EVANS (CONT'D) look out and almost see constellations as well as you could by looking out the window, but not quite as well.

SCHMITT I looked once or twice through the optics at the Earth. It appeared to be an excellent Earth-viewing system.

EVANS Yes, it is. A couple of times, I observed the Moon through the sextant. However, the field of view through the sextant was so small that you had to look through the telescope first to see where you were and then look through the sextant because you couldn't recognize the general features at all.

SCHMITT Trim displays and SPS displays - Were they all what you expected?

EVANS Evidently, from where I was sitting in the cockpit, plus 2 and minus 2 on the gimbal drive check always ended up a plus 2.2 and a minus 1.8 from *my* left seat viewing angle.

The trim values were always just a bit higher than what I thought they should be, which didn't bother me much either. I finally got so I would set the SCS gimbal trim position just a bit higher than what I thought they ought to be.

SCHMITT During those checks, each movement of the gimbal was indicated by an increase of amp loads on the buses.

EVANS The other thing that's more noticeable in the vehicle than in the simulator was the feeling of the dynamic motion every time the gimbals move. You also got an indication on the rate display. If you were in the 51 setting, rate display would go up to maybe a tenth of a degree before it would null itself out again. You could definitely see the spacecraft banging back and forth within the dead band.

The CMC SPS TVC - I think the greatest difference in that field and the simulator was in the roll rates involved in the SPS TVC. In all of the burns, the roll rates were almost always up around 0.4° per second within the dead band. In the simulator, it always stayed on the same side of the dead band. But, in the actual vehicle, it would hit one side of the dead band, bounce back, and go back across again at about 0.4' per second and hit the dead band on the other side and then come back. So it was oscillating back and forth across the dead band, whereas we had the simulator pretty much set on a 0.1' per second. I think it always hits one side of the dead band. The pitch and yaw rates during the TVC/SPS burns seemed to be almost steady, very little change. When you had the yaw change during TEI, it was a nice gradual change. The rates were not noticeable at all; just steady as a rock.

EVANS (CONT'D) The only part utilized in the SCS system was attitude control during the TVC checks, and I guess the other time was when NOUN 20 got its glitch. We switched to SCS control, which took care of the rates right off the bat, caged the BMAGs, and maintained attitude quite adequately. I guess entry was the only other time I used SCS minimum impulse on the command module only, after command/service module separation. And, in that case, you always had residual rates, which wanted to yaw the vehicle to the left. You had to continually yaw it to the right, and in pitch when I was trying to pitch down, it would continually decrease the pitch-down rate. It was essentially evolving its own body pitch up. But, minimum impulse, control of the command module only, is quite adequate. It's a little bit different than the simulator in that in the simulator, roll control is the one you can't quite get with one minimum impulse blip back into zero roll. In the vehicle's case, it's yaw. You'd either give one blip, and it would go to the other side. You'd give it a blip back the other way, and it'd never end up with a zero rate in the yaw axis. However, I never did try it with the single ring authority. The only maneuvering I did again is the minimum impulse on the command module in SCS.

Thrust vector - We never did any SCS/SPS burns.

EVANS (CONT'D) Power up/power down. We never did power down. It was powered up all the time. We never did power it down.

Attitude hold worked quite well. Whenever you switched to SCS control and you had all 16 auto RCS selects on, then you had a continual bang, bang, bang, back and forth within the roll dead band. If you put limit cycle on, that kind of knocked it down a little bit. But, of course, the best way to control SCS in roll is to use two-quad authority and not four-quad.

The Delta thrust switch - I would always wait until average g on the computer before bringing the Delta-V thrust A switch. All burns were started on Delta thrust A first. Or, if it was a single-bank burn, it was Delta-V thrust A.

The Delta-V remaining counter and rocker - the EMS Delta-V worked real fine. The difference between the actual spacecraft and the CMS is that in the CMS, you can see them count up and down, but in the command module when you held the button down to maximum increase or decrease, the last three digits remain solid. It really counts up, so you wouldn't have time between each of the counters to see the numbers change. It stayed on whatever number it was on. Actually, it just sat there as an eight, a constant eight all the time because it was whipping through there so fast. The Delta-V

EVANS (CONT'D) test worked all the time. There was always a minus 22.2 or 22.1 on all of the EMS Delta-V tests except the one prior to entry, which ended up as minus 27 or something. That's when the accelerometer was picking up some extraneous counts and counting a little bit more than it should have.

SPS thrust direct ON switch - I never did use it.

Direct ullage button - I never did push the direct ullage button. I don't even know if it worked.

Thrust ON button - I never did push the thrust ON button, so I don't know if it worked, either.

Engine thrust vector alinement - I don't recall any attitude deviations or maximum rate changes because of thrust vector misalinement at the initiation of any of the burns.

SPS chamber pressure indicator - During the LOI burn, the bank A indicator came up to about 87 percent, which was a little lower than anticipated. I was expecting somewhere around 95 or 97, somewhere in there. That's about 10 percent lower than expected. When I turned on bank B, I got the nominal 5 percent increase, and then throughout the LOI burn, the chamber pressure just gradually increased a little bit and finally got up to about 97 percent at the end of the burn.

EVANS (CONT'D) The other anomaly on the chamber pressure indicator was that after the LOI burn, we noticed that we were down around 5 percent, and then later on, sometime in lunar orbit, it ended up back at zero again, and I'm not sure when it went back to zero. On all the rest of the SPS burns, the chamber pressure on bank A would always come up to about 86 to 87 percent and then a 5 psi increase when you put on bank Bravo.

SCHMITT PUGS - The PUGS was essentially nominal in general. Apparently, there were some sensors out, so it was erratic in its sensing of the LOI burn. It tended to hang in the decreased area. I went to decrease and left it in decrease for the LOI burn, and it seemed to try to keep going low. After DOI, we didn't see any real change to it. Then I guess it acted pretty much the same for you on circ. When I came back in, it looked like it had decreased more than when I looked at it last.

