[redacted]

197

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

cy to CCK Div

APOLLO 9 CREW TECHNICAL DEBRIEFING

(U)

AS 504/CSM 104/LM-3

Prepared By

MISSION TRAINING SECTION
MISSION OPERATIONS BRANCH
FLIGHT CREW SUPPORT DIVISION

MARCH 20, 1969

GROUP 4
Downgraded at 3-year intervals; declassified after 12 years

CLASSIFICATION CHANGED TO Unclassified
BY AUTHORITY OF EO 12356
1 Aug 82
DATE 11 Aug 82

CLASSIFIED DOCUMENT - TITLE UNCLASSIFIED

This material contains information affecting the national defense of the United States within the meaning of the espionage laws, Title 18, U.S.C., Secs. 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.

MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

~~CONFIDENTIAL~~

CONTENTS

TABLE

1.0 SUITING AND INGRESS

1.3 Life Support Equipment

SCOTT — I'd like to comment on the POV's that we had on launch day. They were improved over the ones we had for CDDT for about the first 10 minutes of their operation. Then they started to cool down, and the inlet temperature got pretty cool by the time I was ready to ingress in the spacecraft. I think something needs to be done to keep them from getting too cool.

1.8 Ingress

SCHWEICKART — During CDDT, we had all decided that we wanted to be strapped in in a reasonably loose manner rather than very tightly, and I think that all of us felt that that worked out quite well. On the launch day, when Clyde Teague strapped us in, I was quite comfortable, and the shoulder straps weren't too tight. I could reach the gearbox handle and also the pump handle selector with relative ease. I never felt any lack of security anywhere

SCHWEICKART through the launch because of being relatively loose in the straps.

1.10 Comfort in Couch

SCOTT I think our major problem prior to launch was the temperature in the suits. I don't remember exactly what we were reading as the inlet — it was running somewhere between 50 and 80 as we modulated it back and forth. The modulation wasn't adequate. By having to hold the bypass valve in one position for 20 seconds or longer, we were either at full hot or full cold; and the full cold was too cold, and the full hot was too hot. I think that we should do something significant to improve this. The big problem was that the inlet temperature, as we read it on the pad, didn't seem to agree at all (from a sensing standpoint) with that which we felt in orbit. When we were reading 50 suit inlet temperature in orbit, we were - I was quite comfortable. This was not necessarily so on

SCOTT the ground. It created an unnecessary discomfort prior to launch.

McDIVITT I might mention one thing about the humidity. When we did have the suit bypass on or the temperature up high, the humidity in the suits was such that when you breathed on your helmet it fogged up and didn't clear right away. As a matter of fact, sometimes mine stayed fogged for as much as 3 or 4 minutes.

SCHWEICKART I might comment also on cycling the bypass valve for comfort. On my side of the spacecraft, with the long hoses, I evidently picked up a lot of heat exchange from the cabin; and Jim and Dave were much more aware of the changes in temperature than I was. The primary thing I could notice on the right-hand side was the change in relative humidity, which was evidenced by the fogging of the visor.

1.11 Cabin Closeout

SCOTT I think that during the cabin closeout, when the backup CMP draws water out of

SCOTT — the system, he should be provided with an adequate container and not a plastic bag. Dick had to pass the plastic bag with water in it over our heads to get it out the hatch. One drop of that bag and we'd have had a problem.

1.12 Vibration or Noise Sensations

McDIVITT — The vibrations and noise that we encountered prior to lift-off were as we had anticipated, as we had encountered them in CDDT, and as we had been briefed by the test conductors. There wasn't anything abnormal.

1.13 Ground Communications and Countdown

SCHWEICKART — Communications during the countdown were superb compared to the CDDT. I don't have any adverse comment about them.

2.0 STATUS CHECKS AND COUNTDOWN

McDIVITT Under "Status Checks and Countdown," there was nothing abnormal at all that happened during this period except that we might say that we could feel swing arms retract. It wasn't a big bang or anything; they just retracted and you could feel it.

3.0 POWERED FLIGHT

3.1 S-1C Ignition

McDIVITT

The lead into the ignition was very good. Stoney talked to us — started a countdown at T minus 15, gave us the ignition time, and started on up. Stoney called out ignition at 5 in this particular case. On our transcript of the air-ground communications, it looks as though Stoney called lift-off at 03. Whether or not it actually occurred before that, I do not know. As I was watching the instruments, I noticed that when he got down to 4-3-2-1-0 we had all the lights come on and go off the way they are supposed to do. The spacecraft started vibrating, and I could feel it lift off at about the time he said, "Lift-off." Dave thinks that we lifted off a couple of seconds late, and I am really not sure when we did. I could feel it lift off about the same time I got the lift-off call from Stoney, and I knew we were on our way.

McDIVITT The clock started up, and we shifted into P11. So, we had all the indications onboard that the thing had lifted off. The vibrations really were not as great as I had expected. I could see a vibration on the rate needles of about 1 deg/sec in all the axes. There was no pitch rate or roll rate.

3.2 Noise and Vibration Levels

McDIVITT It was just a vibrational input to the needles that came out indicating plus or minus 1 deg/sec. The noise and vibration was much less than I had expected after having talked to the Apollo 8 crewmembers. We could hear very well and had no trouble discussing anything with the other crewmembers. The noise was not too bad until we started getting up in the MAX g region at approximately 50 seconds, where the noise and vibration did build up some more. We went right through MAX g without any major oscillations. The angle of attack did not get

McDIVITT over about 10 or 15 percent during launch.

3.3 Holddown Release

McDIVITT I should mention that I could feel the holddowns go when we lifted off.

3.6 Roll Program

McDIVITT The roll program started when it was supposed to start.

3.7 Pitch Program

McDIVITT Also, the pitch program started when it was supposed to start.

3.8 Roll Complete

McDIVITT The roll was complete. There were not any abnormalities during this particular time.

3.10 Cabin Pressure

McDIVITT The cabin pressure decreased when it was supposed to, and it was very obvious when it did.

3.12 MAX q Noise Levels

McDIVITT

The MAX q noises and the vibrations were both high but certainly not unexpected. I do not think they were excessively high.

3.13 Control Response in High q Region

McDIVITT

The spacecraft and booster flew through the MAX q region with no trouble.

3.14 Emergency Detection System

McDIVITT

The EDS seemed to be operating properly.

3.18 S-IC Inboard Cut-off

McDIVITT

The inboard engine cut off when it was supposed to. I called it out and, sure enough, it cut down.

3.19 S-IC Outboard Cut-off

McDIVITT

Then, we had the outboard cut-off, which was probably the most spectacular part of the whole flight that is, when the S-IC shut down. It almost felt like the retros fired before we separated the S-IC and the S-II because it threw us all forward. Dave and Rusty were in the instrument

McDIVITT — panel, and I do not really remember where I was.

SCOTT — One thing I might comment on relative to the shoulder harness. It was nice to have them comfortable and loose prior to launch; but at S-I staging, I got thrown pretty far forward into the straps. I did not contact the instrument panel, but I had to put my hand up on the panel. I might suggest a more intermediate adjustment to the straps rather than having them too loose.

McDIVITT — I had the impression that I was completely enveloped in a cloud of smoke at the time, although I am not really sure that I saw any out through the windows. I was not looking out the windows very much during launch. As a matter of fact, I did not look out until we were almost in orbit. But, as a matter of fact, it is interesting — going through the air-to-ground communications here — that the LMP and the CDR seemed to be

McDIVITT	intermixed with what they actually were saying and what the transcript has. Anyway, when we did the S-IC cut-off, it was very abrupt and very hard with a big bang and a cloud of smoke.

3.22 <u>S-II Engine Ignition</u>

McDIVITT	The S-II started up just the way it should have. We flew along for awhile.

3.23 <u>Gaseous Products</u>

McDIVITT	Somewhere along here, I began to see smoke curling down between the boost protector cover and the window on the left-hand side. It wasn't any concern. I just thought that the boost protector cover was burning. I might comment — right at lift-off, something which was behind the main instrument panel on the left-hand side, came hurling out from behind the paneling. It bounced off my helmet and down into the LEB. It was quite a sensation right at lift-off.
SCHWEICKART	Did we ever find out what that was?

McDIVITT No. I don't know what it was. The S-II ignition went the way it should have. We flew along. I started up the gimbal motors, and they started the way they should have. I could feel the S-II second plane SEP. It made a distinct thud when it went off; and the light went out, of course.

3.28 Unusual Noises or Vibrations

McDIVITT When we got to approximately 7 minutes 30 seconds, or in that neighborhood, we began to pick up a very small oscillation on the S-II. This built up mildly until the staging of the S-IVB. It was never of any concern to us. It was just a very, very mild oscillation in the background, which was certainly nothing to be concerned with. Never was any doubt about whether or not the vehicle would hold together.

3.29 LET and BPC Jettison

McDIVITT We jettisoned the tower as planned. It went away with a big cloud of smoke and

McDIVITT

a bang, just the way it should have. The S-II steered the way it should have, and it was a very nominal ride. We will let the other people comment on their impressions of the launch or I will just continue. We seem to have some disparity between what everybody expected. The largest rate that I detected, except for the roll rate, during the entire launch profile was 1 deg/sec, which is the steering rate of the vehicle.

3.30 Guidance

SCOTT

I will just go over the guidance part relative to the DSKY and the onboard chart, I would like to say that the chart was very good. It gave us a good indication of where we were, what was going on, and what would occur next, provided that the guidance was good — that the onboard G&N was good, which it was in our particular situation. The S-IC part appeared to be very close to nominal all the way up to staging. After we staged and got

SCOTT on the S-II, the H dot velocity plot showed us to be somewhat low. In other words, the H dot was lower than nominal for the inertial velocity that we had off the DSKY. However, this did converge and come back into the nominal curve about the time we reached the S-IVB early staging to orbit point, which occurred almost exactly at the time the ground called it up. The chart and the ground were in agreement all the way, as far as times go. At the time we had a go from the ground for tower jet, we also had better than 3 minutes TFF off the DSKY on the NOUN 50 display, which indicated that the G&N also said we were go for the tower jet. At approximately 02:30, I called the NOUN 50 to take a look at TFF and monitored that to tower jet; and then, at 5 minutes or so, I called the NOUN 62 to watch the inertial velocity get the S-IVB to orbit, which as I mentioned, agreed with the ground.

SCOTT

As we approached S-IVB cut-off, we were monitoring NOUN 44 which gave us the H_p to ensure that we got 75 miles and that looked as if it was going to be a close race between cut-off and 75 miles. We had just barely passed 75 miles when we got cut-off, and it was a rather rapid convergence of about 20 miles per step out of the DSKY. Several seconds before cut-off, we were still minus H_p, which was a little exciting at that time. There seemed to be some question about the validity of the G&N during launch, probably, because of a possible platform misalignment or the X-PIPA bias; but the insertion reading out of VERB 82 was an apogee of 103 and a perigee of 89.5, which was somewhat different from the initial ground call of 107 by 98.9. Later, after insertion, the refined ground-based orbit was 103.9 by 102.3. There was a disparity between the G&N and the ground tracking as far as the initial orbit was concerned. Later, SCOTT — when we got ready to do SPS number 1, the ground called and commented that we would be off by some 2 ft/sec because of an X-PIPA bias problem; so this probably was the contributing factor to the orbit. The initial IMU realignment to P52 was performed at approximately 40 minutes after the optics were installed. I got a set of gyro torquing angles which were plus 0.116 and minus 0.032 and a minus 0.108. These are fairly close to what you would expect from a nominal platform.

3.33 S-II/S-IVB Separation

McDIVITT — The S-IVB staging was much less severe than that of the S-IC and the S-II.

3.34 S-IVB Engine Ignition

McDIVITT — The S-IVB engine ignited the way it should have which was very mild. It was a less-than-1g ride. It steered the way I had expected it to — the way I had seen it steer in simulations. We never had any very large oscillations. Again, the

McDIVITT — steering rate was 1 deg/sec, just the way it should have been.

3.37 Scale Change

McDIVITT — I never changed the scale to 50 15; I used 5 and 5 all the way into orbit.

3.40 Distinction of Sounds and Vibrations

McDIVITT — There were no oscillations on the S-IVB. The separation lights all performed the way I had expected them to perform. During this time, I was getting a good description of our trajectory from Dave. He was telling me where we were on the curve. We got into orbit.

SCHWEICKART — Between S-IC inboard cut-off and the outboard cut-off, I had a very definite impression of longitudinal vibrations or oscillations, almost a chugging kind of feeling. It would be hard to estimate the frequency, but it was somewhere down below 10 cycles. Also, there was a very definite physiological feel in the seat of the pants. I was not expecting these, SCHWEICKART — and it lasted right through S-IC cut-off. My reaction to S-IC cut-off was very much like Dave's. I had the feeling that we did not experience simply a release of g but that we actually experienced a slight negative acceleration at S-IC cut-off, which threw both Dave and I forward toward the instrument panel. I vaguely recall using my hands to hold me off the panel.

3.42 <u>S-IVB ECO</u>

McDIVITT — The S-IVB shut down very mildly, and we checked the DSKY. I will let Dave discuss what we saw there.

3.43 <u>Communications</u>

McDIVITT — My communications with the ground were good all the way up. I never had any difficulty reading them, and I assume they had no difficulty reading me.

SCHWEICKART — I felt that the COMM was good all the way up, with the exception of the vicinity of the MAX q region. Here, my own subjective impression was that, had we not been

SCHWEICKART wearing helmets, it would have been very difficult to communicate at that point in the flight. I think, perhaps, that each of us had different impressions at that point; but I was not able to read Jim and Dave too well at that point. Also, I was aware that, to be heard, I almost had to yell into the microphones. However, it did not last too long, and the majority of the launch had a very low noise level. The communications on the S-band during launch were generally worse than what I had expected. Somewhere in the time period, just before 3 minutes, the S-band began picking up a good bit of noise. The noise increased from time to time to the point that I was forced to reduce my S-band volume to communicate with the other crewmembers. It began to clear up at approximately 5 minutes 30 seconds or more into the flight. In fact, I guess it was just before 6 minutes that we seemed to get

SCHWEICKART

a nice clean lock on, and the noise stopped. It was before switching to OMNI D. The noise then lasted for almost 3 minutes on the S-band. I had a feeling that I should have had the freedom to go ahead and to switch antennas manually to improve the communications on the S-band. I think that if the entire crew were on S-band, it would have been bothersome to the point that it would have interfered with crew operations. Luckily, we ran with only the LMP on S-band, and it was not really necessary for me to be involved in communications between Jim and Dave. Once we got onto OMNI D at 06:15, as I recall it, the S-band stayed nice and clean all the way into orbit and through Canaries.

3.44 Control and Displays

McDIVITT

One of the things that was of some concern to us was when Rusty called out that we had lost SPS helium pressure at lift-off. As soon as we got through the crucial

McDIVITT mode 1A and 1B regions, I wanted to find out if we really had an SPS engine because, if we didn't, it would have been a little difficult to perform mode 3 and mode 4 abort. We got confirmation from the ground that we had good SPS helium pressure and that we had just lost either the gage or something onboard the spacecraft that contributed to the readout.

SCHWEICKART I could also feel the lift-off. I think the thing which preoccupied me, at that point, was that the SPS helium pressure indication looked as though it was tied to the ground. Exactly at the instant we had lift-off, the needle went right to zero. I did not say anything about it until approximately 30 seconds into the flight, when most of the commotion of tower clear and all those kinds of things were over. At that time, I mentioned it to Jim. I think we were somewhere up in mode 1C region when I asked Jim whether he would like for me to mention that to the ground. He said, "Yes," and I called

SCHWEICKART — Houston with it. Houston called back with something completely irrelevant to the remark on the SPS helium pressure which led us to believe that they did not read us. Jim checked on that and sure enough they had not heard it. As soon as they were aware that we had a bad onboard indication, they told us that we were go. At that point, we speculated it might be a circuit breaker or something of that nature, and we planned to check it in orbit. It turned out that there was nothing we could do about it. It was apparently a transducer failure.

3.45 Crew Comfort Through Powered Flight

McDIVITT — I was as comfortable as, I guess, you can get during a power flight. It was mild. As far as the g-levels went, they were low and sort of like an old lady's ride into orbit.

SCOTT — My physiological sensations were about the same as those Jim described.

4.0 ORBITAL OPERATIONS

4.1 First Day

4.1.1 Insertion to Separation

McDIVITT

2. Postinsertion systems configuration and checks: After we got into orbit, we checked to make sure that we had a safe orbit. As soon as we determined that we had a safe orbit, I turned off the gimbal motors; and we started into the postinsertion checklist, which went very smoothly. We had it configured in the timeline type of thing with my checklist having a director's composition to it so that I could make sure that all of the checks were done and that each individual checklist had a detailed operation in it. We went through the checklists and just put postinsertion checks, which were a conglomeration of things that had to be done. They went along fine. We did the ECS postinsertion configuration, ECS redundant component check, ECS monitoring check, GDC align, EMS test, EPS monitoring

McDIVITT: check, installed the optics, service module RCS monitoring check, and right on down the list. We had no anomalies except for one or two. The helium pressure on the command module RCS was reading slightly low — 3900 and 3820. It remained at that reading throughout the flight which was below the limit that was set for us in our checklist. At the end of this particular check, I ended up with a few things that we had not accomplished because of time and inaccessibility of some of the handles and things that we needed with which to work. These were the leak check in the secondary loop, the backup voice check, and a PIPA bias check which we completed later on in the day. Another thing that we did not complete during this particular time was the main regulator checks, which we also completed at a later time.

SCOTT: The intent was to perform the main regulator check over a ground station, but

SCOTT — the timeline just did not work out efficiently so that we could do it. We had to perform it without ground contact, but the check was acceptable.

SCHWEICKART — In the postinsertion checks that I pulled, there were some recordings I took which I suppose should be reported here. The three fuel cells were all pulling 25 amps apiece; Bat Bus A was reading 32 volts, Bat Bus B was reading 32 volts, and Bat Bus C was reading 37 volts. I made the dc voltage-amperage check and the battery relay bus check. I recorded it at 3.5 volts, and I am not exactly sure why it was down to 3.5 at that time. The SPS monitoring check data was recorded. The helium pressure was off scale, low. Everything else was nominal. The SPS oxidizer and fuel quantities read 88.9 and 88.6, and the unbalance read plus 50 or 50 increase.

McDIVITT — I guess it is worthy of comment at this time that throughout our checklist we

McDIVITT had places to record data, and this data was duly recorded in the appropriate checklist; so I will not read off a thousand numbers which probably do not mean anything to anybody anyway. If there is any interest in all of these numbers, we can get them out of the checklist.

SCOTT 4. Optics cover jettison: The post-insertion alignment has been discussed, and it worked very well.

10. All systems verification and post-insertion configuration — docking probe extension: The optics dust covers came off as they were supposed to, and we extended the docking probe and got the same sensations that we had in the chamber. The probe went out in 0.2 or 0.3 second; and we felt a definite thud when it hit the end, indicating that it was all the way out. We checked the talkbacks, and they gave us the proper indications.

13. S-IVB manuever to T&D ATT: We proceeded with the checklist; we got set up to do the transposition and docking,

SCOTT

switched couches with no problem, got over MSFN, went through the pre-pyro arming procedure, and got a GO for PYRO ARM. The S-IVB, during this time, was maintaining orbit rate. The only thing on the S-IVB worth noting was that we could see the attitude control system in the S-IVB firing at night — the thrusters firing. Other than that, the S-IVB performed as we expected, completely nominal with a well defined ORB RATE. The venting of the S-IVB provided no problem with doing the alignment at night. There were no extra stars, and it was easy to track the stars at the ORB RATE that the S-IVB had.

14. Subjective reaction to weightlessness: The sensations to weightlessness were as expected. I felt a fullness in the head but no vertigo or visual disturbances. I remained in the couch until we were well into darkness to ensure an adequate accommodation to the weightless state. When I did go down to do the alignment, I felt

SCOTT — no unusual sensations other than a fullness in the head.

McDIVITT — When we got into orbit, I felt the way I had expected to feel. We were upside down. I knew we were going to go into orbit upside down, and it did not bother me to be apparently hanging in the straps. I had no sensations of any feeling that would be bothersome.

SCHWEICKART — My first reactions to weightlessness were the same as the other two guys. I had the fullness in the head, but I had been well briefed in advance on it. I did not particularly have any sensation of head-down position. I did not move around very much, purposely. My intention was to stay in the couch as quiet as the situation would allow and was able to do so. I suffered no feeling of nausea or vertigo throughout the first day. I avoided most of those situtations involving "rapid head motion or rapid individual movement." I had the feeling

SCHWEICKART that if I had moved my head rapidly, I would have felt dizzy.

