It shouldn't be up to us to filter out which is the best way to do it.

If we're going to have to do that, we don't need the recommendation in the first place.

In regard to physiological or psychological feeling in flying the command module, I think the three of us all felt that when you are strapped into the command module, it's very much like being strapped into Gemini. If you have some force upon your legs, your back, or your shoulders you really lose the perspective of zero g. After being up there for almost 8 days, when we were strapped in, we almost really felt that we were no longer in zero g.

STAFFORD I felt like I was back in one g when I pulled those straps down tight.

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CERNAN

This was the condition we had in Gemini. On Gemini, maybe we didn't really have this true free-floating zero-g concept. Now, when you do have this free-floating zero-g concept, it is a little bit different. I think everyone is different in the way they adapt to it. After the excitement of launch and TLI and everything was over after the realization that you're settling down to live in this environment, I felt good. I didn't feel like I was ready to go out and do handstands and all these other things in the command module. By the end of that first day, I was moving around the command module; and I felt more comfortable. The second day, I felt a little more comfortable; and by the end of the second day, I felt great. The third day, the night we went into the LM, I could have flown standing on my head or sideways; it would not have made any difference. What I am saying is, in contrast to Stafford and Young, it took me a little bit longer to adapt to this real zero-g floating-around environment -- no trouble, no dizziness, no trouble taking the suit off or anything else. I had just a comfortable feeling of being able to say that I can do anything I want to in terms of maneuverability with the body in zero g in the command module. It took me about two days.

We were briefed with a recommendation that if you do get an uneasy feeling, you try some head movements to see if you can

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increase your adaptation rate - head movements as described by part of the D-crew and by the medics. As far as I am concerned, these head movements do nothing but aggravate your feeling of insecurity of not being 100 percent at that point. If you are ever going to get sick and get nausea, all I've got to say is start doing head movements and you'll push yourself in that direction. To prove a point, I did this after the 4th, 5th, and 7th days when I had already been in the LM. I had been upside down, I'd been in every attitude, and I felt that there was nothing in the world that I couldn't do up there. I started doing those head movements, and I swear that if I had continued those head movements for over three or four minutes, I probably would have got myself sick. I strongly recommend that over the two or three day trip to the moon you let yourself adapt to it normally.

STAFFORD I think there is a tremendous variance among individuals. My adaptation, I consider, was instantaneous. I think everybody has noticed that his head feels a little stuffy, which is a natural reaction when blood distribution changes from one g to zero g. In my case, I had a sensation that I was flying upside down for about 8 to 10 hours, however it didn't matter to me. I was all over the spacecraft. I have had a strong stomach and it never bothered me. I think John was the same way. There is a tremendous variance in individuals.

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YOUNG

I agree with what Gene says. I really believe that making head movements when you feel bad already is exactly like when you are out on an acrobatic flight and you get yourself feeling bad. What you do is you stop the acrobatics, go back and land, and drink a cup of coffee. You don't continue doing acrobatics when you are already feeling bad. It's absurd, patently absurd.

CERNAN

I just didn't feel that great the first two days, but I was going uphill rapidly. Tom told me, "Gene, don't move." So I stayed where I was, and then I started progressing around the spacecraft slowly, getting myself adapted in the normal, everyday fashion. The point we brought up earlier, and that we'll make again, is that in Gemini we were continually strapped in and continually had pressure against our body. The sensation of zero g that we now have in the command module was a little bit different. When you can totally unstrap and float around, free to move throughout the vehicle, it's truly a different state of zero g. It might affect any one just a little bit differently. These head movements that have been recommended -- I am absolutely and forceably recommending against them. Let the two or three day trip to the moon allow you to adapt normally like any human being might be required to adapt. One may need no adaptation: someone else may need

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two or three days. And I am not ashamed of it, because there isn't anything I couldn't have done at the end of that second day.

STAFFORD

I thought the PAO requirements were handled very well, with the flightcrew directors working through this routine as previously agreed. We had no problems. I think that all the photo coverage that is required from all the centers should be coordinated and an effort be made to avoid flaps between centers again.

CERNAN

Let me say something about PAO, because I guess I'm right in the middle of this real-time conversation. The LM COMM situation is such that much of the time we will be operating in a S-band hot-mike configuration. Possibly, we'll be on VOX when an occasion arises where you say something and you've forgotten you're on air to ground or you don't know you're on air to ground. This last flight was probably an extremely good example where things went outside the control center about as quickly as they came in. All the real-time comments went out, and there are flaps about them going on right now.