EVANS Well, on the plane change burn, the ground called up saying to start it in decrease. So I went to decrease, and I think it didn't have time to stabilize at all because we ended up with a gage with data of 400 decrease.

SCHMITT When we picked it up after that for TEI, we started TEI full decrease and left it there. It was, in fact, low and gradually worked itself up until it was almost balanced about 30 low at the end of the burn.

EVANS That's with the switch in full decrease.

SCHMITT And that corresponded with what we read on the gages. So, I guess you'd say it ended up nominal, but it was a little erratic during the burn, and that may have been the result of those sensors.

EVANS I think I'd better back up there a little bit on the chamber pressure indicator. Evidently, the chamber pressure indicator had a bias on it on the low side because we were definitely getting full thrust.

SCHMITT Yes, in checking the V go versus time chart, you were ahead of that on V thrust. You were getting more than the nominal thrust and that corresponded with our cutoff time.

EVANS Service module RCS - We had no anomalies with any of the quads. The audible cues are not like the simulator, but you can hear some back there. You hear something that's more than the clicking of the solenoids on and off. I don't know what it is, but it's more than the solenoids.

SCHMITT As a matter of fact, it was like somebody in another part of an old house turning on a water faucet and when it's turned off, you hear the water pound against the faucet. I think it probably was the plumbing more than the solenoid.

EVANS Whenever you started a maneuver or were in a maneuver, you could always tell because the vehicle would vibrate a little. The vehicle would move around and when it got to its position, it would sit there and shake a little bit, and then when it started moving, it would also shake a little bit, more than I had anticipated that it would do.

The command module/RCS - We had no anomalies there.

SCHMITT I guess I was impressed by both the service module and the command module firings at the amount of unburned fuel and/or oxidizer that was propelled out of it. My impression was that the command module gave more afterburn material than the service module, but that may be because I was closer to the command module and I watched it. Also, in regard to the service module evasive maneuver after separation, it was very clear what was taking place. You could see those particles streaking out.

EVANS I guess the other thing is, whenever an engine fired at night or on the dark side of the spacecraft, you always got a white flash.

SCHMITT Fuel cells were perfectly nominal as far as I could tell on board, and the ground didn't call anything. The one switching anomaly we had was that, in the process of some activity, one

SCHMITT (CONT'D) of the fuel cell pumps got turned off, and I don't have any idea how that happened. It obviously happened on my watch, and they caught it within 5 minutes.

EVANS Well, I turned the laser altimeter off one time when trying to maneuver to a position to see out the window. My feet were flailing all over the place, and I kicked them off with my toe. I must have. So, I think that's probably the same thing that happened with the fuel cell.

SCHMITT In high power loads, we did see some caution warnings on the O_2 purges, which I didn't expect to see, but it was just barely triggering the high flow. The ground called saying not to worry about it. The batteries were nominal as near as I could tell. I never did quite figure out whether the ground was concerned about the vent pressure after charging because it hung at 0.6 for a long time and then gradually creeped up. They didn't seem bothered enough about it to discuss it with us, so, I ignored it too. It was always within limits. The only thing that I was a little bit surprised at is that they left the batteries uncharged longer than I had expected. I expected more calls. We never really got our entry batteries charged up until the day before entry. We had time to charge them before then. It seemed to me that after TEI we waited

SCHMITT (CONT'D) a long time to get the batteries back to charge, but that's a minor point.

We launched with our batteries down more than normal, so that's probably what started us off in a real-time call in the battery charging because we left battery A charging - I think it was A first - for a long time, practically 24 hours, I think. I'd have to go back and look, but it was a long time recharging. And when we put it on, it carried over 2 amps on the battery charger, which is impressive because in the simulator you never see more than 1. The battery charger was, as far as I could tell, perfectly normal.

Caution warning - Very soon after insertion, we got something like 7, if I remember correctly, before we had comm with the ground again, spurious master alarms. It gradually became evident to us that it was associated with switching panel 2 switches. Ron hit it with a helmet once. It was with the neckring, and he got an alarm. During the pressurization for the first LM entry, we got a couple more. I thought it might be associated with a higher pressure cabinet. That's the only other correlation with that anomaly. I guess after that, we never saw it again.

EVANS Well, one thing we want to mention is that we never got a caution warning light.

SCHMITT The gages - There were no anomalies or power levels that I jotted down at various times to keep track of any possible shorts. Things seemed to be perfectly normal, and anytime it jumped up, you'd always be pretty confident that you could look up and see that the O_2 meter should have come on. There was one time when I thought I saw a major blink on the lights when we weren't expecting any power surge. The ground couldn't find anything on their records, and I suspect it was my imagination.

AC, nothing - I was surprised as I always am, and I've seen it in the chamber that the AC-1 voltages were as low as they were. They are right down at the lower limits, but they're not below the limits. We've asked that question in chambers, and nobody ever worries about it, so I'm sure that's standard.

AC inverters, perfectly normal - We did run inverter 3 for a while as a heat source when the cabin got cold during some of the weird SIM bay/transearth coast attitudes in conjunction with manual control of the mixing valve.

Main bus tie switches, no problem - One surprising thing was the first time I put them on at launch, during the first try

SCHMITT (CONT'D) at launch, the fuel cells apparently were performing much higher than I was used to seeing on the GSE in the chamber. Very little current was drawn from the batteries.

My normal mode of monitoring the bus ties to see if they got it or not was to watch the battery amps, and in those particular cases, I got no indication (for a few seconds anyway) of any amps off the battery. Gradually, a little came up and you could see there were 2 or 3 amps. Then when we checked the gimbal motors. (The batteries were not a good place to check the gimbal motors.) I went to fuel cell amps to check gimbal.

EVANS I always used the fuel cell amps or the O_2 flow.