4.1.2 Separation, Transposition, Docking, and Extraction

SCOTT The S-IVB maneuvered to the T&D attitude at the correct time and went to the proper angles as were defined prior to flight. It took us a number of months to get these angles for the S-IVB, and I guess the efforts paid off because they were proper. It maneuvered to 181.94 and 14.78. We had preset the G&N error needles to these values, and at the completion of one S-IVB maneuver, the needles were nulled within the S-IVB dead band.

At the completion of the S-IVB maneuver, we proceeded according to the checklist to prepare for the separation, transposition, and docking.

3. S-IVB tank pressure measurement reading accuracy: After we armed the pyros and began to proceed with the separation, we noticed that the launch vehicle tank pressure gage was not indicating what we expected it to. In looking back, we

SCOTT found that we had added a step shortly prior to flight to pull the EDS circuit breakers which, after insertion, disabled the LV tank pressure gage. This was going to be our prime indication of separation. At this point, we did not take time to troubleshoot the problem, feeling that we would get a good indication of separation.

4. Pyro operation: At the time of separation, we got the loud pyro bang and a definite indication that we had separated from the S-IVB.

5. Separation from SLA: We started the DET at the time we separated from the S-IVB. The plan was to thrust for 4 seconds which should have given us about 0.8 ft/sec separation velocity. I noticed on the EMS, which had been set up at 100 ft/sec to compensate for the drift, that after 4 seconds we only had approximately 0.4. I continued thrusting until we had approximately 0.6 on the EMS which took approximately 6 seconds.

SCOTT At the time I attributed this to a difference between the simulator and the actual vehicle.

We started the pitch around at 15 seconds at approximately 2 deg/sec. I guess the first indication I had that we were doing alright was when Jim saw the S-IVB. As I recall, it was well before we pitched 90 degrees that Jim saw it through the hatch window. His comment was that we were in the proper position for the turn around. When we completed the 180-degrees pitch maneuver, I noticed that the alignment was somewhat off in pitch and that to get the needles nulled, I would have to pitch up approximately 10 degrees. At that time, I became suspicious of our angles that we had gotten in preflight because we previously had so much trouble with them.

A summary of the transposition and docking is contained on the onboard SONY tape. Upon looking back at the indications we had on accelerations and pitch attitude

SCOTT after the separation and during the transposition, it is obvious that quad C was not working, because we got less than the nominal amount of acceleration. Also, we were in the improper pitch attitude when we turned around which might justify the technique of accelerating out at a greater-than-necessary velocity to compensate for a quad failure, which is, incidently, one of the things we did not have time to simulate very much other than the procedures. Another significant thing that we noticed was that the venting of the S-IVB caused a somewhat greater acceleration than what we had expected from reading the preflight data and also, from observing the vent model in the simulator. You could visually see the venting take place from the side of the S-IVB. It is a continuous vent, but you can see the pulses as the system vents. We did not get any indication from the ground as to what the vent model was — whether it was a high vent model or a low vent model.

SCOTT

7. Visual inspection of SLA panels: The separation from the S-IVB was a loud bang as we had expected and we felt the acceleration. We could see a lot of debris through the windows, and Jim also noticed a panel almost immediately — one of the SLA panels moving away from the spacecraft and moving backwards. The control systems worked very well once we got the quad problem squared away. Both the SCS and CMC DAP were good solid control systems, and the docking task was relatively easy as far as the aligning with the standoff cross and doing the actual contact.

SCHWEICKART

8. Photography, sequence and still: We had our cameras set up with the 16mm sequence camera mounted in the left-hand rendezvous window — the number 2 window. However, the remote control cable was being employed and ran across the cockpit to the LMP. I used the 70mm Hasselblad camera to take pictures (through the number 4 window) throughout the transposition,

SCHWEICKART — docking, and extraction maneuvers. These apparently came out good.

McDIVITT — 11. Docking: After we had completed the docking and had gotten the good solid bang of the latches, we pressurized the tunnel.

13. LM pressurization: Everything worked in the LM the way it was supposed to work. We followed the checklist, and the pressurization procedures worked fine. The pressurization procedures went very rapidly because of the gaseous oxygen that we had available in the command module. It took something less than 5 minutes; we are not really sure of the exact time. By using the PLSS bottles and the surge tank, we were able to equalize the pressure across the hatch in a very short period of time. I believe that when we finished the pressurization, we still had something on the order of 700 psi in the surge tank; and we had approximately 4 psi in both spacecraft.

McDIVITT

The upper tunnel hatch mechanisms worked properly. It was a well designed hatch.

15. Docking latches, umbilicals, power:

We were able to get it out in a very short time and to connect the umbilicals. The lighting — the tunnel lights — were certainly adequate for us to do the job that we had to do. The umbilicals are in a rather precarious position and are attached to the side of the LM with Velcro, and it is a little difficult to see around on the other side of the drogue. I was very careful about getting those umbilicals out, because it appeared that if I had ever hit one and got it unstuck from the Velcro and if it had gone out through the tunnel, we would have had a real problem on our hands trying to get it out. We are not recommending a change. We are just recommending great care in extracting the umbilical, because if you do get it stuck on the other side of the drogue, you are going to have to fish for it; and you may even have to take the probe and drogue out.

McDIVITT

Another little bit of information is that when we had finished dumping the PLSS tanks, we had the DELTA-P across the tunnel at 2.4, and we had expected 2.8. There are a lot of little numbers here that would probably be of some interest, but the main thing that we should get across here is that the procedure we had for pressurizing the tunnel in the LM worked very well. It was quickly done, and we had no problem of waiting around for the tunnel to pressurize so we could get in there and perform the job that we had to do.

When I looked up in the tunnel, I was not able to see any large scars on the drogue, but I was not able to really see the drogue very well. I went around and checked each one of the latches; they were all locked and latched. There was no problem at all in verifying that they had operated properly. The bungee fairings were all vertical and you could see that immediately, which indicated that the things were all latched. I went around and inspected each

McDIVITT one of them though. It took a little time, but I wanted to make sure that we had a good solid tunnel because of the stroking test, which we were going to do the next day.

SCOTT 18. Evasive maneuvers: The ejection maneuver went as planned. We thrusted aft for 3 seconds at 5 seconds, pitched down at 25 seconds, and were prepared to do the 6-second aft thrusting at 3 minutes after ejection. There was no question that the vehicles had been ejected from the S-IVB. You could see movement and clearance from the SLA ring before we even did our aft 3-second thrust at 5 seconds. After we'd completed the 6-second evasive maneuver, we could see the S-IVB as we had planned and as we had seen in the simulations; but it appeared that we were not moving away from the S-IVB as rapidly as we had expected. We maintained a closer relative position than we had expected. It was easily visible in the forward and hatch windows at all times.

SCOTT The preflight curves were really a function of the vent model and the magnitude of the vent. With no vent, you continue to rise above the S-IVB relatively and to fall behind. The higher the vent on the preflight curves, the closer, of course, you remain to the S-IVB; and you drop down below, which is what occurred in our particular situation. We went up above the S-IVB, back down below, and almost directly aft of the engine. We crossed directly aft of the engine at about S-IVB ignition minus approximately a minute and a half, and we were about 1000 feet away at the time.

McDIVITT 19. Work load and timeline: The work load and the timeline were about as we had expected. I do not think we ran into any unforeseen problems during this entire time, except the one that Dave mentioned. It took a lot longer to dock because of the lack of thrust left or translation left that we had. As a matter of fact, we had a few rather bad moments there trying to figure out what was going wrong.

SCOTT

The transfer to the LM power went very well according to the procedures, except that when we looked at the systems test meter we noticed some rapid fluctuations in the voltage — 0.4 to 2.0. There were some oscillations about the low values and then jumps to the high values. At the time, this gave us some concern, but it was subsequently passed up from the ground that that was the same cycling that the LM heaters had been performing prelaunch. [After a certain period of time, the oscillation stabilized to less rapid movements and more of a cyclic nature.]

The evasive maneuver was performed according to the checklist and occurred approximately 5 seconds late, correction — on time. We had waited about 3 minutes after sunrise to ensure that we had adequate lighting to see the S-IVB, which worked out to our preplanned time of 4 hours and 11 minutes.

4.1.3 S-IVB Closeout and SPS Burn 1

McDIVITT

2. Preparation for first S-IVB restart and restart: As we were rotating around, we kept the S-IVB in view, of course, because we were staying quite close to it. It was interesting to note that the engine had gimbaled over to one side. It wasn't right straight down the minus X-axis of the S-IVB. As we got right behind it, it was a little difficult to tell if the engine was pointing right at us or not. Then as we dropped down a little bit below it, we could see that the engine was indeed pointing sort of sideways. I don't know when it came back into the straight down the X-axis or through the c.g. as it should have been. We were close enough behind it so that when it lit up there was some concern about what the debris coming out of the engine would do to the two vehicles. However, we didn't reorient the spacecraft or anything. We stayed where we were, and we could see its engine start cycle and some particles coming out of the engine.

McDIVITT — It went through the normal sequence that we had expected. There was some debris that came down toward us. Whether it ever got to the spacecraft or not I can't really say, but it looked like it did. However, we didn't feel any chunks apply to our vehicle from its engine ejection or anything like that. We were able to take pictures of it while it started up and flew away. There never was any concern about it running into us; it was just a concern of the ejection from the engine.

SCOTT — During the time prior to the S-IVB ignition, we were able to keep it in view by using roll only.

SCHWEICKART — 4. S-IVB venting operation (LOX-LH_2O): On the S-IVB venting, after we turned around, it appeared to me that the vent on my side of the S-IVB would open up for about a second (somewhere between a second and 2 seconds), then close down for 2 to 3 seconds, and open up again for another second to 3 seconds. It followed that same cycle of open and close, open and close. You

SCHWEICKART could see it as a sort of very tenuous white exhaust coming out of the vent on the side.

McDIVITT As a matter of fact, it looked like that was a nonpropulsive vent. There were two vents coming out opposed to each other, and I'm not sure, as I think about it, that I ever saw the propulsive vent come out.

SCHWEICKART From my side, it appeared as though the vent was located toward the forward end of the S-IVB but was pointing aft and thrusting; that is, exhausting away from us and therefore thrusting toward us. At one point, when we were lined up with it, I got to see both vents at the same time, and they did vent together. There was apparently no rotational motion or any apparent motion associated with the S-IVB when the vents went off.

McDIVITT 7. S-IVB closeout: There was very little that we had to do with the S-IVB closeout. It's already been discussed in our transposition, docking, and ejection of the LM.

SCOTT 8. IMU orientation realign and alignment check: The realignment prior to SPS number 1 was nominal. I mean, it was preferred.

McDIVITT 9. Preparation for SPS burn 1: The first SPS burn occurred at approximately 6 hours. We were not rushed in getting into it. We worked our way down through the checklist without any problem, and the burn was quite nominal.

10. Parameters and performance of burn 1: In looking back at it now and comparing this burn with the retro burn, for example, there was a significant difference in the acceleration that you feel between an empty CSM and a full LM/CSM combination. The engine comes on abruptly, but with the tremendous mass there, the acceleration is very low. It was 5 seconds to get 36.8 feet per second; or that was with a nominal, and that was about what we burned. There really isn't too much to say about it. We only used one set of ball valves, set A. At the time that we had the burn,

McDIVITT — I believe Rusty reported that one of the SPS ball valve indicators was a little slow to return to its normal open position. One was a little slow to open, but the ground indicated that, from their data, they were opening properly.

SCOTT — 11. Daylight star check: The daylight star check with the optics was performed at 6 hours and 49 minutes at sunrise. There was one check each at sunrise minus 15, sunrise, sunrise plus 5, and sunrise plus 10. The significant point here, I think, is that the number of stars visible at sunrise was 19. The orientation of the spacecraft was such that the moon was about 5 degrees above the top of the field of view of the telescope, which was adequate to eliminate it from the field of view but still pretty close. If it had been in the field of view, it would have washed out the stars almost completely.

At sunrise, the earth cloud cover could not be seen, but the LM quad visible in the telescope field of view began to shine from

SCOTT reflections from the sun. As the sun rose, this became brighter and brighter until it was a brilliant source of light through the telescope. At sunrise plus 5 minutes, it completely washed out the stars. The landing radar is also visible in the telescope field of view; and at the right sun angle, it too would present a brilliant object because of reflection. These two items, the quad and the landing radar, really occlude the field of view, not so much from their size, but from their reflection capabilities. Even with those there, in the daylight the sextant stars can still be seen for final alignment in auto optics. Back to the daylight star check. One thing I forgot to mention was that the moon reflected on a split in the prism of the telescope and provided a nice wide band of artificial light across the center of the telescope, a brown light.

McDIVITT 13. Doff PGA's: Towards the end of the day, we doffed the PGA's and stowed them. The LMP's PGA was stowed underneath the

McDIVITT — left-hand couch. The CDR's PGA was stowed in the lower part of the L-shaped bag, and the CMP's PGA was stowed in the upper part of the L-shaped bag. We didn't have much difficulty doffing the PGA's. At least, I didn't.

SCHWEICKART — In doffing and donning the PGA the next day and in getting your head in and out of the neck ring while bending almost in half, (once you got your head inside the suit, so that you really couldn't see), there was a sensation of tumbling, even though you weren't. At least, that was my subjective sensation. The other guys might comment on their's.

McDIVITT — I never had any abnormal sensations in getting in or out of my suit at any time. I put it on very quickly and took it off very quickly a number of times, and I felt nothing.

SCOTT — The first time I put mine on, on day number 2, I ducked my head rapidly and stuck it through the hole and did get a slight sensation of gyro tumbling, but after that

SCOTT there was never any problem.

McDIVITT 14. Powerdown SC: In powering down the spacecraft, we powered down the computer, the IMU, and the SCS. We had a checklist that we had worked out preflight, and it worked very well. We went right through it with no problem at all. We ended up with our spacecraft in a situation with all the thrusters disabled. The stabilization control system was disabled so that it could not fire any thrusters, and the PGNCS was disabled so that it could not fire any thrusters. Our primary concern was to get the guidance system set up so that we wouldn't have any inadvertent jet firings during the period that we were sleeping, and we would not have to worry about the IMU going into gimbal lock. We were able to go through this powered down checklist rather quickly.

On the first day, we were supposed to start our rest period at 9 hours. I have a note in the flight plan that we finally got to bed at 11 hours, 2 hours late. It was an

McDIVITT associated comment of terrible housekeeping. It was just a matter of trying to get all the things done that we were supposed to do. We'll comment on these in greater detail later. As for the timeline for the first day, we found that the housekeeping required a fair amount of time, and we hadn't really put it in the timeline.

4.2 Second Day

4.2.1 Powering Up and Down of Spacecraft

McDIVITT — In the morning, when we started powering up the spacecraft, we had a checklist that we followed carefully and got everything running again — just the way we had anticipated. We did not find any problems except that it took a little longer to get everything done — not just the powering up and the powering down of the spacecraft but the auxiliary things as well; such as changing the lithium hydroxide canisters, trying to chlorinate the water, getting to the bathroom on time, getting something to eat, and then suiting up. All these things took a very long period of time.

4.2.2 Flight Plan Updating

McDIVITT — We got the flight plan updates early, and we were able to incorporate them.

4.2.3 Communication Setup for Rest Periods

McDIVITT — The communication setup that we had

McDIVITT — used for the first night rest period was A and B RECEIVE VHF with the S-band turned down. It turned out that the VHF B frequency picked up a tower. I assumed it to be an airfield tower somewhere in southeast Asia. We could hear the communication between the aircraft and the tower on four passes during the night, two of them relatively long. It almost seemed like we were getting better coverage out of the tower than what we got out of a lot of the MSFN ground stations at the time. Obviously, it interrupted the sleep period for the first night considerably. After that, we went to a VHF A only at night, and we were going to use the crew alert light as the backup for that. We all slept a lot better after getting off the chatter.

4.2.5 IMU Orientation Alignment and Realign

SCOTT — The initial IMU's, P51 and P52, were absolutely nominal. No problems.

McDIVITT We did the realignments between each of the burns. It was at this time that I first noticed that the shaft mechanical read-out on the optics panel was stuck at 64. I had intended to use the mechanical read-outs as a quick way of doing a star sextant check, but found out we couldn't do that because of the lack of the shaft drive. The realignments were all pretty nominal. We did have to rush through a couple of them because of the realign burn schedule that we had. Without having had a great deal of practice using the optics, I discovered that the landing radar, the RCS quad, the earth, and the moon made a box within which it was pretty difficult to identify stars through the telescope. If you spend a long enough time in looking, dark adapting, and maneuvering around to avoid looking at the objects that we already discussed, it wasn't too difficult. It was pretty hard to identify some of the stars. The torquing angles were all reasonably small; I don't think there is any

McDIVITT need to discuss them. The alignments all went reasonably well. Okay, I may have spoken incorrectly here. The problem with using the mechanical read-outs was that the read-out didn't operate. The drive apparently drove the shaft around. The units and tenths digits in the mechanical read-out on the optics panel did not move. They were stuck at 64.

4.2.8 Performance of Burns 2, 3, and 4

SCOTT SPS number 2 was a G&N burn of 1 minute and 51 seconds with a 40-percent amplitude stroker to be initiated after the first minute of the burn. After the start and during the first minute, the G&N rolled to the left edge of the deadband, pitched up approximately 3 degrees on the error needles, and yawed right about a degree so that the error needles were offset by 3 degrees and a degree when the stroker was initiated. The 40-percent stroker resulted in a zero-to-peak of approximately 0.1-degree maximum pitch oscillation, and it damped in approxi-

SCOTT mately 5 seconds. One other thing noted was that when the DELTA-V thrust B was turned on at ignition plus 3 seconds, there was a slight chug in the engine in the thrust level.

McDIVITT Prior to starting the stroking test, we had been maneuvering the spacecraft; and with the tremendous mass of the vehicle, the minimum impulse was almost imperceptible on the rate needles. We had used the acceleration command on a number of occasions, and when we did, I felt that there was coupling between a pitch input and a vehicle response of some sort — an oscillatory response in both pitch and yaw. It felt as if it were coupling the same way that the SPS stroker test coupled on the ME104 simulations that we ran at North American. Frankly, I had expected to see some tremendous oscillations when we did the first stroker, and I didn't expect that we'd even get into the second stroker because of the way the spacecraft combination responded to just the RCS thruster inputs.

SCOTT Yes, I agree with that; and it seemed that with a good acceleration pulse, the whole combination would bend. You could almost feel it bending; but when we actuated the stroker, we didn't get this same bending sensation physiologically that we had experienced with the acceleration command RCS. The feeling was not so much like a loose joint between the two vehicles but more like there was a flexible rod that would couple pitch and yaw because of the bending.

After the stroker damped on SPS number 2, the needle stabilized to a yaw left of approximately 3 degrees and a pitch of approximately 1 degree. At the completion of the burn, the residuals were relatively small. They were minus 0.1, plus 0.7, and plus 0.3.

SPS number 3 was a G&N burn of 4 minutes and 42 seconds, with a 100-percent amplitude stroker after 1 minute and an MTVC SCS rate command for the last 45 seconds of the burn. The start was the same as SPS

SCOTT number 2. When we initiated the full-amplitude stroker, the response was similar to the mission evaluator at North American, except that the amplitude was not as high as we had experienced there. The pitch rates during the first 3 seconds were approximately 0 to minus 0.2, 0 to peak, and then at damp to plus 0.2 and oscillated around the plus 0.2, coupling in yaw as it did on the mission evaluator. There would be an oscillation cycle in pitch; then it would couple to an oscillation cycle in yaw and then back to pitch, with amplitudes about one-third the values that we saw in the mission evaluator. On the mission evaluator, we saw an oscillation of plus or minus 0.2 degree per second, approximately a minus 0.2 in pitch; whereas, in flight, it was just an oscillation from 0 to 0.2. Therefore, it was about half the amplitude that we saw in the mission evaluator. It appeared that all the oscillations damped within approximately 10 seconds after the completion of the stroker. After the strok-

[redacted]

SCOTT er damped, the DAP again drifted over to the minus 5-degree roll deadband and sat at that point until we initiated the MTVC by switching the spacecraft control from CMC to SCS. When we performed the switch-over, the SCS TVC brought the spacecraft back to zero roll with a noticeable transient. In fact, the main transient that we noticed was in roll. This was noticeable physically and on the FDAI. By the time the rates stabilized after the switchover, the G&N error needles were almost full-scale yaw left and pitch up, which required a manual control back to null the error needles, since we were using those for our display. The GPI indications at the time of switchover were at pitch of approximately 1.9 degrees and a yaw of approximately minus 0.6. The trim values were set at a pitch of plus 1.1 and a yaw of minus 0.2. Thus, there was a noticeable difference in the gimbal trim settings relative to the actual position of the gimbals when we switched over.