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23.0 ONBOARD CREW COMMENTS

STAFFORD The PRECAL sequence was completely satisfactory. The total flightcrew OCP for wakeup times and physicals progressed in a nominal manner. Ingress to the spacecraft was made on time. Throughout the rest of the count the crew was approximately 20 minutes ahead of the nominal count along with the STC. Part of this could be attributed to the fact that we did not have a suit integrity check. The suit temperatures from the ventilators and also the suit temperature in the spacecraft was satisfactory. There was no noticeable coolant or excessive coolant as had been noticed by previous crews. Discussion was held at minus approximately 30 minutes concerning the RCS ring B oxidizer. The RCS oxidizer burst disc had ruptured. It was decided, after we inserted into orbit, that we would go through a procedure which would close the RCS propellant valve, turn on the RCS ring B heaters for 15 minutes. This should theoretically vent the oxidizer from the isolation valve out to the engines. The countdown proceeded as prescribed. Ignition was called at minus 6 seconds. A definite feeling of the turbines coming up to speed and thrust chamber pressures were as previously briefed. Engine lights went out at approximately T minus 2 seconds. At T zero positive acceleration - a

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slight positive acceleration was felt and the lift-off light went on. At 2 seconds, the yaw maneuver was initiated. The magnitude of the yaw maneuver was approximately one half of what had been observed on the CMS and the DCPS. Tower clear was called at 12 seconds followed by immediate roll and pitch program initiate. The complete first-stage ride was very smooth and the aero-dynamic noise compared to Gemini was less. At staging, a longitudinal pogo that persisted for approximately 4 cycles was felt. It was impossible to ascertain the magnitude of it. We'd estimate that it went to a negative one-half g, and then back positive and continued on in that fashion for a definite 3 to 4 cycles. When it stopped, the J-2 ignitions on the S-II had been completed, and they were all up to thrust. The S-II propulsion was noted by very smooth burning and very little vibration. Practically no noise at all was sensed. At 7 plus 40, the inboard engine was shut down as programmed. The profile continued out to staging where another pogo was felt immediately upon the shutdown of the S-II stage. The magnitude of the longitudinal pogo was not as much but persisted for approximately 3 cycles. Ignition on the S-IVB occurred as programmed, and it was noted by the crew that the noise and vibration on the S-IVB were rougher than experienced on any of the other stages. The roughness in the

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somewhat sinusoidal manner was noted all the way to SECO. At SECO, the postinsertion checklist was completed. At a GET of 18 minutes, the command module RCS propellant B ring heaters were turned on to vent the ring of the oxidizer downstream from the propellant isolation valve. The flight continued as programmed with the state vector updates over the states and the TLI pad. TLI was initiated on time, and the sequences for the S-II SEP lights coming on and off were exactly in sequence to the second. Again, the crew noted the seeming roughness of the J-2 engine on the S-IVB. At approximately 3 minutes from the start of TLI, a high-frequency pitch and vibration could be heard and also felt. These were superimposed upon the regular somewhat sinusoidal vibration of the J-2 engine. It did not build in magnitude, and the S-IVB continued its thrust profile as planned. At TLI cutoff, it was noted that the EMS monitor read minus 0.6 of a foot per second. The total crew timeline from insertion through TLI was not rushed, and the crew was 5 to 10 minutes ahead of all the programmed activities. Transposition and docking were performed and geared to take only a small amount of fuel. The turn-around was completed approximately 80 feet from the S-IVB. The closure rate was made straight in, and then the total profile followed according to procedures. Immediately upon the SEP from the S-IVB a check was made on

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the propellant valves in the RCS and we found that all of them were still open. A positive indication of docking was felt by the crew members at the same time that the ring A and B indicators went from gray to barberpole. Contact was made between 0.1 and 0.2 of a foot per second. When the rate had damped and the attitude aligned, the primary retract bottle was fired, and the probe pulled the two vehicles together. This required approximately 3 to 4 seconds. The making of the docking latches appeared to have less noise than we had previously experienced in the altitude chamber. There were no anomalies associated with this. All the caution and warning lights appeared to be nominal. All total operations were nominal. The withdrawal of the lunar module from the S-IVB continued on schedule. When the S-IVB/LM SEP switch was actuated, a positive acceleration was felt, and a straightout movement could be noticed as the LM moved out from the S-IVB. Both the EMS and the DSKY read 0.2 of a foot per second. From a visual observation, it appeared that the opening with respect to the S-IVB was approximately a half a foot per second. This is what you would expect from this opening velocity only on the sensing vehicle. The 3-second RCS maneuver was used on the AFT-firing thrusters — on the forward-firing thrusters. Later another 1 second and a half, second firing was made with the forward-firing

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STAFFORD
(CONT'D)

thrusters to ensure separation. After a maneuver to the programmed pitch attitude, the S-IVB could be seen out of the right rendezvous window and right window. The LM and command module separated. The distance slowly opened out to 500 or 700 feet. The CM/LM moved slightly upward from the S-IVB. It maintained this position until the separation maneuver was made. The separation maneuver was performed on time, and the residuals are noted as in the flight plan.

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