SCHMITT On the simulator, I always used the battery flow. That's another thing I might mention is that the H_2 and O_2 flow in the fuel cells aren't any good for that because they're too sluggish, much slower than the simulator. The simulator reacts instantaneously to changing loads, whereas the real fuel cells are quite sluggish in their reaction. The sensor bus switch, we turned off once for EVA.

The cryogenic system - The ground was playing games with the H_2 fan because of a thermistor shift, scale change or something like that. We did a lot of manual switching on their call, but that was no inconvenience whatsoever because they

SCHMITT (CONT'D) had a sleep configuration that they could go to and it didn't bother us at all. One thing, it seemed that we, at least as far as the tank pressure was concerned, carried our H_2, $\perp$ and 2 tanks, with us after the service module jettisoned. I don't know why.

EVANS This is a good point to mention, the surge tank was biased a little bit low, too.

SCHMITT That's right, but we were alerted to that. It performed just as the alert specified.

Cabin lighting controls - One thing we didn't use initially but used later on transearth coast was the fixed position being brighter than the maximum on the restat.

EVANS I used that a couple of times trying to get enough light in there to use a camera.

SCHMITT Split bus operations - They worked fine.

EVANS Oxygen masks - We never took them out of the bag. With the gassy situation in there, I was tempted to, but we never did.

We very seldom, utilized the cold water dispenser.

CERNAN Most of the cold water came out of the gun.

EVANS It was handier; that was the reason. You wanted to keep the hot water hot so you keep it going. The water-gas separator stayed on the hot water tap, and we always ended up with gas bubbles generally of about 1/2 to 3/4 inch in diameter in the hot drink or hot beverage, things like that. In the cold water, drink gun, seemed like there were a lot of very small bubbles - just little bitty ones maybe a centimeter in diameter that would end up in the drink gun.

SCHMITT The hot water bubbles were bigger.

EVANS Suit circuit - No problems.

We mentioned the difference in the bias on the surge tank already.

CERNAN The waste management system was all right as far as the CSM was concerned. I still think it's a poor system from a standpoint of hygiene in waste management control. I made that statement in different sections and I'll specifically say any time you use a condom-type system you want to make the valve end of the condom of a larger diameter so that whenever you reroll it for the next use, you can reroll to a larger diameter and get your penis as far up in the system or towards the valve that you possibly can. If you don't, you have to

CERNAN (CONT'D) stretch and pull the condom and half the time your penis might be part way in and half the time it may be all the way in. Any time it's not all the way in the condom, you can almost invariably end up with urine residual in there that has to be cleaned up in one way or another, in spite of the fact that you tend to push it through the valve like it's recommended. The entire system still needs improvement.

EVANS It still needs improvement and in *my* case the condom was *too* small. In other words, I anticipated a shrinkage and the shrinkage did not occur.

CERNAN I did too but I think what I just mentioned would tend to solve that. It's getting it over the head really.

EVANS That's right. That's right. We said everything we want to say about waste management.

We stowed everything in the waste stowage compartment except for two feces.

The CO_2 absorbers - No problems this time. Nothing sticking.

CERNAN Telecommunications - The whole thing was nominal.

EVANS The high gain worked great. There wasn't any problem with that.

EVANS (CONT'D) DSE operation - Ground handled most of it and where the ground did not and the CMP was required, we just said configured and we did it that way.

Tunnel and hatch probes - All operations were nominal with the exception of the things that are noted on the air-to-ground tapes about the docking latches.

SCHMITT (CONT'D) the exception of gyro cal, I think it was Z on the first activation, was slightly out of spec. Not out of limits but just slightly out of spec numbers that were given to me by Jerry Thomas, which was 0.3° spec limit. I think it was 0.5 or 0.6.

Rendezvous radar navigation on the AGS was done in AUTO with the exception of the post midcourse 2, where we put in three sets of marks manually in order to maintain the AGS state vector as close to docking as possible. The AGS state vector did just that - maintained itself within 2 ft/sec and was right with the PGNCS on range at the initiation of braking. Actually it was better than that at the initiation of breaking about 500 feet it was still within two feet per second.

Engine commands - All the engine discretes seemed to get into the AGS. The ground did not mention a single anomaly and I saw none on board. There were no electronic anomalies. Burn programs were perfectly nominal. In monitoring the DOI 2 and the midcourses, the AGS, as expected, did not see the short burst trim pulses that Gene made with the TTCA. The acceleration levels did not seem to be high enough to be sensed by the AGS external Delta-V.

Controls and displays were excellent. After every 400 plus 3 X, PGNCS alined. There seemed to be about a quarter-degree constant bias between the AGS and the PGNCS alinement in pitch and

SCHMITT (CONT'D) yaw. I think it was a combination of pitch and yaw. A little bit of motion on the ball switching from PGNCS to AGS. One further thing on calibration - there seemed to be an accumulating accelerometer bias in X that was well below any significant problem. Probably something like 0.1 ft/sec. I noticed this after the first cal and then after insertion. After insertion I did do an accelerometer cal, 400 plus 7. That seemed to improve the problem although it did not eliminate it completely. It was not a serious problem with the AGS monitoring of its state vector.

CERNAN AGS control check - I checked it out in both pulse initially. I checked all three axes out in pulse. I got the continuous rapid fire pulses. It checked out in three axes. I checked it out in rate command both for command and attitude hold. And it was a very tight system. I checked it out in min deadband only. It was GO. There was absolutely nothing wrong with the AGS system either during powerup or during the phases of checkout.

19.3 PROPULSION SYSTEM

CERNAN The descent burn was extremely nominal in all respects. We monitored the start and attitude hold was steady. I monitored the throttle up on the PGNCS, watched the PGNCS command it, and watched the descent followthrough. It was 100 percent on

19.0 LUNAR MODULE SYSTEMS OPERATIONS

19.1 PGNCS

CERNAN PGNCS inertial subsystem performed exactly as advertised with the initial powerup and with the lunar surface powerup. We did not get a restart light on the initial powerup. That was the only thing we did not get on the initial powerup. The ground said it was a GO.