SCOTT The rotational hand-controller response seemed more sensitive than on the mission evaluator at North American. However, the needles could be nulled without difficulty but tended to start moving immediately after reaching a null position.

McDIVITT It was more difficult to stop the needles and have them remain at some fixed position than it had been in the simulator. The stick integrator appeared to work alright; it just seemed as if the c.g. was changing more rapidly than we had experienced in the simulator. The residuals on shutdown were plus 2.7, minus 2.1, and minus 2.6. The EMS DELTA-V counter was minus 6.6 and that was used for the automatic shutdown of the EMS. The DELTA-V_c on the EMS and the V_g display on the DSKY compared very well throughout the burn, and the time also was fairly accurate. The burn time was approximately 2 seconds different from the actual cutoff time for the long burn.

SCOTT SPS number 4 was a 20-second burn, G&N automatic, and that was completely nominal.

SCOTT Residuals were plus 0.2, plus 3.5, and plus 3.3. Throughout all three burns, we had quite a number of SPS PU sensor lights, which resulted in, I believe, seven master alarms during the long burn. On burn 4, the EMS DELTA-V counter performed very well, also. The reading at the end of the burn was minus 6.2, and the difference between the G&N and the DELTA-V counter should have been approximately 6.4, according to the ground update, the maneuver update.

4.2.10 Orbital Navigation Landmark and Tracking

McDIVITT We did not do any P22's on this particular day, nor did we do any orbital navigational landmark tracking with the LM on because of the very highly packed timeline. We delayed them until we had completed the LM operations.

4.2.11 ORDEAL and ORDEAL Rates

McDIVITT ORDEAL and ORDEAL rates really did not apply too much on this particular day because we flew with the platform aligned out of plane the entire day, and

McDIVITT ORDEAL is absolutely useless in that mode.

4.2.13 Drifting Flight Operations

McDIVITT The drifting-flight operations were okay. With the platform on, you have to sort of nursemaid it at all times, and we found that the spacecraft tended to drift into the gimbal lock area on this day. We spent a lot of time flying it out of the gimbal lock because the particular vehicle configuration we had wanted to trim. It seemed like the spacecraft tried to get back into the plane all the time. Because the platform was aligned out of plane, we had problems with it — not a lot of problems, but we had to stay on the attitude to make sure we kept out of gimbal lock.

One thing that is worthy of comment here is that every time we went into drifting flight, we brought the vehicle rates down to something fairly low. I do not believe, as long as we had the LM attached, that we ever awoke to find the

McDIVITT rates to be over approximately 0.1 deg/sec in any axes. After we jettisoned the LM and were in the command and service module only, we awoke to find rates of approximately of 0.2 deg/sec or less. I think that one day we had 0.3 deg/sec in one axis, but it was a situation where we did not intend to build up rates by ourselves without any thruster inputs during the night, and I rather thought that we would.

4.3 Third Day

4.3.1 Command Module

SCHWEICKART

1. Don PGA's: The donning of the PGA's took place on the third day. Because of going into the LM, I donned the LCG for the first time; and I noted that donning the PGA with the LCG is considerably more difficult from the mobility point of view than donning it with the CWG. The primary difference was the increased diameter of the arms caused by the LCG. Secondly, and of more significance, is the connection of the water hose to the adapter in the LCG. This hose restricted me from pushing the suit away to get my head into the neckring and made the slipping of the head into the neckring a major task. It almost required two people to bend the suit to get the head into the neckring. The same thing is true for doffing the PGA; we adapted the technique of having another crewman reach inside the suit and disconnect the LCG water connector

SCHWEICKART from the suit prior to doffing of the suit. Otherwise, it would have been nearly impossible to get the PGA off.

SCOTT 2. Tunnel and LM pressurization: We left the tunnel valve on LM PRESS overnight; and in checking the DELTA-P, we still had a good seal on the LM. The LM was still pressurized so there was no need to pressurize the tunnel.

3. Clearing tunnel: We cleared the tunnel, and I'll go through the general hatch/probe/drogue operations for installing and for clearing the tunnel. The hatch, as Jim mentioned earlier, worked fine. It was well designed — easy to remove and easy to stow. As a matter of fact, it is probably easier for one man to clear the tunnel than for two, because the other two men can get out of the way. It is easy enough to move the components of the tunnel around so that one man can do it and direct the components to the proper stowage location. This is easier

SCOTT than having two men in the tunnel because it gets awfully crowded in the LEB. The hatch stowage bag is too small, and there seemed to be no need to have that form fitted. If the stowage bag was larger, it would be easier to get the hatch into it and that would be adequate to hold the hatch in position during the temporary stowage. We did not zip the bag closed because it was not necessary at any time. We used a utility strap which was placed across the front of the bag on two snaps to retain the hatch during the tunnel-clearing operations and that was all that was needed. The thermal control coating on the outside of the hatch was much too delicate for handling inside the spacecraft. It came apart, and the insulation beneath it flaked off. This had been reported a number of times prior to the flight but had never been corrected; and again, we ran into the problem during the flight. The hatch is easy to move from the tunnel area to the

SCOTT

stowage location with the exception of binding on the tunnel handholds. There are four handholds located inside of the tunnel. I never did seem to find a definite need for these handholds; thus, consideration should be given to removing them. This would make the movement of the hatch and the drogue through the tunnel somewhat easier. The probe worked as advertised. There were no problems with it at all, and the timeline was comparable to the 1-g counterbalance operations on the ground. The probe was easy to collapse and to install. It took the same number of strokes as we had predicted to install the probe, with the estimated forces on the rachet being less than 50 pounds. There was no need to have any retention to remove or to install the probe. The center couch provided adequate support, and you could brace your back against the side of the tunnel to stroke the probe during installation. The drogue was probably the

SCOTT most difficult of the three items to remove because of the requirement to orient properly the lugs on the probe to get them through the diameter of the tunnel. I guess the entire tunnel clearance went very well; it probably took anywhere from 7 to 10 minutes to clean out the tunnel completely and to reinstall it. The only major obstacle is the suit hoses which are constantly in the way and which push you the wrong way. They twist and are cumbersome; it is difficult to get the components down into the command module because of the hoses. Some consideration needs to be given to solving the problem — probably more flexibility in the hose. The tunnel checklist is excellent; it is positioned in the right place, it provides adequate descriptions to remove and to install all the hardware, and it saves considerable time which would be spent holding on to or going through a handheld checklist. During tunnel

SCOTT

operations, the temporary stowing (for example, putting the hatch under the left couch, putting the probe under the seat pan on the right couch, and putting the drogue between the seat pan and the LEB) seemed to work out very well. They were easily retained and readily accessible.

4.3.1 Command Module

SCOTT

3. Clearing tunnel: After clearing the tunnel for the first time, we inspected the drogue for damage, and there was no apparent damage at all. The only visible effect of the docking was a mark about the width of a pencil some 4-1/2 inches long from the apex of the drogue back into the cone.

4. Closing tunnel: The tunnel closeout worked just as well; the only thing worth noting was that the hatch integrity check took approximately 10 minutes.

5. Orientation alignment and realignment of IMU: During the IMU orientation and alignment on the third day, we discovered

SCOTT

we had a telescope which would occasionally hang up at approximately 64 degrees shaft. We never did determine the cause of the malfunction. It occurred a number of times until the fifth day. After that time, we left the optics switch on all the time. We also noticed the occasional hangups of the telescope were at multiples of 64 degrees until, I believe it was the fourth day, we noticed that it also occurred at other points — one time at 15 degrees and another time at 37 degrees. It seemed to occur in DIRECT and RESOLVE.

6. LM power transfer: At the completion of Rusty's tunnel transfer to the LM, we did a LM power transfer which worked nominally in a VHF checkout. The only significant item is that there did not appear to be any difference in the CSM antennas relative to the LM VHF. After Jim transferred to the LM, the tunnel was closed; the hatch was closed; and the hatch-integrity check was performed. The interior of the command module was

SCOTT

configured for an EV transfer, as it was on each of the LM days. This included removing and stowing the center couch and doing the EV PREP down to the point of donning helmet and gloves and depressing the cabin, which was approximately a 10-minute job. This meant that the command module was configured within 10 minutes of opening the hatch. The center couch was easy to remove and to stow; it took approximately 5 minutes to take it out and to stow it under the left couch.

9. Maneuvering for AOT star observations: At this time, AOT star observation and LM S-band antenna checks were not made.

10. Maneuvering for LM S-band steerable antenna attitude: Because no AOT star observation or LM S-band antenna checks were made, we did not do the maneuvers to those attitudes. Back to the CSM configuration, I have a note here that

SCOTT — it took approximately 20 minutes from the time the hatch was closed until the CSM can be configured completely with the couch removed for the EVT, if you hustle.

14. Minimum deadband attitude hold: Note, that in going to MINIMUM DEADBAND for the coarse align with four-quad roll and SCS, the SCS was overshooting by about 0.1 deg/sec and would oscillate firing the jets and not null. By turning off two quads, it would still overshoot by about 0.05 deg/sec; however, in turning the LIMIT CYCLE ON it damped out and seemed to be a very stable control mode.

SCHWEICKART — The support of the LM communications checks went without any particular problems, and the COMM sounded good throughout.

15. Preparation for docked DPS burn: The preparation for the docked DPS burn also went as planned. The monitor of the burn was set up (according to the procedures prepared prior to flight) by loading the

SCHWEICKART DAP and the CMC with the special parameters that MIT prepared to monitor the LM burn in real time.

16. Monitor DPS burn: During the LM DPS burn, the time to go (h_a and h_p) were good parameters and correlated very well with the numbers that the LM was reading. By looking out the window during the burn, I determined that there was no visual plume from the DPS. The acceleration level was low enough so that there was no problem of hanging in the straps; controls were easy to reach, and it was easy to monitor the systems in the command module.

The attitudes in the command module were similar to what we experienced during the simulations, but the excursions were not quite as great. As I recall, it was something like 2 to 3 degrees from zero; whereas during the simulations, it was up to 7 degrees.

SCOTT At the completion of the DPS burn, the residuals in the command module read

SCOTT

minus 4.7, plus 3.8, and minus 1.3; the DELTA-V counter read 1740.6 with an apogee of 271.7 and a perigee of 109.1; and the cutoff time seemed to agree between the two spacecrafts.

17. IVT to CSM: The IVT back to the command module from the LM was the same as previously described.

18. Tunnel operations: Reinstalling the tunnel hardware after the CDR and the LMP had transferred to the command module took 14 minutes for the drogue, the probe, and the hatch.

18. Tunnel operations: The tunnel operations were the same as previously described.

19. Center couch installation: The reinstallation of the couch was no problem, and the reconfiguration of the command module back to a normal three-man operation went nominally.

21. Preparation for SPS burn number 5:

SCOTT — The IMU alignment and preparation for SPS number 5 was nominal.

McDIVITT — 22. SPS burn number 5 performance and final parameters: SPS burn number 5 was supposed to be a minimum 40-second burn to ensure that we would be able to use the SPS for future maneuvers; there was some concern prior to the flight that there would be a lot of chugging and a possible engine shutdown. We had some very elaborate plans to take care of all these contingencies. The ignition was normal; we came out with bank B. We got the little chug that we usually got with bank B, and then we started getting a relatively large attitude excursion. The attitude error needles pegged in yaw to the left, and the attitude continued to go out but at a decreasing rate until it finally stopped. I would guess the attitude excursion and yaw initially was approximately 7 degrees. It then steered back through zero, off the other side, and shut down before the

McDIVITT steering oscillations had damped out. There were not any propulsion chugs. The propulsion portion of the burn was very nominal. We got the thing started and stopped, and the chamber pressure stayed up near 100 percent or 100 psi. There were no significant discrepancies. The only problem was the steering. We ended up with residuals of plus 1.9 in X, plus 11.1 in Y, and plus 3.4 in Z, with a DELTA-V counter reading of 9.9. The resulting orbit was 129.6 by 127.7, I think. This was the greatest excursion that we saw in any of the burns during the mission, and we had expected it. We had seen in simulations that this particular 40-second burn with the LM configuration attached always ended up with a fairly large dispersion in Y; sure enough, we got this predicted 11 ft/sec. We did not clean it up by burning out the residuals; this was not included in the flight plan, and we ended up with somewhat of a noncircular orbit for rendezvous. I

McDIVITT think, from a propulsion standpoint, it was a highly successful burn. Although we had subjected the service module to negative g's for almost 6 minutes or more, we were able to retain enough fuel in the 0-g cans to get the engine running. The resultant maneuver kept the fuel in the can and did not allow any noticeable amount of the gas to get into the chamber or to create any abnormalities as far as chamber pressures went. I might add that we used a four-jet, 18-second ullage for this maneuver to make sure that we did have the fuel settled. Interestingly enough, in the P30, our h_a and h_p came out as 135.3 and 128.1; and we ended up with a resultant orbit of 129.6 and 127.7. These things are not too correlatable but just bits of information.

23. Power down of spacecraft: I think the powering down of the spacecraft was comparable to the one described earlier.

McDIVITT 24. Doff PGA's: Also, the doffing of the PGA's was comparable to the one described earlier.

SCHWEICKART Another point on the CSM attitude control during day 3 with the docked configuration was the continual necessity to monitor and the attempt to avoid gimbal lock. Again, we had an out-of-plane alignment for the docked DPS burn, and I had to continually avoid (with minimal impulse) the gimbal lock region. It seemed as though the spacecraft wanted to trim inplane into the gimbal lock region continuously throughout the day.

McDIVITT The timeline in the morning from the end of the rest period to the time when we were supposed to transfer to the LM was extremely tight. There were a lot of problems that we had not anticipated prior to flight. I believe the major ones were the suit hoses and, because of the bulk of the suit, the inability of the three crewmembers to operate simultaneously and to maneuver around in the space-

McDIVITT craft when all three crewmembers were suited. However, this particular day was complicated by the fact that the LMP became ill just prior to the time when the CMP was to perform the IMU alignment at approximately 41 hours. This delayed the alignment time until just prior to sunrise. At this time, it was too late to complete the IMU alignment, and we had to slip the IMU to the following dark-side pass. This put us approximately 1-1/2 hours behind entry to the LM.

SCOTT There is a correction for the time required to configure for the EVT in the command module, which was stated as approximately 20 minutes. After the hatch is closed out and the CSM is set up for the EVT, the time to configure from this point is approximately 40 minutes. It requires 20 minutes to reconfigure after completing the day's activities, reinstalling the center couch, and reconfiguring for standard operation.

4.3.2 LM Initial Preparation and Checkout

SCHWEICKART

1. The LM AOT star observation pad and the S-band steerable pad: We did not pick up because we were running approximately 1 hour 10 minutes late at ingress to the LM.

Once Dave got the tunnel hatches, probes, drogues and things out, operating the dump valve went smoothly because it was in the OPEN position. In the DUMP position, there was no hiss, no differential pressure across the hatch. Opening the hatch was no problem as far as mobility, handling, lighting, or anything else was concerned. Upon going into the LM, I realized after I had gotten over there that the hoses were on the right-hand side of my PGA, which we had not mentioned in the checklist. They should be connected to the left side, so that one can connect the LM hoses to the right side. The transfer hose was barely long enough to get the job done. There were switches in the forward left-hand and the forward

SCHWEICKART right-hand side of the cockpit (the audio control switches) which were just barely within the reach envelope with the transfer umbilical connected. Aside from that, the IVT went smoothly. I connected the inboard aft LM restraints to hold me down to the floor, and I had no trouble in getting back and forth from one side of the spacecraft to the other.

4. Entry status: The entry status check went nominally. There were no comments on the entry status check. Everything was as planned.

5. Systems activation and checkout: The system's activation went along as planned, with the exception that the glycol temperature got in the vicinity of 70 degrees prior to completing the circuit breaker activation of panel 16. So, we went ahead and activated the primary glycol EVAP flow to get the cooling started. On the CAUTION and WARNING checkout, the lights (as called out in the checklist) were exactly the

SCHWEICKART ones that were on. That was the first time that we had seen any simulation or any place where the lights were as advertised. They were exactly as listed in the checklist. One other thing — on the suit fan H_2O separator check, the H_2O SEP component light would take a very long time (greater than 3 minutes) to come on. Then, rather than use the time, because we knew from prior activation of the suit fan that the H_2O SEP component light did work, we went ahead and switched over to the other suit fan without waiting for the H_2O SEP component light to come on. On the S-band VHF activation, we started out with a great deal of noise in the LM, which we finally recognized to be S-band hiss. When I turned the S-band volume down, the VHF came through loud and clear; and there was no noticeable difference in any antenna combination between the CSM and the LM. They all sounded essentially identical and were all 5 square.

SCHWEICKART: 6. Close tunnel operations: Following the transfer of the commander into the LM, we began the LM closeout. The OPS's were verified only to the extent that the pressures were up in the nominal region on this day, because we were well behind the timeline at this point. The tunnel closeout started at about 44:27.

McDIVITT: The tunnel closeout was performed according to the checklist; we put the drogue in place, placed the probe in through the drogue, and examined the capture latches. We could determine from the LM side that the latches were closed. This information was given to the CMP. Then, we closed our LM hatch. Total tunnel closeout took 17 minutes. At the completion of the tunnel closeout, we tried to stow the OPS's and ran intc a fit problem. The pin that goes through the cylindrical hole on the fitting, in the pack where the OPS pallet fits, would not fit in its own hole, even with the pallet off. I never was

McDIVITT able to make the pin go through the hole and to lock in, although it had been done on the ground. After a considerable amount of pushing and shoving, I got the pin into the point where I thought it would, at least, hold the OPS pallets. Unfortunately, it did not. Later on, during the course of the day, the OPS pallet (with its 80 pounds of OPS's) was found, a number of times, floating around in the back. On subsequent days, I took a piece of the Beta cloth netting that was fastened near the handle (which made it very difficult to operate) and actually pulled that Beta cloth out and used the web of it to hold the handle in the pin hole so that, although the latching device didn't work as it was supposed to, it did retain the OPS pallets on other days. During this period, it was not tethered to the floor by the tie-down system. I was floating around free on my hoses, and I found that I did not have too much difficulty except when

McDIVITT

working in the extreme rear of the spacecraft. I also found later on, when I tried to do the docking, that the top of my helmet was very badly marred. I am sure that this marring came from the three times that I had stowed the OPS pallets in the back.

8. Daylight AOT star visibility: We did not do the daylight AOT star visibility check because of the lateness of our start and our attempt to get back on the timeline.

SCHWEICKART

9. Communications tests: The communication test, I believe, is a VHF activation (I've already commented on that).

McDIVITT

11. Lighting of interior: The lighting in the rear of the spacecraft is very poor; and when you are trying to operate back in the area of the OPS pallet. The lithium hydroxide canisters, or the battery compartments, there's practically no lighting at all from the flood lights. You either have to bring the utility

McDIVITT

lights back, which are extremely good lights but which don't have any place really to fit in the rear, or to use your flashlight — and that makes it a little inconvenient.

12. Window shades: The window shades don't really keep the light out; they keep the sun out but not the light.

They were somewhat marred; and the big problem that we had with the window shades was that, when we unfastened them from the windows, they did not roll up into the tight roll like they had on the ground. They were in a rather loose roll, and what we finally ended up doing was to wedge them down behind the bars on the windows or continue to fold them up and to try to get them out of the way. I found them to be in the way a lot more than I had anticipated.

13. COAS lighting: It was at this time that I first noticed that the COAS lighting against the cloud-covered earth was

McDIVITT very poor. Even with the COAS turned full bright, the reticle was very difficult to see against the clouds. I checked it out in both the forward and upper windows and used this time to see how the COAS pattern lined up with the target window in the command module. It wasn't a very good lineup, but we had expected that this wouldn't be lined up in the docked configuration. It turned out that the center of the docking target was 4-1/2 degrees low in the COAS and a half degree to the right.

SCHWEICKART 14. S-band steerable antenna: This antenna check was not performed because of the late ingress into the LM.

15. MSFN S-band conference: The MSFN S-band conference was not performed because of the late ingress into the LM.

16. Landing gear deployment: The landing gear deployment was done over the Canaries and followed the checklist essentially as written. My subjective

McDIVITT — impression from the right-hand side was that you could hear the pyros go off when the landing gear was dropped. Within about 1 to 2 seconds, there was a rather solid thud as all four gears seemed to hit the stops together. At that point, Jim called out a gray indication on the talkback; and the gear was down and locked. When we put the gear down, they just went down with a big clunk, and it was pretty obvious that we had at least one gear down. We could look out and see some of them. In fact, I think we could see three of the four gears.

SCOTT — From the command module left-hand rendezvous window, you could see one gear come out and snap into place.

SCHWEICKART — 17. PLSS preparation: The PLSS preparation went essentially as planned. We found no trouble in connecting the OPS to the top of the PLSS. I think that the new pin that was put in about a month or two before lift-off made the operation much smoother with regard to bringing the

McDIVITT OPS and the PLSS together. There was no problem in connecting any of the communications connectors. Rather than have the PLSS tethered somewhere in the cabin, we felt that the safest mode of operation was to have it on my back; therefore, we released the straps from their stowage location and strapped on the PLSS. With the PLSS on my back, mobility at that time was rather severely restricted.

I had no trouble in maintaining position and never felt that I was endangering anything in the cockpit by having it on my back. It was more a matter of not moving around very much or not being able to move around very much. One operation concerning the PLSS worthy of note was locking the battery into the PLSS. This is an operation with which we had experienced difficulty from time to time on the ground. For apparently unexplained reasons, even after a good bit of training and familiarity with the locking mechanism, one could spend 2 to 5 min-

McDIVITT

utes trying to lock a battery in; and then with one more try, it would go right in. That very thing happened in flight. I spent about 3 to 4 minutes and was just about to give up on it. I tried one more time, and it went in like a piece of cake. To this day, we don't know what the difficulty was, but my feeling is that we ought to consider seriously a redesign on the battery-locking mechanism. It shouldn't be very complex. In my opinion, the present design is a little bit overly complex for the job it does.

19. Post-PLSS check: There was essentially nothing in the post-PLSS check; that's just a matter of taking it off and stowing it. We had no trouble with that.

20. Establishing PGNS, AGS, and LGC activities: To establish some reasonable probability of completing the docked DPS burn, we had to arrive back at a timeline where we could start checking the space-

McDIVITT craft out again at the time in the timeline when it was supposed to start. The first item that we had to get to was the DPS/APS RCS TEMPERATURE/PRESSURE check which was supposed to occur just prior to Carnarvon. Then we had to get our PGNS turned on, self-tested, and things like that. Therefore, we made an effort to get back on the timeline at this point. From this point on, we followed the timeline precisely. At some points we were a little ahead, but we never fell behind again, once we were established on something that resembled what we had planned on doing.

SCHWEICKART I believe that the only thing worthy of comment on the DPS/APS RCS TEMP/PRESSURE check was that they were all approximately 70 degrees. It did not appear that at any time during the flight we came even close to freezing any of the propellants. The PGNS, turn-on and self-test went as expected. The AGS activation and self-

SCHWEICKART

test also went as expected. The rate gyro check was pretty much as we'd experienced in the spacecraft testing on the ground. The rate needles on the 2 sides of the spacecraft exhibited their own peculiarities as far a hysteresis and inaccuracy were concerned. The 5-degree per second scale especially lacked sensitivity. Jim will comment on this later as to its effect on the operations. As far as I could see, there was no difference between what we saw in flight and on the ground. That means that there was no improvement in what we saw in flight. Jim mentioned that on his FDAI, there did appear to be a greater offset in flight than there had been on the ground. The LGC clock initialization went quite smoothly as did setting T_{ephem}. We conducted the E-memory dump during the tunnel closeout to get a leg up on the checking of the E-memory. To our knowledge, that went smoothly on the ground. We had no return from

SCHWEICKART

the ground on that. On second thought, one thing that came out of that was readjustment of the unit-W vector. We had two erasable memory locations which had to be readjusted because of the 3-day slip in launch time.

21. IMU coarse align while docked: The LM IMU docked alignment went essentially the way that we had trained on it. As we came through the tunnel, the docking ring angle (I don't think that's been mentioned yet) was plus 2.1 degrees indicated, and that cranked into the equations. The first set of gyro torquing angles from the ground came out to be plus 0.91, minus 0.15, and plus 1.20 degrees, which appeared to be quite nominal because of coarse align errors.

The PIPA bias check was performed as planned. The results showed that the PIPA's needed adjusting. The launch values of the X, Y, and Z biases were plus 10, plus 6, and 0. After perform-

SCHWEICKART

ing the PIPA bias check, we adjusted them respectively to plus 12, minus 3, and plus 1. This was repeated twice, just to make sure that we were getting consistent results on the PIPA bias check. We did get consistent results.

It was at this point that we executed a rather significant operator error. It's interesting that we were led into this trap because of the simulations in the LMS. The three PIPA registers that we adjust were erasable memory locations 1452, 1454, and 1456. In the training cycle, these were always set at zero; that is, we always simulated essentially zero PIPA biases in nominal cases and then superimposed a bias in each of the PIPA's, which we loaded. The intervening locations (that is, 1453, 1455, and 1457) also were always zero in our simulations and led us, without ever really checking it, to the idea that the PIPA bias was a double precision entry in the LGC. When

SCHWEICKART

we went to load our new values after the PIPA bias check in flight, we therefore loaded not only 1452, 1454, and 1456, but also zeroed the three other registers, if the total double precision word should have been reloaded. Luckily, this was observed by the ground. They called up that we should reload 1457, and that cued us to the idea that we had probably mis-loaded the other two, 1453 and 1455, also. We called down to the ground to check this and, sure enough, they wanted us to reload those also.

I guess that what this points out is that the LMS training ought to be as authentic as it can possibly be. Rather than having perfect PIPA's zero scale factor errors, and things of that kind, we ought to have some numbers even if they stay the same. One ought not to be led inadvertently into traps such as assuming that we've got a double-precision word when it's really single precision.

SCHWEICKART

22. RCS pressurization, cold fire, and hot fire: Again, the RCS pressurization went essentially as planned. The pressures came right up to the expected values of 185 psi. The RCS cold fire worked exactly as it had in the LMS except that the hand controller proportional checks worked very smoothly; that is, steps 3 and 5 in the checklist (where we deflect the controllers to the soft stops and observe the DSKY registers count up in proportion to the deflection). There was no interruption of the display as we had witnessed all through our training in the LMS. The normal 2-second update cycle of the LGC was apparent, but the values in the registers never jumped back to zero and stayed there for several seconds before going back up, which was the case in the LMS.

The RCS hot fire also went essentially as during our training, with the additional benefit that there was no problem whatever in audibly verifying that one or more jets

SCHWEICKART

were firing as they were called on. The rate needles essentially moved as expected; that is, there was no apparent coupling during the tests. This led us to conclude that the proper jets, that is, all the jets were firing.

It was about this time that we received notification from MSFN that the up-firing thruster on QUAD 4 had a faulty thrust-chamber pressure switch indication. This would affect our RCS/TCA CAUTION and WARNING system to the extent that an OFF failure, that is, a failed OFF condition on that thruster would not be detected by the CAUTION and WARNING.

The indicated supercritical helium pressure was zero. We had no display of that quantity. At a later time, we checked it and it read 730. This display during the flight would read alternately no indication or the actual pressure, which was always approximately 730 throughout this day. Following the DPS/APS/RCS temperature/

SCHWEICKART

pressure check, the supercritical pressure read 830 psi.

24. LR, RR self test: The landing radar self test went as called out in the check-list. All the displays indicated as we had been led to anticipate in training and systems tests on the ground. There were no apparent spurious lock-ons of the landing radar all through the tests or, for that matter, through the rest of the flight. The behavior of the cross pointers and the range/range rate tape was as we had seen it in FRT on the pad.

The rendezvous radar self test was somewhat of a surprise to us. The indications on the range/range rate tape display were as expected. However, the interface with the LGC was somewhat of a mystery to us. The behavior was not consistent nor was it what we had expected from our training. In particular, the range-rate indication and the range indication in NOUN 71 of the rendezvous radar self test routine

SCHWEICKART did not appear as it was displayed on the tape meter or called out in the checklist. We reran the test three or four times, and in most cases, the range rate would appear and look essentially normal. I have written down in my checklist minus 494 ft/sec. However, the range, all but one time, read zero all through the test. There was one time that we repeated the test; and for approximately 4 seconds during the test, we did see a range of 195.5 miles. However, the next time we tried it, it read zero again. We could not get consistent behavior from the self test.

It's of significance to mention that we did not unstow the radar for this test. Because of the problems that we had had with the nausea earlier, at this point we were not planning to perform the EVA the following day. For this reason, the rendezvous radar was left in the stowed position.

The landing radar temperature started

SCHWEICKART

out at 81 degrees just prior to the burn and, just after shutdown, indicated 100 degrees. It stayed fairly steady at that point. On the order of 2 to 3 minutes after cut-off, the landing radar temperature was still 100 degrees and, as I recall it, finally reached a maximum of approximately 110 degrees.

25. Updating, alignment calibration of AGS: The REFSMMAT and state vector update were as expected. The AGS initialization was the next place we ran into a problem, and this is one that surprised all of us. Everything went normal except that, in the updating process, the AGS 414 would not go back to all zeros when the PGNS sent the update across the interface. We repeated the AGS initialization several times, all with the same results; that is, no apparent response in the AGS with regard to receiving the update. The ground advised us later that we had to be in high bit rate on the telemetry to get the update across. This is the

SCHWEICKART first time that we had ever heard this. After going into high bit rate and attempting it again, it worked as we had seen it work all through the training cycle.

On checking the h_a and h_p in the AGS, they compared within tolerance with the PGNS orbit parameters. Again, the AGS calibration went as we had simulated it. I think it's worthy of mention that the accelerometer bias coefficients exhibited almost no change on all of the AGS calibrations. However, the gyro drift coefficients were not quite as consistent. Prior to the AGS calibration, the gyro drift coefficients were reading plus 0.27 deg/hr, plus 0.47 deg/hr, and plus 0.06 deg/hr X, Y, and Z. Following the calibration, they had changed to plus 0.21, plus 0.36, and minus 0.20. Therefore, the largest shift that we saw was a negative shift in the Z gyro of 0.26 deg/hr. On subsequent AGS calibrations, the bias coefficients and the accelerometer coeffi-

SCHWEICKART

cients remained essentially as we was them here in the first calibration. However, the gyro drift coefficients again altered almost every time we did them, although never by more than about 0.2 deg/hr.

26. Preparation for DPS burn: The DPS pressurization went as expected. The only thing worthy of note was that the descent supercritical pressure, although in limits, was at the bottom end of the expected range. We had a range of 715 to 1200 psi on the supercritical pressure, and at this point in flight it was reading 730, only 15 psi above the minimum. The LM docked IMU alignment was quite successful. We read the angles back to the ground at this point and received new gyro torquing angles. They were minus 0.04, plus 0.18, and minus 0.16 degree of required torquing. So it looks as though we experienced less than 0.2 degree torquing with about 1-1/2 hours between alignments. That appears to be well within the ball park.

McDIVITT — The command module maneuvered us to the attitude, and we were very close to the correct attitude when we switched over and took control with the LM. The command module went inactive. We made the final maneuver without any problem. There was not a large amount of thruster activity. We maneuvered over and held at the right attitude. The checklist that we were using to prepare for the burn seemed to have all the things in it that we needed. We were a little ahead of time when we got to our attitude, and we went right on through and never were behind in this particular portion of the mission.

SCHWEICKART — In the preparations for the docked DPS burn, the NOUN 86 data compared very close with the pads sent up from the ground. I put the NOUN 86 data into the AGS. It was at this time that we noted that address 407, which we set to a zero prior to the burn and the first acceleration is supposed to freeze the inertial reference frame by switching 407 to a plus 1.

SCHWEICKART

This address would change by itself under attitude control prior to the burn to plus 1 and had to be reset several times to plus all zeros. I believe that I finally terminated the monitor on 407 on the order of 30 seconds before the ignition. At that point, I switched over to read the 500, 501, and 502.

The behavior of address 407 was exhibited through the rest of the flight and did require special care. I think that this is a situation which very definitely needs improving. You can't sit there and babysit one address continually.

4.3.2 LM Initial Preparation and Checkout

SCHWEICKART

27. Docked DPS burn: About 20 seconds prior to engine cut-off, the heater CAUTION light came on, and it was speculated at that time that the cause was high temperatures on the RCS quads. However, on reviewing that now in my mind, I don't believe that was the case, since the quads were not being used. We had inserted a

SCHWEICKART VERB 65, which inhabited RCS jets for firing during the docked DPS burn, and I have a feeling that it was probably the landing radar temperature or one of the antenna temperatures. The landing radar temperature prior to the burn was 81 degrees. Somewhere in the middle of the burn, I observed it to be 95 degrees. Immediately following cut-off, it was indicating 100; and at cut-off plus somewhere between 10 and 15 minutes, it peaked out at approximately 110 degrees.

McDIVITT 27. Docked DPS burn: At ignition, the engine lit very smoothly, the thrust-chamber pressure went from zero to 10 percent very smoothly, and there was a real lack of noise. I had expected to hear the engine a lot in the spacecraft, and we really heard it hardly at all. There was a sensation that it was running. There wasn't any doubt that the thing was actually running, but certainly there were no big bangs, thuds, or anything

McDIVITT

like that.

Throttle-up to 40 percent at 5 seconds after ignition went smoothly, and there didn't seem to be any appreciable lag at all between the thrust chamber pressure and the throttle position. It followed right with it, with no lag whatsoever.

At 26 seconds after ignition, the engine then throttled up to full throttle.

Again, it was a very smooth throttle-up with no apparent chugging or noise to be concerned with. There was just the firm feeling of the engine throttling up and a definite feeling after the thing was under control.

The attitude excursions were much less than we had anticipated. We were obviously trimmed in the right place, and the engine mount compliance and those things seemed to have been taken care of.

The attitude excursions were probably less than a couple degrees. The rates were very low. The spacecraft guidance

McDIVITT

was obviously compensating for all the things, and we got right up to 100 percent and had very little excursions. The monitoring problem was considerably simplified over what it could have been, because we had anticipated somewhat larger excursions. We had a limit of 45 degrees transient and 10 degrees steady state. We never even came close to any of these.

We had pressurized the DPS earlier, and the other squibs fired at ignition. The pressures that we were looking at were nominal at ignition and began to drop down to the region of approximately 180 psi. I believe it was 180 psi. I believe that it dropped from 240 to 180. I was somewhat concerned that it would continue down, but the pressure turned around there and went right back up to the normal regulated pressure of 240.

At ignition, I switched the master alarm switch from ON to OFF before I started

McDIVITT

the throttle-up. This is to protect us against any inadvertent relay closures in the pyro system during engine firing. It had been suggested by FOD. We accomplished this and then throttled up so that the throttle-up took place maybe a second or so after 5 seconds as in the flight plan.

The propulsion and guidance parts of the burn were very nominal until we got out to about 5 minutes, or shortly before we started the throttle profile. At this time, there was a very slight oscillation that could be felt in the spacecraft. I'm not really sure exactly what was causing it. You could speculate on a number of things. There was a definite oscillation — a very low amplitude — but it could be felt. The LM yaw-rate needle was moving slightly. I can't explain exactly why. That was the needle. We were getting a very little bit in roll rate also. The roll rate on the left hand side looked like the oscillations

McDIVITT were something on the order of one-half deg/sec, peak to peak. You could see the needle moving, but little else was apparent. The attitude on my attitude indicator did not appear to vary at all. I think that it's appropriate at this time to have Dave mention what he saw on the CSM.

SCOTT The steering and the propulsion parts of the beginning of the burn were exactly nominal. The only off-nominal things that we had anywhere through the burn was this slight pulsing approximately 45 seconds before we began the throttle profile. They were very low amplitude and low frequency and did not cause any concern whatsoever. The only reason we're mentioning them here is that they were discernable, and other people should be prepared to feel something like that if they do a docked DPS burn. I'm not sure that the same kind of dynamics would be present for a nondocked DPS burn.

McDIVITT

At approximately 130 ft/sec, we began the throttle profile which was the standard throttle profile. We felt nothing abnormal during this period. There were some very slight transients in attitude, but we had expected these because of the engine mount compliance, the bending of the structure, and things like that. We found nothing really abnormal. This part of the burn went very smoothly.

We got down to the fixed-throttle point, the fixed-throttle position, of 40 percent for the last part of the burn with about 30 seconds to go. Just exactly as we had planned preflight, we ran through that and shut the engine down manually at 3 seconds to go.

We locked up the ullage and the regulators at 10 seconds from cut-off and, from that moment on, operated the descent propulsion system on the locked-up pressure. There were no apparent spurious lockons by the landing radar during this period.

SCHWEICKART During the burn, my sensations on the right-hand side were essentially the same as Jim's. I saw no visual evidence whatever of a plume, nor was I able to hear the descent engine running. It was very quiet, essentially the same as the descent engine OFF, with regard to noise and vibration. I felt no noticeable vibration. The only thing that was apparent was the commanded changes in thrust level.

Following shutdown, the residuals read plus 4.2, zero, and plus 0.2 in X, Y, and Z.

Following the burn of the AGS, residuals of 500, 501, 502 plus 3 ft/sec minus 5 and 0. Calling the orbit parameters with the VERB 82, they came out to 109.2 by 273.0, which was right on the money. The oscillations that we experienced toward the end of the fixed-throttle point part of the burn appeared on the rate needles to be very similar to what I had witnessed on the FMES at Grumman

SCHWEICKART as fuel slosh. That was not only by watching the rate needles, but you could also feel it as a very definite movement, a force on the body.

On my side of the cockpit, I didn't notice the yaw rate. I don't think I even looked at it, but my roll rate needle appeared to be oscillating in the order of plus or minus 1 deg/sec peak to peak. I would guess that the frequency was somewhere between 6 and 10 cps, something like that. It is very difficult to estimate. Make my lower limit on that something like 2 cps.

McDIVITT 28. Sequence camera (DPS plume effect): I looked down to see what the plume looked like, and the plume was practically non-existent. It was very difficult to see anything, to see that there even was a plume. Unfortunately, we were face down going across a cloud layer prior to the time that I looked down at the plume, and I certainly wasn't dark adapted. When I looked down where the plume should

McDIVITT — have been, there just wasn't anything there. Therefore, I would assume that the plume, with regard to a detriment to visibility, is practically nonexistent in the environment in which we were. I'm sure that it would be different if we were trying to land on the moon, but in orbit it's no factor whatsoever. We were doing the burn in daylight so that there wasn't any light reflected from the plume.

SCHWEICKART — The 16mm sequence camera was operated as called out in the checklist for the burn.

SCOTT — 29. AGS calibration and LR self test: Concerning calibration of the AGS, the proper attitude could be obtained by maneuvering the command module to an offset of 22 degrees in pitch and 22 degrees in yaw from 0-0-0 on the ball or 180-180-0 on the ball. The roll angle didn't seem to make too much difference. This would give a proper orientation if the REFSMMATS were the same. For the

SCOTT

actual calibration, the CSM was damped to less than 0.1 deg/sec and then allowed to drift for 6 minutes, which would maintain the LM within its 22-degree deadband with no problem.

SCHWEICKART

Following the burn, we picked up with the AGS calibration again, and the accelerometer bias coefficients remained what they had been after the first calibration. The gyro drift coefficients changed again. This time, following the calibration, they were reading plus 0.07, plus 0.28, and plus 00. The landing radar self test following the burn was absolutely identical with what we saw prior to the burn.

31. Sublimator dryout: We initiated the sublimator dryout before we had begun clearing the tunnel, or just about the time we had begun. As a result, both the commander and the LMP were on the suit loop through what I would guess to be 90 percent of the dryout time. The significance of this is that the water in the suit loop, since we've

SCHWEICKART

shut off the primary EVAP flow, had no place to go. Therefore, that water was entrained somewhere within the suit loop, even though the dryout appeared to follow very close to the expected temperature curves that we had in the systems data book. I guess that we ought to correct that to say that the LMP was on the suit hoses for more than 90 percent of the dryout; the commander was on for longer than expected, but we'd guess now on the order of one-half hour.

4.3.2 LM Initial Preparation and Checkout

SCHWEICKART

32. Deactivation and power down: In the final power-down, where the repress valve is positioned from AUTO to CLOSE, there was an extremely loud and sharp bang which was caused by moving the valve from one position to the other. When I first heard this sound, I immediately switched back to AUTO. Then, I recalled that LM-4 had exper-

SCHWEICKART

ienced a similar noise upon repositioning that valve in the altitude chamber run. We had not seen this in LM-3 during the altitude chamber run. I did recall this; therefore, I positioned the valve from AUTO to CLOSE which resulted in another extremely loud and sharp report. The closest thing to which I could compare it would be a rifle going off about 2 feet from your ear. It was loud enough that the CMP in the command module heard it — with some alarm. The magnitude and nature of this sound remained as some concern to me throughout the flight.

It is difficult to imagine a mechanical system, especially one which involves seals and things of this nature, which could tolerate or generate that magnitude of noise without suffering some kind of degradation. I don't know whether or not there was any degradation associated with this phenomena. We had reasonable

SCHWEICKART assurance from the ground that this was normal.