I was a little disappointed in the AOT. It really performed like the simulator did. I could split the image on the reticle, both on the XY axis and the spiral cursor. By a slight movement of my eye, left or right or up or down, I could place the star within the reticle optical line of sight. I had to try and find a neutral position for my eye on the eyepiece so that I could be consistent in every one of my marks. That bothered me a little bit on the initial alinements until I got a constant position. That's something that, if I flew a lunar module again, I'd certainly like taken care of. The alinements came out good. But they came out good because I found an eye position where the star was focused and where the reticle was focused. I could put the star within the confines of the reticle for a good solid alinement by simply eye movement and not spacecraft or spiral cursor movement.

CERNAN (CONT'D) Rendezvous radar power up and checkout was outstanding in performance during the rendezvous. No anomalies. The landing radar was not only without anomalies, before we started our 70° yaw we started to pick up some indications of radar lockon. I was about halfway through the yaw to the 340 position during the landing when the radar locked on solid. Don't remember exactly what altitude that was, but it was far in access of 35 000 feet.

SCHMITT I think I did two or three PGNCS landing radar checks starting at about 2000 feet. They were within the motion of the tape, exactly on with each other. No anomalies there.

CERNAN Computer subsystem - I utilized the computer exactly like the simulator in terms of verbs and nouns during descent and ascent. Every one of them came up in what I called the prescribed amount of time. We never had any overload master alarms. We never had any program alarms. We never had any anomalous program alarms. It was a duplicate and repeatable of the way I handled the computer in the simulator. Exactly.

G&N controls and displays - The DSKY speaks for itself, The displays that came up on it were exactly what were called for both in the power up in the descent and the ascent. The other two primary displays are the needles and the crosspointers. During descent, the P64 needles again were nominal in terms of

CERNAN (CONT'D) what the simulator told us they would be. The P66 needles in terms of fore and aft velocity were again exactly what I'd seen in the simulator in terms of fly-to needles to null the lateral velocities.

Crosspointers - I matched the crosspointers in terms of forward and lateral velocity with what I saw out the window in P66 for final landing. That is lateral velocity on the crosspointer was effectively zero, and I agreed with that out the window. The forward velocity was probably 1 to 3 ft/sec on the cross-pointer. The best estimation of my forward velocity out the window is that I had some. So, again, they were nominal.

Procedural data - The checklist, in terms of the flow through the power-up through the descent, and through the ascent, were well written. The PGNCS performed exactly as advertised in every respect.

SCHMITT As we said about the CSM checklist, I don't think we had any changes to checklists that reflected any procedural errors prior to launch. I don't think we had any changes to the check-list that I can remember. The checklists worked perfect as far as I am concerned.

CERNAN Let me back up and say something more about the PGNCS. The only time that the PGNCS surprised me was after TPI, when we

CERNAN (CONT'D) had large residuals that I had not seen in the simulator. We had residuals in the area of 7 ft/sec in X and 4 plus or minus a few tenths in Y and Z at the end of the short nominal TPI burn. The simulator residuals were always much less than that. We had no problem. We just nulled them out with the RCS. But, nevertheless, they were there and it was about a 3-1/2 to 4-1/2 second burn. That surprised me just a little bit. We don't have the exact numbers written down because I rolled the residuals right away and went right into P35. I do know they were 7, 4 and 4 plus or minus a few tenths, Prior to descent, they gave us a zero gyro drift compensation. They said the PGNCS was right on. However, right after orbit insertion, it looked like we might have had some g sensitive drift in Y.

SCHMITT You did. The AGS saw it.

CERNAN. For rendezvous navigation and the short rendezvous burn, we did not see any effect of it at all.

SCHMITT The ground tweak was 7 ft/sec and the AGS would show 9 in the same direction.

19.2 AGS

SCHMITT Modes of operation - Nothing off nominal was used. Initialization went perfectly nominal. Calibration, the sighting with

CERNAN (CONT'D) the indicator, on time at 26 seconds. We saw a throttle-down again within a few seconds of that predicted from the ground, but exactly on time with that which we saw commanded from the computer.

The ROD, during the last phase of descent, during P66, responded extremely well. I knew exactly what rate of descent I had simply by the number of clips I put into the ROD.

Descent and ascent was a nominal operation as prescribed and as we saw in the simulator.

SCHMITT The one thing we previously mentioned on caution and warning was that we got a descent quantity light after touchdown by several minutes, presumably due to either fuel sensing or or an actual fuel leak.

19.4 REACTION CONTROL SYSTEM

CERNAN Attitude control modes - I flew it most of the time in pulse. After rendezvous for stationkeeping, nominal operation in all modes, nominal operation attitude hold in AUTO. Translation of control was nominal for ullage and for stationkeeping.

SCHMITT The RCS ascent feed was good. We might add here that we did have a transducer shift in the ascent helium tanks. Tank 2, I believe, was reading hot. I believe that was what the ground

SCHMITT (CONT'D) called it as. They seemed to think they had a mixture ratio problem. They weren't completely sure. They had us terminate ascent feed early. It must have been 5 minutes or something like that. We terminated that early but there was no Significant degradation in our RCS capability.

CERNAN Every explosive device in the spacecraft audible.

SCHMITT Except one. That was the second landing gear. Didn't you say you didn't hear that?

CERNAN No, I heard it too. I could feel it when I hit the switch.

SCHMITT I thought you said you didn't hear that.

CERNAN The first landing gear operation, we felt, of course, the landing gear go out. The second one I could feel, in the switch, the activation.

19.5 ELECTRICAL POWER SYSTEM

SCHMITT The batteries were excellent. There were no battery anomalies. The DC monitoring was no problem. I might mention that the ascent batteries did seem to require longer than nominal warmup time, although I do not believe it was longer than expected with reference to the ground. We unfortunately got started 4 minutes late so we flew the first part of powered descent

SCHMITT (CONT'D) with battery 3 off the line in order to increase the load on the ascent batteries for preconditioning. That was not a problem at all. Battery 3 was put on somewhere in powered descent without any interference with that operation. DC monitor was fine. AC monitor was fine.

Power transfer CSM/LM/CSM went nominally in every case. Abort stage configuration - Nothing to discuss that would be off nominal. Main buses performed nominally and dead facing was nominal.

Explosive devices in all cases seemed to perform as expected. We heard the pyros, I think, in every case except possibly the second set of pyros on the landing gear. That might be expected, not to hear those. We heard the first, but we may have been really hearing the bolts let go and the gear start to move into place.

Voltages were unchanged throughout the whole flight. Lighting - There were no lighting anomalies. Caution and warning - No anomalies. There were one or two configuration caution and warning signals which will come under ECS. What was that caution and warning we got right at the end of descent?

CERNAN Descent?

SCHMITT Right af'ter touchdown.

CERNAN No. All we got was descent quantity.

SCHMITT That was after we vented, wasn't it?

CERNAN No, it was before we vented. The descent quantity did not come on until after we landed and when we went through all the ascent checks. The fuel side was going down all the time. We never talked about it; we never asked.

SCHMITT We don't know why that happened. That's right. The fuel side af'ter touchdown continued to decrease. Sometime into the post touchdown pre-vent checklist, we got a descent quantity light. That was the only caution and warning anomaly.

19.6 ENVIRONMENTAL CONTROL SYSTEM

SCHMITT Oxygen cabin pressure was nominal except for a leaky main A reg, which potentially was caused by having my hoses stowed at one time with the suit in suit flow. That's up to the systems people to decide. But it did reset itself on time. It was not a serious leak. After that time, we did fly with only reg B in use. It was pretty clear that A was a usable reg; it just was leaky.

Cabin atmosphere was good, good ventilation, good odor clearing. The dust clearing was remarkably good, considering the amount

SCHMITT (CONT'D) of dust that we had. It was within a couple hours after ingress. Although there was a lot of irritation, at least to my sinuses and nostrils, soon after taking the helmet off, about 2 hours later, that had decreased considerably.

CERNAN The LCG cooling was perfectly nominal.

The LCG cooling, I think, was a mandatory requirement pre-descent and pre-EVAs. I don't think the air cooling in the spacecraft was adequate prior to descent, which I said a long time ago, back several missions. This was really a godsend. We did not wear the liquid-cooled garments out of our own choice for ascent rendezvous, and I was very comfortable during that phase of the mission.

SCHMITT Yes. I think had you worn them and not had cooling, you would have been uncomfortable.

CERNAN Water supply. My first impression was that, after the first several gulps of water, there was a lot less gas in the LM water than in the command module water.

SCHMITT True. We used all our water. We essentially ran dry at ascent. We drank a lot of water and we even used some additional water on our hands. Water glycol was nominal, and the suit circuit, with the exception of what I mentioned about REG A, was nominal.

19.7 TELECOMMUNICATIONS

SCHMITT There was no problem monitoring the comm system. Operation of S-band high gain antenna was variable. We had some initial problems on the housekeeping day of lockup. It seemed to me to be a ground problem. I don't know their final resolution of that. It seemed that the same kind of thing happened to us on ascent, and again when we came around the horn prior to PDI. It seemed to be a ground lockup problem because it happened on the omnis as well as the high gain. We were just not getting a good strong uplink signal. I don't know what else to say. On ascent, as soon as we lit off, we lost the high gain, went over to omnis, and the omnis were giving the same indications - low signal strength, lots of noise, and a high squeal. Not a real high squeal, but an obvious squeal. It wasn't until somebody else did something that we got the comm back. I did not get the comm back; it just came back. We came through the command module for a little bit. Then they instructed me to do things I'd already done as far as going to the omnis and stuff, and then suddenly they came back up. So, I'm not sure what happened. But when we had S-band comm, it was excellent. Excellent voice.

CERNAN The VHF comm after separation and throughout rendezvous was excellent.

SCHMITT That's right. There was a little bit of a problem close in. I think, again, it was a question of overdriving too much.

CERNAN The EVA antenna operations were all right, but the EVA comm was excellent throughout the first two and a half EVAs. The latter part of the third EVA, I began to get some noise in the background that the LMP did not get. It did not *make* the comm unreadable, but the noise was very evident. That lasted throughout the closeout of EVA-3. The LMP had no significant comm problems on the EVA, and had excellent comm. Procedures and operations of the audio center throughout the LM checkout and EVA changeover setup was nominal. It worked just as advertised.

SCHMITT Flight recorders - I have no idea. I should mention that I probably left the LM DSEA on during the third EVA, because it was barber pole when we got back in. I suspect that we ran out of tape at that time. My regrets to Don Arabian.

20.0 LRV OPERATIONS

SCHMITT LRV deployment was nominal. Didn't we almost slip out of the hinge pins there once?

CERNAN I think they dropped into them. The walking hinges did not drop. They were locked in, as we reported. It seemed to have fallen into the hinges. That was the only time when there was a slight jolt. Throughout the mechanical deployment, which followed the procedures as written, she came down just as advertised and broke loose from the saddle just as advertised. The setup was nominal.

SCHMITT We did have to push the hinge pin in.

CERNAN I went back and reset a forward hinge pin. One out of the four hinge pins was not locked in; the yellow was not flush.

Mounting and dismounting was simply a case of getting acclimated as to know how to mount and how to dismount. The biggest problem with mounting and dismounting was to be able to mount without kicking dust all over the LCRU.

SCHMITT In my case, the problem was keeping a twist out of the lap belt, which made it difficult to unbelt.

CERNAN Mounting on a slide slope aided dismounting.

SCHMITT Almost all in one motion.