32. Deactivation and power down: The power-down part of the checklist went as expected. The only problem that we ran into was that, as we finished the final deactivation, there was a little discrepancy between panels 11 and 16 when we came to the configuration of the translunar bus-tie breakers. Upon looking at the checklist at this point, it's not clear why the confusion was generated. In any case, we recognized that the final circuit breaker configuration was proper, with both translunar bus ties in the open position. However, the confusion this day set up, unfortunately, the error in configuration on the following day (the EVA day), to which we will get.

Our power transfer back to the command module power was nominal. The indication internal to the LM was that the caution-and-warning power-caution light on

SCHWEICKART panel 2 extinguishes. At night, the command module pilot can look out the number 2 window in the command module and see the docking light go out on the power transfer.

33. LMP and CDR IVT to CSM: The LMP IVT to the CSM was done with no particular difficulty. At this point, the dump valve on the upper hatch was left in the AUTO position.

McDIVITT 34. Work loads and timelines: Workloads and timelines were a major factor in the activities of this day. As mentioned earlier, we began the day approximately 1-1/2 hours late; it went fairly quickly and we caught up a little. We were operating approximately 1 hour late on our timeline, which meant that some of the checks that we were to do over fixed ground stations were going to have to be skipped. We had already eliminated the daylight AOT star visibility check. We got a little further behind when the LMP became sick again. We established a

McDIVITT point to get back on the timeline regardless of what had happened in the early part of the day's activities. This point was at approximately 47 hours and 10 minutes when we began DPS, APS, RCS temperature/pressure checks. From that check to the docked DPS burns, we had to follow pretty much the original timeline, or we were going to have to slip the docked DPS burn a revolution, which then would have taken 1-1/2 hours out of the rest cycle if we were going to continue the next day with the same timeline. Therefore, we had to fix this as the point to return to the nominal timeline. We did, and from that point through the rest of the day, we operated on the timeline that we had established for ourselves.

Some of the communications checks were achieved this day, and some of them were achieved on the EVA day. We'll summarize all those in one big package later. We found that, once we were on the indepen-

McDIVITT

dent vehicle activity timeline, we were able to stay on it very much as simulated in the preflight activities.

On the third day, we had decided that there would not be an EVA for the following day. Both spacecraft would be depressurized, the hatches would be opened, and we would exercise the PLSS as much as we could, depending upon the well-being of the LMP at that time.

When we awoke in the morning, we started on a plan that had been generated by the flight-planning people on the ground. It included the hatch opening on both spacecraft, the donning of the PLSS (but not the integration of the OPS into the EMU package), and having the LMP remain on the LM suit hoses and the PLSS hoses rather than the OPS hoses and the PLSS hoses.

4.4 Fourth Day

4.4.1 Command Module

MCDIVITT

Concerning the command-module fourth day, it's worthy of note here that the housekeeping prior to beginning operations for the day's activities was quite a bit more than we had planned on in the preflight planning.

1. Don PGA's: The nature of the suit-hose combination, which we'll go into in much greater detail later, was something that took considerably more time to prepare ourselves, and caused us to work in a serial rather than a parallel fashion once we were suited.

2. Tunnel operations (anomalies): Once again we found ourselves late beginning the tunnel operations.

SCOTT

3. General transfer operstions: The tunnel clearance went as before - very easy, following the checklist, the masses were easy to move and easy to store. The only problem encountered, as it was each time, was the operation around the hoses.

SCOTT

The hatch-integrity check took a little longer than anticipated, about 10 minutes to depress the tunnel and make sure that there was a good seal on the hatch.

4. PLSS communications check with LM: The communications check with the PLSS and the LM went very well. The COMM was good and clear. The VOX on panel 9, with panel 10 in the backup mode, worked very well except for the delayed time at the end of the transmission, which is too long. The configuration inside the command module was with the CMP on the CMP hoses and COMM using panel 10 in backup, the CDR and LMP hoses in a position to support an EV transfer and a vacuum transfer inside the command module for the CDR.

5. Maneuvering to EVA attitude: The EVA attitude was established using the BMAG's only. The IMU was powered down because we didn't anticipate doing the EVA. I maneuvered the vehicles to an attitude relative to the sun as near as possible based on our preflight orientation

SCOTT

determination. The object was to keep the sun from shafting in the command module and on the command module MDC. Pointing the plus Z-axis at the sun and pitching down 15 and rolling left 80 worked out very well. Throughout the EVA, there was no sun shafting inside the command module.

6. Preparation of ECS and cabin for DEPRESS and PGS integrity: Cabin preparation for the EVA went according to the checklist with no problems. The checklist seems to work very well and the sequence is also very good. The EVVA was difficult to get on. It appeared to be too tight for my helmet, and I had to take my helmet off and use quite a bit of force to get the latch over center on EVVA.

In preparing for the DEPRESS and evaluating the equipment, it became apparent that the EVA gloves would be impossible to use on the rotational controller. So I put the right EV glove on and used the

SCOTT

IV glove on my left hand so I could control the spacecraft if it was necessary. I put the rotational hand controller on the left armrest of the left couch and stowed the translational hand controller in the LEB.

It sure seems that there's a lot of work necessary to make the EV gloves operational. The pair I had were absolutely poor. The set that I had was one generation earlier than the set that Rusty had, which apparently were a little better. I wanted to make sure I had one EV glove in case the hatch got hot or cold before closing.

After the initial preparation of the cabin to the point where it could be depressed and the CMP could prepare for a DEPRESS relative to EVT, it took about 20 minutes from the time I was ready to start to DEPRESS to go through the integrity check (helmet and gloves) and get the hatch open for DEPRESS. If the PGA integrity check were eliminated for some

SCOTT reason, it would take about 10 minutes to go through a complete DEPRESS, if the situation arose where an EVT were necessary after a rendezvous.

The hatch was disconnected from the counterbalance with a pit pin. The counterbalance was vented completely. The pit pin was stored in R-1 so it wouldn't get lost. When the counterbalance was vented, it was about one-third full scale on the gage, and it took it about 1-1/2 to 2 minutes to vent completely.

The suit-loop-integrity check in the command module was approximately 0.2 psi/min, well within the tolerances.

McDIVITT During this period of activity, we had attempted to shorten the work period and lengthen that night's rest period because we had a great desire to get started on time the next morning and also considering the delay we'd been having achieving the transfer to the LM. We felt that we should wake up at least an hour early on

McDIVITT

the rendezvous day because this was a day when we could not slip anything. We had a very, very tight timeline prior to separation, and if we got started late, we would be in reasonably bad shape. We didn't want to slip the beginning of the rendezvous by one REV because it would have made the ground tracking less desirable than it already was. So we had eliminated essentially one REV from the flight plan by doing the EVA on just one dayside pass rather than one dayside, a darkside, then one dayside pass. Even with the elimination of this 1-1/2 hour period, we finally found ourselves getting to bed approximately 1/2 hour after we would have normally. So, we found ourselves with about 2 hours more work after the EVA was over than was in the flight plan.

This was typical of the problems that we'd been having in preparing ourselves and the spacecraft in the morning, and, I guess, unpreparing ourselves in the

McDIVITT: evening. What it amounted to was a very short rest period between the EVA day and the rendezvous day.

SCOTT: 7. DEPRESS: The cabin was depressed about 8 minutes prior to sunrise and it took about 3 minutes to run through the standard procedures for depressing. The hatch was opened about 5 minutes prior to sunrise and it took less than a minute with the standard hatch-opening procedures. It took about 40 pounds to push the hatch to the full-open position. It would stay at any intermediate position at which it was left. At the full-open position, it seemed to want to stay there fine without any need for a lock of any type.

The only comment I have on the hatch gearbox is poor markings on the shear pin.

8. Sequence camera operations: The sequence camera mount on the hatch was good. The wire which runs to the remote cable seemed to work out very well.

SCOTT

The camera for the first film MAG worked as advertised. The Hasselblad worked well. It was tethered with a tool tether to my wrist. On trying to put a second magazine in the sequence camera, I had considerable difficulty primarily due to the EV gloves and the inability to manipulate fingers with that thing. Once I got the magazine in, the camera wouldn't run. A subsequent investigation in the spacecraft after a fuse change enabled us to get it running again.

12. Side hatch operations: On closing the side hatch at the completion of the dayside pass, there were no noticeable temperature extremes within the IV gloves. The hatch came with little effort - approximately 40 pounds or less. Once I got the hatch to the ajar position, I held it such that the dogs were over the striker plate with about 30 pounds of force. I stroked to close with the normal four strokes on the gearbox.

SCOTT

15. REPRESS: The REPRESS took approximately 4 minutes to go through the hatch-integrity check - or checking the seal - and to bring the inside of the command module up to 2 psi with the PLSS package. Then, from 2 to 4 psi, the LM oxygen was used through the tunnel. It took it a couple of minutes to get up to the tunnel and open the tunnel REPRESS valve. From 4 psi to 5 psi, I used the PLSS tank again. It bled the surge tank on down to about 700 pounds, and that took another 2 minutes or so.

The procedures on REPRESS are straightforward and simple to use. It's easy to reach the necessary valves with the center couch out, and with the mirror it's easy to observe the cabin pressure and the suit pressure. I believe that the procedures as developed will work adequately for any necessary EV transfer.

16. PostEVA systems configuration: The postEVA systems configuration took approximately 50 minutes from the time the cabin

SCOTT

was repressed until the hatch was open and access to the LM was available. This included repositioning the center couch, reinstalling the hand controllers, the L-shaped bag, stowing the thermal samples, and the other sundry items that go with reconfiguration. A few small things were not performed in an effort to prepare the tunnel as soon as possible.

17. IVT to CSM: The tunnel, again, was no problem. Everything worked nominally.

18. Power transfer: The power transfer systems test meter appeared to be somewhat different from previous days. It cycled at the lower end of the scale rather than going up to the 2 volts as it had done previously.

19. Tunnel closeout: After the transfer, the tunnel closeout took approximately 15 minutes, and again no anomalies. Because of the necessity for Rusty to go back and pull the LM trans-lunar BUS ties circuit breakers, we had to reopen the tunnel and reclose the tunnel. This

SCOTT complete operation took approximately 10 minutes from the time we started with the closed tunnel until we had reclosed the tunnel.

4.4.2 LM EVA Activities

SCOTT

1. IVT to LM: On the ingress to the LM on the EVA day, the only difference noted in the tunnel operation was that, since the dump valve had been left in AUTO rather than DUMP or OPEN following activities of the first day, there was a slight pressure differential across the hatch. This was noted as a slight hiss as the dump valve was actuated prior to ingressing the LM. I have no way of knowing what the actual differential was, but to give some feel for it, after actuating the dump valve the hiss was audible for perhaps 2 to 3 seconds.

McDIVITT

With these extra systems tests, we were able to do the regular check that we had skipped on the previous day. We were somewhat late due to the activities described on the CSM side of the interface. We therefore deleted some of the COMM checks. We reconfigured and changed the checklist back to the normal OPS, PLSS, EMU, and EVA modes. We elected to

McDIVITT eliminate some of the COMM checks to arrive at a configuration where we could proceed with a seminominal EVA mode at the appropriate time, which, in this case, was 73:07 for sunrise.

Early in the morning of the EVA day, we changed the checklist in our flight plan update to configure the EMU for the LMP so that he would be using both PLSS and LM ECS. After we had begun the configuration, it became obvious that the LMP was in good enough physical condition to perform the EVA. Also, it was obvious that we could achieve an awful lot more by completing the EVA mode rather than by doing the COMM checks. So, we changed the checklist back to the nominal form. Then, we went back and completed those steps that we had eliminated earlier. We configured ourselves according to the checklist with the exception that some of the camera equipment was not in the LM because we had not anticipated doing the full EVA.

McDIVITT

3. Entry status checks and activation: The rest of the IVT-entry status checks, activation of the systems, power transfer, communications in S-band, and that sort of thing were as already reported. Because of lack of time on the systems day, there were a few things that we had not performed. These were systems 32 and systems 33, which I'll expand on in just a moment. We had reason to believe that we ought to do them on this particular day to fulfill the objectives. I'll talk about it in just a moment.

SCOTT

6. EVA preparation: Handling of the ISA during the EVA PREP appeared to be no problem. It was mounted over the MDC and did not significantly interfere with operations within the cabin. The OPS preparation on this day revealed that the commander's OPS heater test circuit did not work. I ran about three checks on the heater circuit and neither of the two green lights came on.

In all other aspects, the OPS checked out

SCOTT nominally, as did the LMP's OPS. When I handed the commander's OPS to the commander, he ran another check on the OPS; and it operated properly, that is he got the green lights. The commander ran the check on his OPS three times, and he got the green lights all three times which indicated proper heater operations. We had no way of knowing whether this was an intermittent operation of the indicator system or whether there was indeed some malfunctioning of the heater circuitry. We decided to continue with the LMP's OPS mounted on top of the PLSS. Also, we decided that if an actual contingency transfer on that day was required, the LMP would mount the commander's OPS on top of the PLSS; and the commander would use the LMP's OPS for the contingency transfer.

SCHWEICKART The PLSS operation was nominal this day. We did not remove the battery used the day before; therefore, we experienced no further difficulties associated with

SCHWEICKART the battery connections. Unstowing of the hoses and preparation of the COMM leads were as we had experienced in the various training exercises and the test runs on the preflight PLSS test.

Donning the PLSS, checking the RCU, and working together in the cockpit with the EMU mounted on the LMP's back proved to be no particular problem. The two crewmen exchanged places, as called out in the checklist, for the donning process. I was on the left-hand side of the cockpit, so I used the commander's two inboard restraints — one on the left side and one on the right side of the suit. They held me in position facing the center of the cockpit.

A following is subjective evaluation of the work required in the EVA PREPS. The zero-g effort of handling the various bits and pieces of equipment associated with the EVA appeared to be a good bit easier in zero g than what we had found

SCHWEICKART in the one-g training exercises.

McDIVITT Upon observing Dave handling the PLSS, the OPS pallets, the big pieces of equipment on the command module side, and similar things on the LM side, I found that the heavy masses were much easier to control than what I had anticipated. They were really no problems at all. There was only a problem on the LM side. Because I had elected to remain unrestrained to the floor, I had a little difficulty sometimes controlling my body. I just floated free and held onto the large masses. They were quite easy to handle. Even in the free-floating mode, I didn't have any trouble getting them where I wanted them or positioning them with respect to Rusty when he was trying to install them.

SCHWEICKART Installing the EVA tether, connecting the LMP suit, and handling the EVVA, while using the antifog in the helmets were all done with relative ease. There were no unexpected complications which

SCHWEICKART arose. In fact, a large portion (greater than anticipated) of the work associated with donning the equipment was done unaided. I installed my EVVA by myself. Jim was doing something else at that time.

The EVVA was self-donned. The wiping of the helmets with the antifog and that kind of thing was all done by the LMP. In regard to the restraint system as I was using it, I found that I had no problem in maintaining my position. I had no tendency to inadvertently back into switches, circuit breakers, or anything of that kind. Therefore, I felt free to take part in the PREPS to a greater extent than what we had planned on the ground. I'd like to comment one little bit on the helmet protector that we wore during the flight. The first time I'd ever seen it was when I opened up the L-shaped bag right after transposition and docking. It was a slightly

SCHWEICKART

different configuration — and I found it to be considerably harder to place on my helmet than the previous ones.

7. Camera preparation: We elected not to use the standard Hasselblad during the EVA in the LM because it gave us two 70mm cameras and a 16mm camera to handle. There were not any good places to tether these cameras when they were not in use; so, we elected to use one 70mm and one 16mm camera. As I had previously mentioned, we were sort of configured at the beginning of the day for no EVA. As the day went along, we elected to go with the EVA.

When we were loading the ISA to bring the things from the command module to the LM, we left the 16mm sequence camera bracket in the command module deliberately. After we got into the LM, we found that we probably should have brought it with us. The superwide-angle Hasselblad and the 16mm sequence camera was configured in a normal manner

SCHWEICKART and was placed in the ISA. We used both in a handheld mode rather than a fixed mode during the EVA.

8. PLSS communications check: The PLSS COMM checks worked better than expected. After activating the communications system on the PLSS, I was able to communicate directly with the command and service module via VHF; and at several points in the timeline prior to egress I was able to hear transmissions directly from MSFN. These were not via relay but were actually direct radiation to the PLSS OPS antenna.

9. Preparation for DEPRESS and DEPRESS: The preparations for depress followed the checklist and included the 2-minute oxygen purge of the LM suit loop prior to initiating the pressure-integrity checks. The only modification that we made to the 2-minute purge was made prior to flight. In flight, we did follow the checklist.

SCHWEICKART

9. Preparation for DEPRESS and DEPRESS: The cabin DEPRESS was initiated after the pressure-integrity check. The only thing worthy of special comment was that the lunar surface filter was placed over the dump valve to prevent any of the flotsam and jetsam floating around the cockpit from being trapped within the dump valve. This slowed the pressure decay in the cabin to some extent. However, the total time elapsed was not sufficient to cause any discomfort within the EMU.

The purge requires no particular comment. It operated as expected. This was followed by the commander's suit-integrity check. For this check, the LMP disconnected by using the suit isolation valve to suit-disconnect, while the commander made his pressure-integrity check. The PLSS fan was activated to keep the CO_2 level on the helmet down for the LMP during that time. The commander's

SCHWEICKART pressure-integrity check was nominal; and on returning to five psi or slightly above, the PLSS fan was turned off and the LMP reconnected with the LM suit loop.

I noted during the regulator check, which we had run earlier in the day, that my right ear was not clearing properly.

I anticipated some problem in performing the PLSS pressure-integrity check.

Following the commander's pressure-integrity check, a final verification was made on the configuration of both the commander and the LMP, as well as the positioning of tethers and so forth.

At that point, the LMP's pressure-integrity check and cabin DEPRESS were intiated. Upon activating the PLSS O_2, the pressure started up very nicely in the EMU. However, as I suspected, my right ear did not clear properly; therefore, I had to interrupt the normal buildup of pressure by turning the PLSS O_2 to CLOSE.

SCHWEICKART

11. PLSS Control during DEPRESS: The feedwater warning tone in the PLSS came on as expected. After the hatch opened, the feedwater valve was opened; and within about 3 minutes, the tone went off. I immediately placed the diverter valve to MAX cooling; and within 10 to 15 seconds, I was able to sense cold water beginning to circulate through the LCG. After a short time in MAX cooling, the diverter valve was placed in MIN cooling and was left there for the remainder of the EVA.

11. PLSS control during DEPRESS: Another change, which had been introduced to the checklist to minimize the possiblity of getting gas into the LCG cooling loop, was to hold the activation of the PLSS pump until after the cabin had been depressurized. This was done as recommended. As the cabin depressurization progressed, the absolute pressure in the EMU dropped down to about 5 psia. This assisted in clearing my right ear.

SCHWEICKART

12. Visor fogging: No visor fogging was noted during the entire operation. The comfort in the suit prior to the sublimator startup was quite similar to what we had experienced preflight, that is, the temperature began to rise slowly but never became objectionable all through the operation.

SCOTT

12. Visor fogging: There was no fogging on the visor. One thing noted in the visor was a bull's-eye on the EVVA when it got in the right sunlight. We checked the thermal samples on the command module and the one next to the hatch was gone as if it had been removed normally. The three on the service module were in place. I attached the thermal sample tether to them and retrieved them into the command module with no problem. There was no strain on the hoses at any time. It was easy to reach down to the edge of the service module with the CMP hoses. Movement inside the command module from the

SCOTT

hatch to the center portion (with the center couch removed) and into the left couch was relatively easy. It would be no problem during an actual EVT ingress to get out of the way into the left couch. However, it would be necessary to have the X-X strut and the foot of the left couch disconnected, which we had done. The work that Rusty did on the handrail seemed to go easily. He was at no time in danger of contacting any antennas. It seemed like it was under control at all times. The control mode in the command module seemed adequate. I was never aware of any attitude excursions, jet firings, or anything. It seemed to remain very well in the attitude that we established at the beginning, which was MAX dead band with LOW RATE and SCS with BMAG's uncaged.

13. Insuit stuffiness: The suit was comfortable throughout, and maintained the same temperature as experienced in the chamber. The suit flow was at MAX

SCOTT

inside the spacecraft. The IV gloves seemed to work very well. The only time I noticed the temperature change was when it was placed in direct sunlight; and then it got warm. I did notice at one time a coldness when I grabbed something. I don't remember exactly what it was, but I did grab something that was cool.

SCHWEICKART

15. Integrity checks: After several seconds of trying to clear my ear (without too much success), the pressure buildup was continued by opening the O_2. We eventually got up to 3.7 psid for the integrity check which, I believe, was quite successful. The decay was between 0.1 and 0.2 psi/min.

16. Hatch operations: The final pressurization took considerably longer than anticipated, probably due to the installation of the filter. The time required to depressurize from an indicated 0.5 psia until the time when the hatch finally opened, which I guessed

SCHWEICKART to be 4 to 5 minutes was longer than anticipated.