CERNAN Vehicle Characteristics - Power-up - when I pushed in the Bravo and Delta circuit breakers, the gages came up just. as advertised. Occasionally, I could feel a little wheel slippage. To the best of my knowledge, I had four-wheel drive and fore and aft steering the entire time, nominal.

The braking action was good.

As a matter of fact, on some of the extreme downslopes we were on, I had to brake continuously and stay below 18 kilometers. We barely hit 18. I had in mind the fact that the brakes could fade on you. We came down some pretty steep slopes at some reasonable speeds, and I had to brake the entire time. I worked the brakes on and off. I had no indication of brake fading at all. I never felt that I was going to lose control because of lack of braking.

Acceleration - Although we could never really go in a straight line very long with the Rover because of boulders, craters, or general terrain features, I drove the Rover full out a majority of the time. Apparently, we were going upslope, especially out to station 2. I was between 10 and 12 kilometers most of the time, and that was at full throttle.

CERNAN (CONT'D) I was a little bit surprised that full throttle did not give me a little bit better acceleration and a little bit better top speed.

SCHMITT I think that 1° upslope was probably there.

CERNAN However, the acceleration when you hit a definite grade or change in grade, you could feel that the capability to climb that grade was always there. In spite of the fact that maybe you slipped down to about 8 or 10 km/hr, you always felt that you had the torque and the power required to make that grade. I never felt that there was a grade that we tried to negotiate that I didn't have the capability to getting over with the Rover. Never.

Steering and Slide Slippage - In 1/6 g with fore and aft steering and four-wheel steering for you, you've got a vehicle that is ready to react the minute you think about putting the command in. Much of the time at the speeds we were driving, as soon as that steering and side slip and sharp turn command went in, you were on three wheels. The reaction was that that you did get side slip. I did feel that the majority of my more rapid or sharp turns, I'd say 50 percent of my driving, resulted in losing the back end on some of my turns. I don't know whether you felt that on the right side, Jack.

SCHMITT Yes.

CERNAN I was comfortable in doing it because I expected it. I felt that in keeping a reasonable speed, the rear end broke loose from me on 50 percent of the turns during my entire driving on three EVAs. It's a vehicle that you have to drive to get accustomed to. It's one you approach slowly, and then you begin to peak out and you begin to live up to its maximum performance capabilities.

You can avoid obstacles very easily. The only hesitancy in doing so is that it requires the same sharp turn and generally your rear end will break out. The turning response is phenomenal.

I was a little disappointed or surprised at maximum speed on what looked like a relatively level surface, which may have been a 1° or so upslope. It was not quite as fast as I thought it might be. Coming down that slope, we did a lot of zigzagging going to different stations. So I didn't get the full brunt of coming back down the same slope. Basically, I felt I could get more top speed out of the vehicle, not that I needed it, but there were times I could have used it in negotiating the surface.

CERNAN (CONT'D) Torque - I don't really think I required more torque. I never lost the wheels going upslope, although I did feel the vehicle working, and you could see it in the amps that you were drawing going up some of those slopes. You could also feel it in the top speed. Again, there was ample torque to negotiate the slopes that we had confronting us. Some of those slopes, subjectively, were quite steep.

Controllability - You had to learn - just like you have to learn on most other vehicles that are essentially like that - to be gentle and smooth during the control. Sharp commands would tend to leave you without the rear end on the ground or leave you with the rear end not exactly where you wanted it. So controllability was excellent, but I felt it was very sensitive.

Crew Restrictions, Limitations, and Capabilities - Displays - I could see and read all displays all the time except when we got dust on the checklist down in front of the hand controller. Then that display became effectively unreadable until I could get off the Rover at the next stop and dust it.

Hand controller operations were as advertised, very similar to the trainer. I used reverse twice, and it worked. I don't recommend it as a standard mode of operation. It's much better to have the vehicle set up for forward only control capability.

CERNAN (CONT'D) My seat and foot rest were, as far as I'm concerned, perfectly adjusted and comfortable as far as position. How about yours?

SCHMITT Fine.

CERNAN Crew Movement Within the Suits - As far as driving the Rover was concerned, I had the same right arm restriction as far as getting my arm back and driving the Rover. But I had no wrist problems as on some of the previous flights. I wore no wrist-lets. I did not rub my wrist raw. I had all the wrist commands. I think that's just a function of where your arms fit in the suit. I had absolutely no wrist movement problems at all. I sat in the suit high enough to be able to see down at the displays and out in front of me. The only restriction I ever had in driving the Rover, out in front, is where coincidentally the last parking angle left the high gain antenna at a planned view. Then I had to look through the high gain antenna. Then the tendency to lose the view beyond was a little bit greater.

Seat Belt Operations - On the left side, I could not have tolerated my seat belt any smaller. It kept me in tight. I felt that I would never lose the Rover. I felt that I'd stay

CERNAN (CONT'D) with the Rover even if we did a 180° roll. Yet it was loose enough to get in and out of. It might be because of just generally getting a little bit more tired, but certainly during the third EVA, I found it occasionally was a little harder to release. How about your side?

SCHMITT Much the same. I mentioned that the seat belt got twisted occasionally. I suspect that made it harder to get out. Being tired, I'm sure, had something to do with that.

Let me skip back up to crew movement within the suit. The only time there was any significant movement was when we were on side hills and moving around all the contours. I noticed I was leaning against the side of the suit, which increased the impression of being on a steep slope.

CERNAN During the lunar Rover samples, the commander was able to take the sample from the LMP and was able to reach over and drop the sample in the LMPs sample bag without any difficulty at all. This was repeatable, based upon ground training. Exactly the same.

SCHMITT The Rover sample worked exactly as we had planned. No changes at all.