McDIVITT 16. Hatch operations: I'd like to spend just a minute on the hatch. There's really nothing significant to say about it except that, when Rusty had the PLSS on and we were pressurized, it was very difficult to get down to the handle. In one g I just sort of fell to the floor, and my weight was sort of pushing up against the LMP's legs. It got me down near the handle; but in zero g, I did not have that advantage. I finally had to end up throwing myself down there — to wedge myself down in a position where I could get a hold on the handle. It was with a little more gusto than what I personally prefer to perform within that kind of environment. But, it was the only way I could get to the handle.
When I got down to when I could reach the handle, it was easy to push in and

McDIVITT to twist. When we pulled the hatch open, it took a lot of force. The pressure had dropped down to essentially zero, and it looked as though we were going to be able to get the hatch to open. So, I kept pulling, but we still obviously had a DELTA-P across it. It did operate slightly different than in the chamber. In the chamber, once I had broken the seal, it was easy to pull the thing open all the way. In this case, when I broke the seal, it still hung up around the top edge. It seemed as though I had to push the hatch toward the floor of the spacecraft to break it loose from the top. Once I had done that, it opened and after that, it worked fine. However, during the EVA, I tried to keep the hatch open at all times to eliminate any chance of it getting stuck in a closed position and in case there was something different that I hadn't been able to see when I was

McDIVITT: underneath the instrument panel.

When we went to close the hatch at the termination of the EVA, I again found it difficult to get down on the floor in such a position that I could push the handle in and turn it. But again, by sort of throwing myself down there and wedging my body between Rusty's legs and the floor, I could get a hold on the handle and could get it closed quite easily. We were then able to cinch it up. It just took a little longer than anticipated.

Rusty just added a little fact here that I didn't realize until just this moment. He was actually pushing on me to help me get down to the floor. In such a suit, you can't really feel all the external input. We did have a little trouble; but once we got down low enough so that I could get my hand on the handle, it was easy to turn.

SCHWEICKART: Once the hatch was opened and the EMU functioning properly we advised the

SCHWEICKART command module pilot that he was cleared to depress the command module. Then he initiated those operations.

17. Mounting of sequence camera and operations: The superwide-angle Hasselblad was passed out by the commander, and about 10 to 15 minutes of photography was taken at that time. Unfortunately, the EVA camera handle did not mate properly with the superwide-angle Hasselblad. This was primarily because the film magazine was greater in dimension than the camera body. Therefore, the camera handle would not mate flush against the undersurface of the camera. Thus, although the camera was very securely mounted to the handle, it was free to rotate with respect to it. Therefore, a little more concern and care had to be taken in handling the camera than what we had anticipated from training.

SCHWEICKART 18. Egress and EVA: At this point, the decision was made to evaluate the operation of the handrail. I removed my boots and the golden slippers and progressed from the front porch up the vertical section of the handrail to the point where it bends around the top of the LM near the radar antenna. In moving up and down this portion of the handrail, it became immediately obvious that the problem of body control and maneuverability was vastly simplified in actual flight compared with any of the simulations that we had run on the ground either in the zero-g airplane or in the water tank. There was absolutely no problem in maintaining complete control of body positioning. In fact, this was done at several points using just one hand and the mobility in the wrist of the suit.

Due to the timeline considerations of getting back in and completing the EVA day at the earliest possible time, there

SCHWEICKART was no nighttime evaluation of the EMU, nor was there any television done of or during the EVA.

Another EVA element worth mentioning was: since we did not expect to go EVA, the same LCG was used on the systems day as was utilized for the EVA. Per preflight plan, I would have changed into the second LCG that was stored aboard the command module for the EVA. However, the decision was made realtime to go EVA. Therefore, we had a 2-day-old LCG. Although it worked properly from all indications and as expected - after removing the suit at the end of the fourth day the LCG was visually congested with entrained bubbles.

18. Egress and EVA: At this point, we were essentially ready for the EVA about 15 minutes prior to sunrise. After being advised that the command module had depressurized and that the hatch was open, I began repositioning in

SCHWEICKART

the cabin. I got to the point where my feet were outside the door. I was laying horizontally on my side, ready to complete the egress.

In repositioning (using a little liberty here) from the vertical to the horizontal position within the cabin, there was some slight difficulty in getting the PLSS and the OPS past the various pieces of the cabin. Also we had experienced this in the water tank, but this was done with no more difficulty than we had seen in the ground simulations. It appears from the commander's observations that the primary interference in repositioning was the top of the OPS in the helmet contacting the Z-27 bulkhead.

After positioning for the EVA, I maintained myself half in and half out of the cockpit until we subjectively determined that the lighting conditions outside were adequate for photo-coverage. At that point, I moved into the complete egress of the EMU.

SCHWEICKART which was a pigtail type of cord, hooked to it. And every time I tried to get it down through the door, the springiness of the cord pulled it back up. When we started this thing through the door, I could feel it bouncing off the top of the hatchway. I guess when it finally got clear of the hatchway, it worked alright. But, I did have to continue to feed the cable through the door; and it got hung up one time.

When it came back through again, later on, I had the same trouble trying to get it back up through the hatchway, except sort of in the reverse technique. It came back in set on 1/500 of a second, with the decal torn off on the side. Unfortunately, that part of the conveyer system didn't work. The 70mm thing worked very well. I think the conveyer system in concept is an excellent idea. Our big problem, I believe, was to not have enough of the sequence camera cord free to take the tension off the camera until clear of the hatchway.

SCHWEICKART The egress itself went very smoothly, with no problems maintaining control during the egress. The first step after completing the egress was to get my feet into the golden slippers. I had no difficulty whatever. After completing the egress and after donning the golden slippers, the tether was used as a conveyer, by using the third hook on it.

22. Photography: Following the 10 to 15 minutes with the superwide Hasselblad, it was passed back in to the commander and the 16mm camera was passed out and another 10-minute period or so was devoted to taking pictures of both spacecraft and the CMP and his activities using that camera. About a quarter of the way through the magazine, which was being run at 6 frames per second, I realized that the shutter speed was set at 1/60 of a second. At this point, I readjusted it to 1/250 of a second. There's some question in our minds whether the shutter speed had been altered in

SCHWEICKART the process of passing the camera out of the spacecraft, or, whether it had been left there inadvertently from internal pictures taken earlier in the day of the tunnel-clearing operations in the command module.

MCDIVITT I had checked the camera and set it to the proper stops before I sent it through the door. I believe that our conveyer system left a little bit to be desired with the sequence camera, whereas it didn't with the 70mm camera. The 70mm was an untethered camera and was hooked to the lifeline and transported back and forth that way. It worked quite well. Our conveyer type of arrangement had worked good in our simulations, because the weight of the camera held it away from the upper portion of the hatch door. This worked quite well with the 70mm, too, because it didn't have any restraining devices on it. However, when I hooked the sequence camera to the conveyer belt, we had the sequence camera cord, SCHWEICKART 23. Thermal samples: After passing the camera back in to the commander, the EVA thermal sample on the LM was retrieved with essentially no problem. And that, also, was passed in to the commander.

MCDIVITT 25. LM repress: The hatch was closed and the repress begun according to the checklist.

The way our checklist was written, we could enter into it at the plus 215 point and just proceed down through the checklist without making any major changes to it. It certainly simplified the operations once we started back in.

SCHWEICKART The one step that we overlooked in the checklist at that point was the closing of the feedwater valve prior to ingress. I recognized this immediately after completing the ingress and closed the feedwater valve. I would estimate that we remained in the vacuum condition for approximately 7 or 8 minutes following closing the feedwater valve. So, I would guess the PLSS sublimator was not com-

SCHWEICKART

pletely dry by the time we repressed the cabin.

25. LM repress: In the postEVA cabin repressurization cycle, once the command module had gotten partially repressurized (using the PLSS fill bottles) the LM was utilized to bring the remaining pressure up to 4 psi. After bringing both spacecraft to 4 psi, the tunnel activity was initiated and the remaining cleanup was performed in the LM.

26. Ingressing: The ingress to the LM was done shortly before sunset and was done asymetrically with respect to the egress; that is, there was no problem or hangup whatever in ingressing the LM. I slipped right in and right up to a vertical position without any particular problems at all.

27. PostEVA activity: In the postEVA activities, we again followed through with the checklist. There was no problem whatever in removing and replacing the

SCHWEICKART — PLSS CO_2 cartridge, or in recharging the O_2 bottle in the PLSS. The indication on O_2 quantity prior to recharging was about 800 psi, and very shortly after opening the PLSS fill valve the pressure jumped right up to 900 psi indicated. We terminated the fill at that time.

The PLSS was doffed at that point and the LMP went back on the LM suit loop. The recharge of the water system was begun and no problems were noted in that recharging operation.

There was no fatigue associated with the EVA. The workload during the entire time was lower than anticipated preflight. At no time was there any sign of fatigue, either total body fatigue or of the arms. There were no particular eye sensations. And the light levels inside the EVVA throughout the EVA were very comfortable.

MCDIVITT — I was wearing just the clear plastic overvisor on my visor. I stuck my head out into the sun a couple of times and I really didn't experience much in the

McDIVITT — way of eye strain, or anything else like that. I suspect that I wouldn't want to stay like that for long periods of time, but for short periods of time, it seems like that particular protector was certainly adequate.

I also had my IV gloves on during this period of time when we were transferring equipment back and forth. I noticed that my hands got warm very fast when I put them in the sun and left them there for even 2 or 3 minutes. I could feel the heat coming through those black gloves.

SCHWEICKART — During the EVA, the cooling in the suit was very good. I left the diverter valve in MIN cooling throughout the entire EVA, and never had the feeling that I was getting warm. Toward the end of the EVA, I remember thinking that I might want to go to intermediate cooling just to see if I got too cold there, but something else came up at the time and I never did that. I stayed in MIN cooling. The only place that became noticeably warm at all

SCHWEICKART was the fingertips. This was expected from the thermal vacuum runs that we had made in the SESL chamber A prior to flight. The temperature at the fingertips was less than we had experienced in Chamber A. I have no objective way of estimating how hot my fingers got, but the only thing I can say is that it was quite a bit more comfortable than we had experienced in chamber A under the thermal vacuum conditions, but noticably warm.

MCDIVITT 28. PostEVA cabin cleanup (restowage): The postEVA cabin cleanup was accomplished pretty much according to our preflight plan. We didn't encounter any particular problems that were new, that we hadn't encountered earlier.

29. Power-down transfer and deactivation: The power-down transfer and deactivation in this particular case were accomplished more along the preflight plan, that is, the tunnel was open and the commander was able to get off the hoses a little quicker and get transferred over.

McDIVITT

30. IVT to CSM: IVT to the CSM wasn't any different than the previous day. This is the point where we ran into the translunar BUS ties. The circuit breakers were left in. At this moment, I can't figure out how they were because of the way the checklist is written. We either were looking at the wrong page or were anticipating something and got it in the wrong configuration.

31. Workloads and timelines: During the course of the day, as the LMP was operating, it became obvious that he was feeling much better on the fourth day than he had on the third day. Therefore, I elected to expand the EVA somewhat. As we progressed, we not only donned the OPS but also integrated in the EMU and performed the EVA, very similar to the original planning, except that the transfer from the LM to the command module was not accomplished. Most of the other things were accomplished, and we shortened the EVA to one

McDIVITT daylight pass outside the spacecraft as opposed to the two daylight and one dark-side pass outside the spacecraft.

4.5 Fifth Day

4.5.1 Command Module

McDIVITT

In preparation for the rendezvous, we changed our wakeup time from over Ascension at approximately 86:30 to over Guaymas at approximately 85:40 in an effort to provide ourselves with a little cushion at the beginning of the day. Also, in anticipation of this high-powered day, we had done some preparation the previous night, that is, packed the ISA with the things that we were going to transfer to the LM, put ourselves in a posture whereby we could get up, eat, get suited, perform the P51's, and other things that we needed, and get right on over into the LM. As it turned out, we were able to do this in a more reasonable manner and were able to ingress the LM well in advance of the time that we had anticipated.

We entered the LM about an hour early; and we managed to stay roughly an hour ahead of time until we were well into the

McDIVITT LM checklist. Although we tried to stay that far ahead, it was difficult because of the ground coverage that was required for some of the checks that we were doing. We approached the undocking period with a fairly good margin on time.

1. Don PGA's: PGA donning went better, probably because we were getting more proficient.

2. Tunnel pressure: The tunnel pressure was fine. We were still in LM PRESS, and there was no DELTA-P.

SCHWEICKART Tunnel pressure: Following pressurization of the ascent system, the ascent feed valves were cycled to their proper position. When I cycled the ascent feed number 1 valves to the open position, the valves made a clonk which indicated that they had been moved away from full open.

3. Assisting tunnel closeout: The tunnel closeout worked as previously with no problems.

SCOTT The tunnel operations were somewhat different today, since we were planning for

SCOTT a separation and had to go through the preloading of probe, which went as advertised. The capture latches were checked by Jim after we installed the probe and then again after the preload. Everything looked nominal. The next step was to cock the 12 latches. The first latch I tried had a problem, which was number 1. It appeared to get the full preload with one stroke. This could be determined by feeling the depth of travel of the bungee and the bungee housing and comparing with several other latches which worked alright. It took about five tries or five cycles on the latch to get it to work normally with a complete preload with two strokes. After that, I tried recycling it and releasing it manually several times, and it appeared to work just fine. All the other latches worked normally, except number 8, which again appeared to obtain a complete preload with one stroke on the first stroke. Several recycles on that cleared that one up. After completion of all

SCOTT

12 latches, I was satisfied that each worked properly. There was no tendency for any latch to hand up, or any hook to hand up on the docking ring. They all pulled clear on the first stroke.

The LM umbilicals were removed without difficulty by the CDR in the LM. The hatch-integrity check again took about 10 minutes.

4. Rendezvous window docking target: The docking target was installed in the right-hand window and worked properly on dim and bright. There is very little distinction between the two. The side hatch was configured for the EVT, as was the rest of the inside of the command module, within about the same time as previously with no anomalies. The spacecraft was configured up to the point where helmet and gloves would have to be donned, pressure-integrity check performed, and then the hatch opened. We were about 10 minutes from a hatch-open situation.

The pre-undocking checkouts went nominally.

SCOTT

5. IMU operation: The GDC aligned well, ORDEAL was working well. The EMS drift test gave us about 0.2 foot per second in 100 seconds, and the EMS DELTA-V test went to a minus 20.3 which was again very good for the EMS.

TT

On the first alignment of the day, we again had a problem with the telescope hanging up. It did one time during the P51 in manual drive. We gave it some consideration and decided to watch it closely and keep everybody posted on the status of it. There was no further problem the rest of the day. It worked just fine.

6. RR transponder: The rendezvous radar transponder worked as advertised. The systems test meter A was 1.6, B was 1.65, and C, although not required as a parameter, was about 0.5.

At approximately 91:45, about one-half hour before undocking, the fuel cell 2 condenser exhaust temperature got up to 178 degrees. It was going up and it

SCOTT

looked like we had a sick fuel cell 2. The ground said they'd keep an eye on it and it shouldn't be any problem. It wasn't.

When we ran the lighting check between the two vehicles, the lights all worked just fine, except for the spotlight. When I threw the switch, I heard it come out - heard the door open, but saw no light. Subsequently, we discovered that the circuit breaker for that particular light down in the right-hand LEB had popped out. But at that time, I wasn't in much of a position to climb down there and push it in. Actually, we didn't even see this until the following day. It's sort of buried on 225.

When the LM radar checks were complete, I called P20 to check the tracking. Even at the close ranges, it automatically pointed the CSM X-axis to within 1 degree of the LM. P20 appeared to be much smoother at the close ranges than it had been in the simulations.

SCOTT I performed a COAS calibration after sunset on Aldebaran, which was about 10 degrees from the LM. It was again much easier than the simulator. The calibration worked out to be 359.74 and 57.167 for the shaft and trunnion.

The only anomaly prior to phasing was the time at which I crossed the 170-degree point for the horizontal adjust chart. It appeared that we would be approximately 3 minutes early at the horizontal crossing and this was the basis of the state vector out of the computer. I believe there's some question as to the validity of this particular technique that we'll have to look into. The horizontal crossing occurred at approximately the same time, with both vehicles. The LM gave me a call about the time I was getting 180 degrees on the state vector local horizontal relative to the X-axis. There was no particular CSM PREP for the phasing burn, other than to line up on the local horizontal and perform a horizontal adjust

SCOTT if the phasing burn was not completed. So, there was no P30 or P40 associated with the phasing burn.

McDIVITT When the command module began his RCS separation burn, I began tracking him in PGNS RATE COMMAND. PGNS RATE COMMAND provides a very good control system. I was in fine scaling. I was able to track him as he moved away; the rates went to about 1 deg/sec, and he was easily tracked in this mode. When we got to some distance where the 1-deg/sec rate looked like it was going to hold, Rusty inserted a VERB 76, ENTER, which put us in PULSE. I then tracked him in PULSE for the remainder of the time and PULSE CONTROL provided an excellent control mode, even with the descent stage still attached. As the spacecraft moved out across the ground, he was very easy to see compared to the other objects I've seen in space. I think the silver color of the Gumdrop and the way it reflects the sun provides an excellent source of light even against

McDIVITT cloud backgrounds. Whenever he moved across the surface of the earth, without the clouds behind him, he was very, very easy to see, and we tracked him out to some considerable distance.

SCOTT 8. Maneuvering and maintaining in minimum dead band attitude hold: In using standard procedure to get to an AGS-calibration attitude, we ended up about 22.5 degrees attitude difference from where we should have been. I believe this was due to the difference in the REFSMMATS between the two vehicles. The point is that in using this technique, we should make sure we understand what the position of the command module ball should be relative to the REFSMMAT in the LM.

Maneuvering the spacecraft to the proper attitude was no problem. It was done automatically with the DAP using the VERB 49 to a predetermined attitude from P30 and P41.

4.5.1 Command Module

SCOTT

10. Photography of undocking: After the undocking, stationkeeping with the command module was relatively easy both SCS and DAP. I set it up in the DAP in order to maintain a position to enable me to take pictures of the LM landing gear as it did its 360. I backed off somewhat farther than I would normally for a landing gear inspection in order to include the whole vehicle in the pictures. There's no doubt that you can tell that the landing gear locks are in fact locked. Not necessarily by the marks on them but by the geometry, and they're easy to see in profile as the LM rotates around.

11. Formation flying and LM inspection: The lunar contact probes were all four down and locked and looked like they'd contact the lunar surface or impale the lunar surface with a certain degree of reliability. There were no apparent pieces missing from the LM. It looked

SCOTT

like it was all solid and in one piece. This was some concern since during the docked DPS burn we had all noticed pieces coming from the LM, small irregular pieces.

12. CSM RCS SEP burn: At the completion of the inspection of the LM, I prepared to do the automatic maneuver to the separation burn and P41. When Jim took over stationkeeping, I went to MINIMUM IMPULSE or free drifting mode. There was very little effect and it's obvious that you could stationkeep in MINIMUM IMPULSE with no problem at all. The separation burn was performed on time and the DSKY read 5.0 and the EMS was 5.2 feet-per-second. It took approximately 12 seconds, which was the same time required during the simulations.

After the completion of the separation burn, I maneuvered to a predetermined attitude to point the preferred tracking axis at the LM for their radar checks, SCOTT — and also to perform a P52. The realignment was done in daytime, the preflight stars were available, and AUTO optics drove nominally.

After the CM SEP burn and the LM went into darkness, it was very easy to follow the visual image of the LM into the image of the light. The tracking light was clearly visible. When the LM came back in the daylight, it was easy to see the light as the LM came into daylight, and then see the LM image itself with the light superimposed on it at the close ranges. The flashing of the light is a good point source of light for marking in the sextant when the LM is at close ranges because the LM fills anywhere from a quarter to a full field of view, depending on how close you are. At these close ranges, you can use the tracking light very well as the point of taking marks with the sextant.

McDIVITT — Prior to the burn, we always made an attempt to verify our general attitude.

McDIVITT

In this particular case, we were able to compare the PGNS attitude errors with the AGS attitude errors, and look out the window and see that we were essentially vertical, that's with the X-axis pointing away from the earth. We did not attempt to use any attitude check stars or anything like that. We knew approximately what the attitude was going to be local vertical, and we knew what this was on the inertial ball. Using AGS and PGNS and the out-the-window general view, we determined our approximate burn attitude and made a GO/NO-GO on that.

SCOTT

14. Rendezvous radar tracking (P20): CSM from post-TPI to TPF — because the LM tracking light obviously was not working, no marks were made. The P35 was called up anyway to run a solution for the first midcourse to see the comp cycles and how it worked, and it came up with a small solution somewhat different

SCOTT

but comparable in magnitude to the LM's. The spacecraft was oriented so that the X-axis would point to LM by P20; and as soon as the LM broke into daylight, it was visible all the way in even though against the light earth background it was visible as a dark spot until it got in closer and then the image became clearly visible. The diastimeter was available to pick uprange, and it seemed to compare fairly well although it was difficult to read because the light in the read-out is so dim. I got one reading at about 2 miles and had to pull my flashlight out to read the read-out in the diastimeter. Another interesting point was that the alignment of the two images was not horizontal. They were approximately 30 degrees off from the horizontal alignment, but you could still get enough comparison to judge the range. As a verification of range, the diastimeter worked very well. The mounting bracket, in particular, was very good be-

SCOTT

cause it had a stow position completely out of the envelope of the left-hand couch. The lighting on the LM was much better than we'd seen in simulations at G&C. The entire vehicle was visible through the diastimeter, and it was very easy to select the edges of the vehicle in order to place them properly to get the ranging.

14. Rendezvous radar tracking: At 3 miles, the LM had a range rate of 42 ft/sec and the CSM had a range rate of 43 ft/sec, which showed close agreement in state vectors. When the CSM was indicating 1.5 nautical miles and 33 ft/sec, the LM radar was at 9800 feet and 32.5 ft/sec. The first visual contact of the LM occurred at some point after the 3-mile comparison of range and range rate, and it was visible in the sunlight as it popped out of darkness. Just prior to that, we had made a comparison of pitch angles. The LM pitch angle was approximately 86 degrees, and

SCOTT

the command module pitch angle was almost 90 degrees.

14. Rendezvous radar tracking: After the LM phasing burn, the target DELTA-V appeared to update the state vector properly, and a P20 maneuver, AUTO OPTICS, pointed the sextant to include the LM in the field of view. The P20 drove very smoothly and AUTO OPTICS tracked smoothly. The LM was easy to see at daybreak and the tracking light was still visible. Prior to daybreak, the LM thrusters were clearly visible every time they were fired, as a large red-orange vapor cloud. Just after daylight, I got a cryo pressure light, which made everything feel like the simulations. Now I had two lights on, the fuel cell 2 and the cryo pressure. Shortly thereafter, the fuel cell 2 light went out. We had an exchange of switches from Houston on the heaters on the H_2 tanks to get them squared away. Several comparisons made prior to the TPI zero GO/NO-GO with the LM indicated

SCOTT

that both spacecraft had comparable state vectors. Range and range rates were running very close to within less than a mile, and about 3 to 4 ft/sec. Throughout the tracking period, the LM was always visible as an image. It was easy to pick out the entire LM in the sextant and the marking was done on the tracking light. The marks were performed as per the checklist and the solutions to the TPI zero were called up as per checklist.

As we approached sunset, the LM was visible all the way into the sunset and changed from a visual image to the flashing light again. So, never was there any problem in obtaining visual contact with the LM throughout this phase. One problem was noticed with the telescope: at the right sun angles, the prism split on the telescope — blanked out the center — and the LM was not visible when the telescope was lined up with the LM in the center of the reticle because of the wide illuminated band across the center of the

SCOTT telescope, but it was plainly visible in the sextant.

The CSM alignment performed after the GO/NO-GO for TPI zero was nominal. The torquing angles were plus 0.083, plus 0.008, and a minus 0.034, which indicated a good platform. P20 was used to point the CSM at the LM during the flyby, or the closest approach. At that range, P20 was still working very smoothly and put the LM within a degree of the center of the COAS.

15. Monitor of LM insertion, CSI, CDH, TPI, and MCC burns: The command module support of the insertion burn was to target the same burn 1 minute later. This was performed on time, no naomalies. An automatic maneuver to the burn attitude was verified by comparison with preflight angles and position relative to the horizon. The communications preinsertion and postinsertion burn worked very well and I was able to get the gimbal motors off very shortly after the completion of the

SCOTT insertion burn.

After the LM insertion burn P76 was loaded with the LM DELTA-V's, the bias time for the burn time, and P20, I did an automatic maneuver plus AUTO optics to point the sextant almost directly at the LM. The marks were incorporated according to the checklist with no problem, and several range and range rate values were read out and compared with nominal. They compared within about 1-1/2 miles and within about 4 or 5 ft/sec of the nominal values for the times that were specified prior to CDH. Just after the first mark period after insertion, the ground called an H_2 tank fan ON, which illustrated the help that the ground was providing and enabled me to spend most of my time on the left and center seats which actually enhanced the operation. I could be assured the ground had a close eye on all the systems. I might comment at this time on the technique that, I guess, evolved from the simulations. When we first started, I

SCOTT spent quite a bit of time monitoring systems. As we got proficient in working with the ground, I got more confidence in their ability to monitor the systems. I spent less and less time monitoring them. During the rendezvous, it was a big help to have the ground watching as close as they did, and it enabled me to spend most of my time navigating and flying the spacecraft. As a matter of fact, the only time I made a complete systems check was prior to each burn, and I would check the complete right-hand side of the spacecraft with the gage selectors and would monitor for nominal values.

At approximately 60 miles, the LM still appeared as a good clear image in the sextant. The size of the LM was approximately 40 arc seconds. It filled the gap between the double lines in the sextant reticle, and I could still see the footpads on the descent stage.

One of the problems we encountered during simulations was a loss of communications

SCOTT between the two spacecraft when the attitudes changed for the CSI and CDH burns. I have a note here that, about 10 minutes prior to CSI, I did lose COMM with the LM. That was about the time I started maneuvering to the CSI burn attitude. For CSI, I targeted the command module with the ground pad 1 minute after the LM burn time, which was a mirror image burn. At about 20 minutes prior to CSI, I checked the out-of-planes of the LM with the VERB 90 and had plus 0.09 nautical mile and minus 0.4 ft/sec at the time of the LM CSI burn. At 11 minutes prior to the burn, I checked the range and range rate. Nominal was 62 miles; I had 60 miles. The range rate nominal was 118; I had 122.

The period from postCDH to postTPI in the CSM is the time during which the most amazing part of the whole flight occurred, as far as I was concerned. After CDH, I did the P76 normally, a P20 to maneuver to the preferred tracking axis, and a

SCOTT VERB 57 to get auto optics. When I took the first look through the sextant, there was the LM about one-half degree from the center of the sextant. This was after 1 hour had elapsed. There had been no marks, and two maneuvers had been inserted through target DELTA-V into the CMC. The ascent stage was a good image in the sextant, and the range at this time was slightly over 70 miles. On the first mark, after acquiring the LM with NOUN 49 display, the threshold of the DELTA-R and DELTA-V was 2.6 miles and 18.1 ft/sec. Prior to flight, we had asked MIT to come up with some numbers beyond which they wouldn't consider convergence in the solution. Interestingly enough, the numbers they had provided us were 2 nautical miles and 15 ft/sec. They said that, at this value, they still had obtained good solutions for any postCDH, preTPI maneuver and that they hadn't really determined what the limits were. Also, they said that this was probably a good limit at which

SCOTT

we could obtain good solutions. So, I decided to go ahead with the state vectors I had, to continue the mark process, and to check range and range rate after the first W-matrix initialization to see exactly where the relative state vector stood in the command module with respect to the one in the LM. After the first mark period, after W-matrix initialization, I got the command module range and the range rate at the same time the LM data was passed. It was 67 nautical miles and 112 ft/sec, with the LM having 67 miles and 107 ft/sec, which meant that the state vector comparison was very good.

At the beginning of the next mark period, I again got a 0649. This time it was 0.3 nautical miles and 3 ft/sec, which meant that the W-matrix was converging and that the solution would hopefully converge, which it finally did. At the end of the second mark period, I took a look at the W-matrix which was 0.11 and 1.1 which indicated that it was coming

SCOTT

down; but it was still providing adequate weight to update the state vector. After the third cycle through P34, which took place after the third group of marks, I could see that the solution was converging toward the LM solution as far as time was concerned. It continued with two extra mark periods, which brought the total number of marks prior to TPI (after the W-matrix initialization) to 30. At the time of the final COMP cycle on the fixed elevation angle, the comparison with the LM was within 9 seconds and the DELTA-V's compared very well, as can be seen in the charts. The TPI burn was monitored by targeting a mirror image burn at the same time or, as we had planned, program P34 with the LM ignition time and by using the time option. Then, at the completion of the TPI, a P76 was used with the actual LM burn and actual TPI time, plus the bias with the burn time.

17. Formation flying: After the completion of braking phase, the LM pitched

SCOTT

over so that the CSM could visually observe the ascent engine. Everything looked as if it were intact with no pieces missing or insulation torn off, and it was easy to look into the engine nozzle and even see the injector and the chamber, apparently because of the sunlight reflection at that particular time. The nozzle was black, the chamber was still silver, and everything looked clean and smooth. The pulsing of the RCS jets was visible. It looked as if the particular control modes used were very active. During the terminal part of the docking, it seemed as if the jets were firing almost at intervals of 0.2 or 0.3 second. The final approach to the contact by the ascent stage looked very smooth. There were no overshoots or oscillations in attitude. It appeared, even though it was a very slow closing rate, to be a very stable closing rate.

20. Docking and pressure integrity:

SCOTT

At the point of contact, when the LM got into the probe/drogue contact point, it was well within the boundary as indicated by the diamond on the target on the LM relative to the CSM COAS; and I would have estimated the contact velocity at about 0.1 ft/sec. Approximately 7 seconds later, I got the barber poles on the capture latches and then proceeded to stabilize and align by using a minimum impulse. As before, it was effective to align the two vehicles by using the CSM COAS and the LM target. We had decided prior to the contact that we would not do an automatic retract because of the questions we had on the EXTEND RELEASE switch. As mentioned previously, when I went to check the switch prior to the docking after the rendezvous and placed the switch in retract, the talkbacks indicated barber pole instead of the gray that they should have been. By cycling the switch up to extend and observing a gray talkback and then back to

SCOTT retract, I did get the gray on the talk-backs, which indicated that the capture latches were cocked and ready to accept the docking. However, to preclude a retraction without capture in subsequent problems, it seemed as if it would be a better idea to go ahead and just do the capture and, after everything was stabilized, to initiate the retraction. After aligning the two spacecraft, I retracted on the secondary system, and it took approximately 4 to 5 seconds. Again, it sounded like we got a double, or two groups of latches. It was a double sound on the latching, but solid, which indicated that we had a secure hard dock. I guess we could describe it more as a finite period of time of noise rather than one bang. It's hard to distinguish two separate bangs, but it might be interpreted as a group of latches going and then the side of the tunnel hitting; but there was a definite, finite period of time during which we

SCOTT could hear latches. After the capture, there were no significant postcontact dynamics and no oscillations, just a slight drift as we had seen on the T and the D trainer.

21. Docking and integrity checks: From the command module side, there was never any question about being able to perform the final docking. The only problem was that the COAS again faded on a white docking target on the LM, and it was very difficult to see the COAS even though it was visible. We do need a brighter, sharper COAS.

22. Tunnel operations and IVT: Concerning the tunnel operations, upon removing the probe from the tunnel it was warm to the touch, approximately 110 to 120 degrees. This was to the barehanded touch.

MCDIVITT 25. LM jettison: When we got to the LM jettison and the separation maneuver from the LM, we had a very interesting experience. I believe that nominally we are supposed to jettison the LM at --

SCOTT — The nominal separation maneuver was to be performed at 101:38:14 at the following inertial angles: 132.9, 105.8, and 23.5. The pad passed up to us had us separating at 101:32:44 at the following angles: 137.4, 92.5, and 21.9. The nominal jettison attitude was 0°, 157°, and 45°. The updated jettison attitude was 18.5, 282.0, and 44.7 --

MCDIVITT — I think that the main point is that we were at a different set of angles from those which we had practiced in this little exercise in the simulator. We had gone through this manuever a number of times in the simulator. The idea was to separate, to stop the translation between the two vehicles, and to do an auto maneuver to the separation attitude — then at the separation time to do this 3-ft/sec, 6-second burn. This maneuver was to be an auto maneuver using VERB 49. We inserted the angles in flight and did the maneuver, and it drove us right into gimbal lock. Since we were using a new set

McDIVITT: of angles, I guess we should have watched the ball a little closer; but we certainly weren't expecting a set of numbers that would do this. After we got into gimbal lock, we had to modify the plan a little. We went back to an attitude that put us out of plane somewhat and was to thrust us in a manner which would clear the LM. We did this. We went ahead and made a 3-ft/sec maneuver in a direction that would clear us from the LM. We were well clear of the LM and had it in view at the time of ignition. We were able to take some pictures of it, and I guess these have been recorded for posterity some place.

SCHWEICKART: 41. DSKY and tape meter changes: On the polar plot which we started updating from 45 miles, all the points we took were within about a pencil width of the nominal line drawn on that plot. The last data point that we plotted was at a range of 30 000 feet, and at that point it became obvious that there was no neces-

SCHWEICKART sity for continuing the polar plot.

McDIVITT 49. RR corona test 1: After we got close to the command module and began station keeping, we did an auto maneuver at one-half deg/sec, narrow deadband, and another one 2 deg/sec in wide deadband. Once again, the DAP performed very well with no problem at all. We were then going to unlock the radar from the command module and perform a test to see if we had any corona problems. We were unable to unlock the radar and, I guess, could have had the command module to turn its transponder off, but we didn't bother doing that. We went ahead and did the maneuvering and saw no change in signal strength on the AGC. We were looking at the transmitter on this particular maneuver and saw no changes in anything. We then went back and reloaded the DAP for two-jet (I think it was system A) tight deadband, 2 deg/sec, and began the docking maneuver.

50. Maneuvering to docking attitude and translating to capture latch: We

MCDIVITT installed the COAS in the overhead window, and it was apparent as we were in close that the COAS on the command module and the command module sunlit completely faded out at any kind of range at all, and that we would have to use a little intuition in the docking. I pitched around to the 90-degree point and then, looking through the overhead window, I found that the upper part of my helmet was all scarred up and I was having a little bit of difficulty seeing the command module through the top of my visor and the COAS. When the COAS is superimposed on the command module, it is impossible to see any portion of it whatsoever. I started to dock and thought that I'd better make sure that the whole thing works. Therefore, I maneuvered to one side and looked to see if it was still all there and got a pretty good idea of where it should be by looking through the overhead window. I moved back in, and as I closed, it was still almost impos-

McDIVITT sible to see the COAS. I had to maneuver my head around and try to see the docking target and the COAS together, neither one of which was very bright. After some manipulation, we were able to get in close enough where the COAS did appear on the docking target, which was back inside the shadow of the command module window. As I got in close (about 4 or 5 feet), I began to see the COAS appear against the darker background of the window, when the window began to fill up a little more of the COAS. At that time, I could tell what my attitude was with respect to the docking target, and I could see what my translational position was with respect to the docking target. I maneuvered around at this fairly close range until I was in a proper attitude, and I went ahead and docked. During this particular time, Dave was telling me that I was inside of the safe boundary, outside of it, or whatever my position was, and gave me a good GCA until I got down where

McDIVITT

I could see the whole thing. I think that the COAS brightness has to be increased manyfold so that it can operate in a bright environment like this; and I think it also would be worthwhile to brighten up the docking target, if at all possible. In positioning myself to look through the overhead window, I did not use the pip pins on my restraint system to hold my hips to the panel 5. I sort of bent my knees and leaned back and looked overhead. I couldn't find a good position that was comfortable. The neckring on my suit stuck into my throat, and I had a very difficult time maneuvering my head inside of my helmet to find a clear part that wasn't all scratched and gouged on the top of the helmet through which to look. I tend to believe that these scratches and gouges came from operating in the rear of the LM while trying to stow the OPS. Rusty seems to think that I should clarify my statement here on the use of the

McDIVITT

pip pins. I did not use the pip pins because I felt that I could position myself better by using only the restraint system and looking through the overhead window without the use of the pip pins. I'm not sure what the closing rate was. It was very low because of the proximity at which I finally located the COAS and the docking target. The light weight of the ascent stage made it so that I never really did stop the translation left/right and the horizontal components with respect to the docking probe and drogue. I had to thrust continually left and right and fore and aft, or whatever that other direction is, to keep myself within the boundaries of where I wanted to be prior to contact.

51. Docking: We got in close, and the standoff cross on the docking target filled the 2-degree mark on the COAS. I went ahead and started thrusting. This indicated that we were at just about the point where we were captured. It

McDIVITT clunked in, and I could feel the drogue and the probe make contact very gently; and Dave called a couple of barber poles. Dave said it took 7 seconds of thrusting from the time I started until the time we got the barber poles. At contact, when Dave called the barber poles, Rusty inserted the VERB 76 ENTER, which put us in a free mode, or a PGNS pulse mode. We were at the end of the probe, captured, but not latched up with the two tunnels together. Dave then damped whatever residuals rates we had because it was very difficult to see these rates from the LM side.

4.5.2 LM Rendezvous

McDIVITT

1. IVT: The IVT check was the same as on the previous day.

2. Entry status: The entry status check was no different than on the previous day, except for the fact that we discovered my OPS heaters didn't work. This time,

McDIVITT

my magic touch with the heater switch didn't work, and we were never able to get the green lights to come on.

When the LMP transferred over, we ran into a problem with the communications. His push-to-talk switches on both the rotation hand controller and his hoses wouldn't work. He was committed then to operating off of VOX for the remainder of the flight. The commander's side operated properly, so it appeared that we just had a malfunction on the LMP's side.

As in the other activations, we had to activate the glycol evaporator earlier than it called for on the checklist to keep the temperatures down.

McDIVITT

4. IMU course and fine align: When we completed the radar check and opened up the radar circuit breakers, we began the first alignment of the IMU using the LM-only data. We maneuvered, AUTO maneuver, to Sirius prior to sunset, and when we got there, I was able to see Sirius without any problem at all. It came right into the center of the AOT.

After I looked through the AOT for awhile, I became semi-dark adapted, although the sun was still shining into the spacecraft or reflecting off the spacecraft and we had all the lights in the spacecraft up. I gradually began to see Canus Major with all its stars, and finally I could see Orion and all of its associated stars. So there wasn't any trouble identifying Sirius in this twilight zone. As a matter of fact, I believe I had 10 marks, five X and five Y marks, on Sirius completed before sunset.

It's interesting to note here that the sun was behind us. Sirius was approxi-

McDIVITT mately at the zenith when the sun set, so we had about 90 degrees between the sun and Sirius. There wasn't any period of dark-adaption to speak of before I started looking through the telescope. I essentially looked through it as soon as we got to the attitude. I had an eyepatch on for maybe a minute or so prior to that time but certainly not dark-adapted.

The technique that we had worked out for alignments was for me to watch the star and call the pulses left, right, up, and down to Rusty, who put them in. It seemed to work even better in actual practice than it had in the simulator. The simulator provides an additional problem in that it's very difficult to see near the center of the telescope because of the mirror configuration in the simulator. In the actual spacecraft with actual stars, we were able to maneuver through the X and Y lines much closer to the center of the telescope. It was much more easily done and done a lot quicker, too.

McDIVITT We did the maneuver over to the next star, Acrux. As the maneuver took place, I could see the stars coming up and the spacecraft pointed essentially at Acrux, which indicated our docked alignment was once again quite good. Here again, we had no problem aligning on Acrux and made the 10 marks that we were going to use there. I might add that at the completion of this, we had five zeros, which was something that we had never even come close to in the simulator. It's much easier to do it in the spacecraft than it was in the simulator. The star angle difference was five zeros.

While looking through the telescope at the stars, the spacecraft was being maneuvered in PULSE mode, and the flash of the thrusters could certainly be seen as an orange cloud, but didn't in any way affect the ability to see the stars.

This particular period between separation and phasing was probably the most heavily loaded as far as workload went in the

McDIVITT entire mission. Our hope was to get through the AOT alignment in some reasonable time, so we could press on with the preparation for the AGS phasing burn. It turned out that we were able to complete this in much less time than we had ever done in the simulator, which provided a little pad at the other end that we could certainly use.

On the completion of the alignment, we did a star check using the COAS. This was not as easily done as I had hoped. Unfortunately, we had the moon in the view. We were using Spica as the star. We had the moon and a very bright planet, and Spica by comparison was quite dim. However, we were able to identify it, and when we did, the COAS calibration showed that the star was 0.5 degrees to the right and zero up and down, which was certainly within the bounds that we expected.

SCHWEICKART From the LMP's side of the cockpit, the alignment went very smoothly. The mode 2 error needles gave me an excellent picture

SCHWEICKART of how the star was behaving in the AOT, and the callouts that Jim would give — one or two pulses right or left, up or down — corresponded exactly with what was displayed on the mode 2 error needles. And this, of course, enabled me to keep track very easily of where the star was with respect to the center of the X-Y lines. The star angle differences Jim mentioned were five zeros and the NOUN 93, the torquing angles, were minus 0.09, minus 0.076, and plus 0.111 degrees, all around 0.1 degree, which is very good, and which indicated we had a very good dock alignment.