CERNAN The vehicle suspension characteristics were outstanding. I negotiated some intentionally, some unintentionally. I negotiated some relatively good-sized rocks, 10 to 12 inches or so, head on with the suspension system and the vehicle just walked right over these rocks without any difficulty at all. I tried to straddle the smaller craters so that we wouldn't get any side slope. In driving the vehicle, the major effort is to deter yourself from side slope activities, whether they're little craters or large craters. So you try and go down through the center of the craters if they're not too deep. If they're small craters, you try to straddle them. We went through some relatively major boulder fields, and the vehicle suspension just accepted it without any difficulty at all. I never felt that we bottomed out. We never bottomed out in terms of the wheels taking a boulder. However, we did scrape bottom once or twice in going over some boulders, centering some boulders.

SCHMITT I never went back to look, but you mentioned you looked like you'd bent a wheel. Is that right?

CERNAN I mentioned something about a golf-ball-size dent in the left front wheel. I inspected all the wheels after that. The left front inboard wheel was bigger than a golf ball. If you

CERNAN (CONT'D) took a fist and just crunched the inner side wall, just punched it and you left an impression of your fist in it, that's about what I saw in that left front wheel. The impression was probably no more than a half an inch to three-quarters of an inch deep and a radius about the size of your fist. None of the other wheels had it because I inspected them after I saw this one. As far as driving characteristics are concerned, you wouldn't know it was there.

Hand Holds on the Vehicle - The hand hold I used most to get in was the low gain antenna on the commander's side to help me to get in a proper position for strap in. Any other hand holds on the vehicle were really relatively useless, particularly in adjusting the high gain and what have you, because the vehicle when it sets by itself was a very unstable vehicle. The tendency to move or shove or lean the vehicle one way or another was very great.

SCHMITT I usedthe accessory stands as my hand hold for mounting and dismounting.

CERNAN LRV Systems Operations - The nav system was excellent. I saw the same characteristic digital movement of the gyro that we saw in LRV sim. But it certainly didn't hamper the operation of the nav system.

CERNAN (CONT'D)

Power Batteries - The temperature on the right number 2 battery was higher at initial powerup. We started powering up at 120°, which I think surprised everybody, including me. It stayed hot, although they both cooled down relatively. It stayed hot throughout the mission. At the end of the third EVA, it was above 138° or 140° and gave us a flag.

Steering and Traction Drive - I wiped out the hand controller as we had planned to prior to the flight about 6 or 8 times before powerup to remove any lubrication problems due to thermal characteristics. The minute I powered up (and you saw it), to the best of my knowledge, I had both front and reverse steering.

Voice Communications and Antenna Management - Antenna management, because of the extensive preflight planning, was excellent. I had no trouble in handling the high gain. I could pick up the Earth and center it. It was there. I just sighted it and looked through, and it was there. I tweaked it up, and there was no problem at all. The low gain antenna, except when we did 360° pans, which I did not bother to adjust at low gain antenna following on the part of the commander to keep us within plus or minus 10° to 20°, was a simple task. It did not require any undue attention.

CERNAN (CONT'D) TV/TCU - Up until the time it failed after lift-off, the TV/TCU worked very well.

Electrical and Mechanical Connections - The only connection I really had trouble with, electrical/mechanical connection, was the SEP connection to the LRV. I had to support the connector bracket with my left hand in order to get enough force on the SEP connector to mate it and lock it to the LRV.

SCHMITT That's the standard EMU connection.

CERNAN That's the standard EMU connection. The only other thing I'd like to mention about the LRV is it's about 99-percent required effort. Even to take a drink of water from the suit drinking bag during LRV driving could put you in some very embarrassing situations as far as following your terrain, craters, and what have you. It was almost 100-percent requirement.

SCHMITT Geology Science Site Response - You've covered pretty well how the Rover performed on various kinds of terrain. Gene, why don't you describe the fender? That was the major dust problem.

CERNAN With the loss of one of the fender extensions, any one of them, the dust generated by the wheels without fenders or without fenders extensions is intolerable. Not just the crew gets dusty, but everything mechanical on the Rover is subject to dust. Close to the end of the third EVA, all the mechanical devices on the gate and on the pallet in terms of bag holders and pallet locks and what have you were to the point that they would refuse to function mechanically even though the tolerances on these particular locks were very gross. They didn't work because they were inhabited and infiltrated with this dust. Some could be forced over center. Others just refused to operate even after dusting, cleaning, and a slight amount of pounding trying to break the dust loose. I think dust is probably one of our greatest inhibitors to a nominal operation on the Moon. I think we can overcome other physiological or physical or mechanical problems except dust.

SCHMITT What we're really saying is that in any future operation, mechanical joints or levers and this sort of thing are going to have to be protected.

CERNAN They should be sealed or protected. We had absolutely no dust problem with the wheels, and those are sealed units. Dust accumulated on the radiator.

SCHMITT That goes for tools too. The only tools we had locks on were the scoop and the rake, and those were getting stiff and wouldn't lock. They wouldn't relock once you adjusted them.

CERNAN The period of time when we had lost the rear fender just put a solid coat of gray dust over everything. Once we got the fender repaired, the dust problem was at a minimum. After the long traverse rides, the radiators all required a good amount of dusting. That required X amount of time. That's going to be required again any time we have a lunar surface operation.

Payload Stowage - Jack, do you have anything? Initially, during EVA-1 prep, I think everything fit under the seats or on the pallet. The pallet fit on the Rover exactly as advertised. The SEP, the deployment of the SEP, the setup of the charges, and the charges on the pallet all fit.

SCHMITT I'm sure we'll get into this in the system experiments, but as a general comment for any radiator surfaces that need to be protected, you need to have more than just a cursory design on the protection of those radiators. The SEP is the case in point, and that was a completely inadequate design to protect those radiators. If we ever do it again in a dust environment, you must have clear and very tight protection of your mirrors and radiators for driving.

CERNAN Something else that dust penetrates that I don't think has been mentioned before is that it penetrates and deteriorates the capability of Velcro. I could see it on the LCRU covers and the SEP covers. The Velcro pulled off to keep the SEP covers closed, but the Velcro that kept them open didn't pull off but it was deteriorating. If you want to use tape on the lunar surface after what you're taping has been exposed to the dust, you first have to clean that surface off with a piece of tape or something and get the mirror dust off before the tape will even begin to adhere to the surface you're trying to apply it to.

SCHMITT We ought to mention here that the gray tape in general is not very good. It will stick to itself, both inside and outside the spacecraft.

CERNAN I had the impression that the gray tape has been sitting around for 10 years. That's the kind of adherence you had.

SCHMITT The tape on the food bags is what we finally used whenever we needed to really tape something. It is much better tape.

CERNAN The gray tape is very poor tape. We covered the stowage, which went exactly as planned. We had no fit problems with stowage or anything on the Rover.

21.0 EMU SYSTEMS

CERNAN PGA Fit and operations - The CDRs suit fit perfectly, including gloves.

SCHMITT The LMPs was an excellent fit,

CERNAN Doffing and donning were just as we expected. The CMP may update this, but as far as we're concerned, he had no gripes or qualms getting his suit on and off.

SCHMITT I think he will have some comments.

EVANS On item 21.0, EMU Systems, everything was normal with the exception of the CMPs prelaunch drink bag. Try and try as I might to get water out of it, I couldn't. After finally getting the suit off in the spacecraft, the drink bag in suit donning had somehow become stuck sideways underneath the neck ring bending the little rubber hose that we drew the water through. It did not allow any water to come through. The drink bag was filled, and it did not expand noticeably from any air that may have been in it. The problem was that it wasn't in vertically. It was kind of wedged in crossways around the neck ring. Everything else from the CMP suit worked adequately.

CERNAN Biomed instrumentation - I think to varying degrees of individuality that we all had sensor skin problems.

SCHMITT Yes, those are documented by the medics. Let me just say that I wore a set of connectors for the whole descent through ascent time frame, and when I took those off in the command module, the electrolyte from a couple had completely disappeared. It obviously reacted with the skin and left sort of a semiscab. It wasn't a bloody scab.

CERNAN The commander had that too. We both had that problem.

SCHMITT If you have the time to change them out each day, it's probably not a bad idea. We just didn't take that kind of time.

CERNAN The LCG operation was nominal. We doffed the LCGs after the EVAs, slept in CWGs, and donned them for the EVAs. It was a very comfortable mode of operation.

SCHMITT I really am surprised that other missions have slept in their LCGs. It just seems to me that this would have been very uncomfortable.

CERNAN Helmet operation - The CDR's was nominal.

SCHMITT The LMP's was fine.

CERNAN You had your visor stuck.

SCHMITT LEVA operation - I did have the sticky visor problem, and it was dust. We could force it closed, once we got it off. We tried once on the surface, and we couldn't get it closed.

CERNAN That was the hard Sun visor.

Lifevest - No comment; nominal. The gloves fit well and tight, and I don't have any gripes.

SHEPARD Did you use the extra set?

CERNAN The extra set is brand new and sitting on the surface right outside the descent stage.

Neck seal - We had no problems sealing the LEVAs, helmets, or anything.

UTCA operation - The CDR used his at every opportunity. I always had a bagful.

SCHMITT I suggest that considerable thought be given to the size of condom that you pick. Mine was too small, and it inhibited the operation of the UCTA. It was a very uncomfortable situation on both EVAs, until I was able to force a urination. After the second ohe, I apparently popped a blood vessel. There was blood, but it disappeared after 24 hours.

CERNAN I ended up with an external scab during the lunar surface EVAs from the sweat,and the condom. It went away.

SHEPARD Was it an abrasion problem?

CERNAN I think it was an abrasion problem. I could not have a larger one because I don't think it would serve the purpose. It was just a lot of work and a lot of walking, and that's all there was to it.

SCHMITT For the third EVA, I stretched the condom and it worked fine.

CERNAN The EMU maintenance kits were fine. We used them as required, as planned.

SCHMITT The drink bags were excellent.

CERNAN Let me say something about the drink bags. We rotated that nozzle 90 degrees. We said it would work in training. I didn't know that drink bag was there until I wanted to get a drink of water. It never interfered with the mikes. I wore it on descent to the surface, on the surface, and drained the bag on all three EVAs.

Ron's bag at launch was doubled up. He can talk about that. They just put it in wrong.

SCHMITT Before you leave the drink bag, there's something down here for the food stick. Neither Gene nor I used all our food stick. I think it was a good idea having it there.

CERNAN I used about half of mine most of the time.

SCHMITT I never felt an extreme desire to eat at all. Every once in a while, I would take a little chunk off of it.

Antifog was fine,

CERNAN There was no fog problem.

The PLSS PGA operations were again nominal as planned. Pressurization and ventilation were good. Liquid cooling was excellent. I never worked for any long duration in high cooling, with maybe one or two exceptions. And generally, I used high cooling only when I was hot and wanted a spurt of cold water. Probably 90 percent of the mission, I worked in medium cooling.

SCHMITT I never went to high, not once.

CERNAN Is that right?

SCHMITT I was in intermediate-intermediate, which is a little better than intermediate.

CERNAN Communications on the surface were good even before we got our antennas extended. I didn't notice any difference after the antennas were extended.

SCHMITT I did, just a little bit. It was a little less scratchy.

CERNAN Connectors and controls were good on the PLSS throughout the flight. They are the one thing that did not seem to get

CERNAN (CONT'D) affected by the dust. They might have gotten a little stiffer, but I could not tell it.

The RCU was good. The RCU fit and operated well. We did not use the OPS.

SCHMITT Let me comment on mine. After the third EVA, we reset the regulator, and that's why we brought the CDR's PLSS back rather than the LMPs.

CERNAN I think Jack activated his OPS with the hose free for just a moment. I think that reset the regulator. Instead of regulating at 39, it then started regulating at 43.