The maneuver to Spica for the COAS check was started at about 93:26, which was 21 minutes prior to the phasing burn. In our simulations, for comparison, we were always in the order of 12 minutes at this point. So, we ended up doing the alignment about 9 minutes ahead of the best we had done in the simulations.

SCHWEICKART

7. DPS gimbal drive and throttle: Again, the gimbal-drive and throttle test was identical with what we had seen all through our training. The values which were updated to us from the ground were slightly different from those which we had expected from briefings preflight, but they were within 10th's of degrees, so that there was no problem in that.

SCOTT

9. Undocking: At 25 minutes prior to the SEP burn, as planned, I moved the EXTEND/RELEASE switch from the OFF position to the EXTEND position. And the talkbacks went from barber pole to gray, indicating that the probe had extended full, but the capture latches did not release. The LM hung on the capture latches and you could feel a definite thud as the probe hit the end of its travel. At that point, I put the EXTEND/RELEASE switch to EXTEND again. Again, the talkbacks went gray, but again the LM did not release. Then I cycled the switch, the EXTEND/RELEASE switch,

SCOTT

to RETRACT to check the talkbacks, and they were both barber pole. Okay, after cycling to the RETRACT position, I again went to EXTEND on the EXTEND/RELEASE switch. The talkbacks were again gray, but this time the LM released, and fell off the end. By this time, we had drifted some 10 degrees in attitude.

Anyway, I guess I hadn't held the switch in the EXTEND position long enough to enable the capture latches to release. We had tried to do this in the chamber in order to give ourselves a check on the full extension of the probe; that is, cycling and holding the switch a short time and releasing the switch before the capture latches would release, which they do after 3/4-inch extensions on the probe. We were unable to do this in the chamber. In other words, the capture latches released too fast and you couldn't get off the switch fast enough to beat the latches. Going back and recycling the

SCOTT

switch to the EXTEND position again and holding it, the capture latches still didn't release. And only until I recycled to the RETRACT position, and then back to the EXTEND position, did the capture latches release.

I might as well throw in the cycle of the switches when we got ready to redock, because there was an anomaly there, and maybe there's some association between the two. After the completion of the rendezvous, I placed the EXTEND/RELEASE switch to the RETRACT position in preparation for the capture. The talkbacks were barber pole, whereas they should have been gray. I again cycled the switch to the EXTEND position; the talkbacks were gray, indicating that the probe was still fully extended. I cycled the switch back to RETRACT and the talkbacks went gray that time. Everything looked nominal for that particular position at that time. The normal procedure is to hold the switch until the talkbacks are

SCOTT gray, at which time I release the switch. As I remember, I did that. I don't remember exactly when the clunk of the probe hitting full extension occurred relative to the time I took my finger off the switch. I believe that my finger was still there when the talkbacks indicated gray, which is an indication of almost complete extension of the probe. This should have been well past the point at which the capture latch is released. Anyway, after we finally got the LM released, we had drifted off in all three axes (primarily pitch) approximately 10 degrees, because neither spacecraft RCS was operating during the undocking portion. After release, I backed off and took a stationkeeping position relative to the LM without an attempt to go back to the undocking attitude since I would maneuver shortly anyway to the proper attitude for separation.

McDIVITT As we started the undocking I could see, through the upper window, the distance

McDIVITT

between the command module and the LM begin to open up. I was prepared to float gracefully off into space when we got to the end of the probe, and, as Dave said, there was the clunk. We sort of hung there. It's a little difficult to judge the attitude changes through the overhead hatch window because it's so small. You've got to look at them from such a funny direction. I also had to remove the COAS and had it down in the front window at this time. So we didn't attempt to do any rate damping or anything like that. When we finally were released, we sort of fell off the end and were in a peculiar attitude compared to what we had been accustomed to in the simulations.

SCHWEICKART

10. Secondary S-band and VHF B Simplex: The secondary S-band COMM checks were run at Antigua, and during those checks, it was noticed that there was some noise on the primary S-band transponder. This disappeared just about the same time that

SCHWEICKART the ground advised us that we were clear to use the secondary transponder. From time to time throughout the day, we did experience noise on both the S-band and the VHF. As best I can recall, at that time we also set up and did the PLSS COMM check with the LM, which worked fine. The LM also transmitted to the command module, and the command module relayed via the CSM one-way relay to the ground. Although we didn't get any word back from the ground at that time, they reported later that the one-way relay worked. That was followed by moving right into the LM two-way relay for the mode 10. The TV pass which followed over the States, was successful, except that the voice did not get down. Following the day's activities and during the water boiler of sublimator dryout, a backup S-band voice check was conducted; and there was some confusion at that time as to whether the backup S-band voice was going down. This confusion came about because we had been

SCHWEICKART advised that the down voice backup on S-band came hot off the intercom bus, and it was not required to use the PTT buttons. When I attempted contact with the ground without using the PTT, I got no response. Alternately pressing and releasing the PTT, I conducted several short counts from zero to five and back down; and CAP COMM reported that whenever I released the PTT, the down voice stopped. There is a recollection of the ground calling back later that one of the COMM checks which did not appear successful at the time was indeed successful and that there was a possibility of a mixup on the ground relay back to Houston.

McDIVITT 12. AGS: On the rendezvous day, when we pushed the circuit breaker in, we found that the LGC was not in STANDBY. For some reason it came up in P06 with the flashing VERB 37 but with the STANDBY light OFF. We had the AGS warning light ON from the time the AGS came on. We were advised by the ground that it was an

McDIVITT anomaly, but to not be influenced by the light, and to treat the AGS as an operational system; which we did. OPERATOR ERROR light on the AGS came on when we were operating the keys, and they had to be operated a number of times. Rusty says that he had to hit it as many as three or four times on the CLEAR button to get the light to go out.

As we proceeded through the systems checks on this particular day, we were staying well ahead of the timeline and were not having any particular difficulty with them. We did a couple of things that we hadn't done previously, like pressurizing the APS, but it was a nominal pressurization. The thing that we had had a problem with on the preceeding day was the rendezvous radar self-test. I made sure that we got to this well in advance of the time that we had it in the schedule. As a matter of fact, I had intended to do it at least two times. It was scheduled in the timeline over Honeysuckle at

McDIVITT about 92 hours. I did it without ground coverage at about 91:40 or so. It turned out that the self-check was fine. We had the rendezvous radar unstowed at this time; and we ran right through the self-check without any problem. I did some of it twice and it looked like it was working fine. Subsequently, we came across a ground station and I asked if they wanted to watch it from the ground. They did not, so instead of completing it two times, I went through it about one and a half times.

SCHWEICKART In performing the PIPA BIAS check for the rendezvous day, we did get new values there of plus 09, plus 01, and plus 01. They were changed from the last PIPA BIAS check on the systems day. On the AGS calibration, the accelerometer bias coefficients remained what they had been prior to and after the docked-DPS burn. Once again the gyro-drift coefficients changed. This time they were plus 0.19, plus 0.13, and minus 0.01 deg/hr. The

SCHWEICKART landing radar self-test was nominal, once again identical with the previous days.

McDIVITT Rusty was watching the rendezvous radar when I pushed the circuit breakers in. He said we had a very, very slight oscillation or movement when we pushed in the DC breaker. One of the milestones in the preparation for the undocking was the pass that began about 91:05 across Antigua, Canaries, and Madrid. In our simulations, we found that this was the one point that we had real problems in getting all the things done that had to be done. In flight, we were able to go through all the things that we needed to do here without too much of a problem. Once we got through that, we knew that we were in a good posture to undock on time. When we did the lighting check — where we checked all the lights that were available to us — I was unable to see the command module spotlight. Between the two spacecrafts, we now had no spotlights at night, which is not a very good posture

McDIVITT to be in. There might be some consideration given to using the EVA light as a stationkeeping light, although it's dim and we certainly haven't had the opportunity to see what it can do in actual practice. It was at this time that I again checked the alignment of the COAS with the target in the command module window. They were off about 4-1/2 degrees in pitch and about one-half (I should say 4-1/2 degrees up and down as you're looking through the window) and one-half degree left and right. It was down and to the right. It was apparent that the brilliance of the COAS was far from what one would like in the daylight. I had checked this a number of times during the daylight and dark. It was perfectly adequate in the dark. We were able to detect that the flashing beacon was indeed flashing, seeing the reflection on one of the quads. The CMP could also see the light flashing on the quad. We were assured

McDIVITT — from both spacecraft, then, that our tracking light was operating.

SCHWEICKART — The AGS was also checked at this time. This close in with the AGS, data coming out of 317 and 440 was garbage all the way.

McDIVITT — 15. Preparation for undocking: The preparation for undocking went smoothly and we were in a position to undock well in advance of the time that we needed to be. I think that our first anomaly was when we actually tried the undocking itself.

17. Maneuvering of LM: At this time, we enabled the flight control system, and rather than do all the maneuvers that we had anticipated, we eliminated some of them.

We enabled the flight control system as planned and did our 120-degree yaw maneuver. Then, instead of doing the 180-degree pitch maneuver, where we show the descent engine bell to the command

McDIVITT module, we decided to eliminate that and just do the 90-degree pitch maneuver, so that we could find ourselves in a position where we were looking at each other and still have enough time to prepare for the seperation maneuver. We did this under AGS control. After we'd done the 90-degree ptich-down, we maneuvered to an attitude that put us in plane. We were still somewhat off in pitch attitude. We then started our 360-degree yaw maneuver using pulse control. We were back on the timeline at this time. We were at minus 18 minutes from the separation maneuver.

21. Formation flying in AGS and PGNS: The pulse modes, both the ones that we had used so far, operated fine. The ATTITUDE HOLD mode on the AGS operated fine, but the RATE COMMAND mode of the AGS for orbital flight is a very poor flight control mode. It's impossible I believe, to command a desired rate at low rates using AGS rate command. The stick is no more than displaced from

McDIVITT neutral when we had rates in the order of 1.5 deg/sec or so. On the simulator, I displaced the stick and established a rate, and then Rusty would move the switch to the pulse position to establish a rate. We had a considerable amount of difficulty getting the rate established at some relatively low rate, and getting the pulse switch thrown so that we could continue on around at this lower rate. I think the AGS RATE COMMAND mode may be alright for landing, but it's certainly a very poor control system for orbital flight.

After completing the yaw maneuver, we went to PGNS ATTITUDE HOLD to stop the rate. We then went to AGS control and did some stationkeeping in AGS. As I mentioned, the ATTITUDE HOLD mode is fine. It doesn't limit-cycle excessively, it attitude-holds properly; it's just that whenever you try to do any rate commanding, it's very poor. The stationkeeping in AGS was no problem at all and the

McDIVITT same with PGNS. We did some stationkeeping in PGNS and it was also very easy to do. It's worthy to note, though, that there were very few inputs required for stationkeeping. It was easy in either control mode.

24. Rendezvous radar lock-on: We brought the radar on the line and I was tracking the command module with the COAS and the radar locked on properly. It was within the range and range-rate constraints.

SCHWEICKART After the radar lock-on, I compared the range and range-rate with the VERB 83, which I had called off on the DSKY.

A VERB 83 at this range is a very erratic display, which tends to alternate good data with garbage on alternate computation cycles. It, therefore, requires waiting a few seconds and watching the DSKY display in order to evaluate when you're getting the valid display of data rather than the garbage display. The valid display was up only 25 percent of

SCHWEICKART the time or less during this time period. But when it did flash up on the DSKY, it agreed very well with the tape, within 1 ft/sec, and you're comparing thousands of feet. We were at about 1200 to 1400 feet on the tape meter when the DSKY was reading a quarter of a mile. So, it compared very well.

Following the VERB 83, the VERB 62 radar self-check was called, and it agreed exactly with the tape meter; there was no difference between them whatever.

McDIVITT After we had completed the alignment, we locked the rendezvous radar back on. We wanted to make sure that we got on the main lobe. At this time, I was actually able to see the command module, and we did the first rendezvous radar lock-on to AUTO TRACK visually. We were able to lock-on quite rapidly. At the ranges that we were at, the AGC was actually reading higher (this is the signal strength read-out on the rendezvous radar) than the little check sheet that we had with us

McDIVITT that compared range and AGC reading. This was an invaluable tool during the entire flight to determine that one actually had achieved the main lobe lock-on rather than a side lobe. And at no time during the

McDIVITT flight did it ever read lower than what our chart said.

The next event was locking the radar back on the command module. Here again we had no difficulty at all verifying the main lobe lock-on. As a matter of fact, throughout the rendezvous the ability to verify main lobe lock-on was considerably easier than I had expected it to be. This was because I was able to see the command module at great distances, which I wasn't really sure of preflight, or, I was able to identify the main lobe from the chart we had for AGC readout. It's also interesting that I was able to see three lobes on AGC rather than just the two that we looked at in the simulator. We had the obvious large main lobe, we had a smaller secondary lobe, and the

SCHWEICKART

tertiary lobe looked like it was about half the output of the secondaries. After initiating P20 to start tracking, and verifying the main lobe lock-on, we keyed the VERB 80 to start incorporating the marks to update the LM vector. The first mark gave us a 3-degree alarm as did the second mark. However, the second mark was quite close to 3 degrees, as I recall. The first one was less than 4 degrees off and the second alarm showed that it was converging toward 3 degrees. The third mark went in without any alarm and the remainder of the 12 marks all went in with no unexpected displays. The AGS solution to the TPI zero indicated that we would have an elevation angle at TPI zero of 32 to 33 degrees, 22 ft/sec on TPI, and 22 ft/sec TPF. Following the 12 marks in the PGNCS, the LGC came up with 30.59 degrees for the elevation angle, and the NOUN 81 data was minus 20.7, plus 0.4, and minus 1.8 in

SCHWEICKART DELTA V_x, V_y, and V_z. The Gumdrop called over an elevation angle after his first solution of 211.49. Subtracting 180, that corresponded with our 30.59 to within one degree. So, it appeared that the navigation was going well from both sides. Following the first final computation there for TPI_0, we reset the RENDEZVOUS RADAR BIAS ESTIMATER to one milliradian and conducted a rendezvous radar self-test and a landing radar self-test, both of which appeared completely nominal. Following those two tests, we went back into the tracking cycle in P20. After completing the tracking cycle prior to TPI_0, the data at 14 minutes (which is our final COMP time) came out to 28.85-degree elevation angle and a DELTA V_x, V_y, and V_z in NOUN 81 of minus 20.1 in X, zero in Y, and plus 1.8 in Z. The AGS by this time had degraded considerably and indicated a 31.6-degree elevation angle at transfer, 20 ft/sec for TPI, and 24 ft/sec on the TPF.

McDIVITT The corresponding numbers that were called over from the command module agreed to 0.1 degree in elevation angle, less than 0.5 ft/sec in X, and Z was about 1.5 ft/sec difference. So, this fell well inside the GO/NO-GO. We had a GO to go on beyond TPI.

McDIVITT As Rusty's already pointed out, we had good agreement with all the inputs that we needed to decide onboard whether we were GO or NO-GO. There seemed to be no problem whatsoever at this moment. The GO from the ground was just sort of a foregone conclusion.

All around the football, as we went around, I always had the Gumdrop in sight. Whenever I really wanted to find him I could just look out and he was flashing light, or, his sunlit reflection was out there. We could always see him. As we got out past the insertion burn, he did eventually disappear.

McDIVITT 26. Preparation for phasing burn: The maneuver to the burn attitude was done manually using pulse mode, which was the flight control mode used during almost 99 percent of the flight. We operated in PGNCS pulse. We flew to local vertical attitude and it was a good chance to see how the spacecraft really performed in this semi-heavyweight configuration. There was a fair amount of fuel left in the descent stage and the ascent stage. I think that this mode is certainly adequate for the kind of maneuvers that take place in orbit. As we got down close to the burn time, we switched to AGS pulse and again this control mode is very good, very good.

SCHWEICKART In preparation for the phasing burn, the AGS was loaded with the NOUN 86 values, which were called after entering P40. Again, as was experienced in the docked DPS burn, after setting 407 to all zeros, it kept changing state to plus one, which necessitated special handling. I reset

McDIVITT

it a number of times prior to the phasing burn.

27. IMU and COAS: The pointing needles on the FDAI seemed to be very accurate when compared with the COAS. In trying to get the correlation between the needles and the COAS, I found that if I put the target exactly in the center of the COAS - the zero-zero mark - I had the needles centered. I was quite pleased with this because in our simulations we never had everything lined up and it was always an extra thing to think about whenever we were doing the relocks. To make sure we had the main lobe lock-on we had to place the spacecraft in a certain position relative to the COAS during simulations. It's a lot easier to just stick it in the middle.

28. Phasing burn performance and parameters: The procedure for the phasing burn was: to start the ullage at 8 seconds and get to 5 seconds, to hit an ENTER on the

McDIVITT PGNS (so that it would count but not necessarily send a fire signal to the engine) and then to enable the engine gimbal (so that it wouldn't be driving prior to this time under AGS control).

At ignition, we expected it to start, obviously; and at 5 seconds after ignition, we were going to throttle rapidly to 40 percent and let the AGS control the burn at 40 percent. When the engine started, we had a very slow, smooth start-up to 10 percent. At that time, which was approximately 5 seconds after engine ignition, I started the throttle up. As I throttled up to approximately 20 percent, the engine began to rumble in a manner very similar to a jet engine compressor stall — or at least that's what it felt like to me. I could actually feel the thing on the floor — and it didn't seem to be following the throttle as it had in the docked DPS burn.

I wasn't as surprised as I might have been on this because of all the discussion that

McDIVITT we'd had with the service propulsion system and it being subjected to negative g's, and the requirement for a 40-second burn to get all the helium out. We subjected the descent engine to the same kind of thing, and I thought we might have some anomalies, but the chugging was a little more of an anomaly than I had expected. I stopped throttling at 20 percent and let the chugging go away. It left fairly quickly, in a matter of seconds, I guess. Then I throttled up to 40 percent. The throttle-up went smoothly and the engine ran properly at 40 percent without any problem. It steered within a few degrees of the attitude that I expected it to be at, and had a very nominal burn with shutdown on time with very low residuals.

Following the phasing burn, the PGNS residuals immediately after the burn, were minus 0.9, minus 0.8, and minus 0.6 ft/sec. Our procedure was for Jim to switch the guidance control back to PGNS

McDIVITT immediately on engine shutdown and then burn out the residuals. After burning out the PGNS residuals to zero, the AGS 500, 501, and 502 read zero, zero, and minus 1 ft/sec. It's probably worthy of note that in burning out the horizontal residual components, the Y and Z components, there was a good bit of control activity taking place. I don't think that this is any different from the simulator. The primary difference to us was that for the first time we were able to sense and hear all the activity when you're burning the horizontal thrusters with the c.g. so far below them. This came as a bit of a surprise to us, and perhaps took an extra 10 or 15 seconds of looking at it and figuring out that it really was working alright.

The checklist procedure for switching inverters for each of these DPS burns was followed, as was opening the cross-tie balance load breakers, to run the busses independently. Unlike the simulator, the

McDIVITT BUS voltages stayed very close together even though the commander's BUS was loaded more heavily than the LMP's BUS. Subsequent to each burn, we had a little debriefing that we went through. On this particular one, we were looking for the ability of the manual translation control to do a proper ullage, and there were no problems associated with that at all. There were no cross-coupling effects that we could determine on the FDAI's. The spacecraft responded dynamically to the gimballing of the engine and the control of the engine made by the AGS. It was really a very undynamic situation except for the propulsion startup. The noise level, except for the grumbling that I mentioned earlier, was nothing to be concerned with at all, could hardly hear it. And the handling characteristics, as Rusty mentioned, after engine shutdown were very sloppy. Lateral translation is a very poor thing to do in this particular con-

McDIVITT figuration. We didn't experience any unexpected torques or venting or anything like that during the burn or subsequent to it.

The radar tracking and marking at this slightly greater range now really began to mean something. It indicated that our rendezvous radar was working properly and we went up through the 12 marks to do the cycle for TPI zero. After we had completed this, I sort of had a good feeling that the radar and guidance/navigation systems were working together. My concern over our rendezvous radar was considerably less from this moment on.

30. Insertion burn: Subsequent to the TPI zero GO/NO-GO, we received a pad for the insertion and we prepared to do another alignment. This alignment was very similar to the first one except that it was started in the darkness. We did not have the opportunity again to view the stars in the daylight. It wasn't an aw-

SCHWEICKART ful lot different than the first one, except that we did an AUTO maneuver and did a star check through the AOT rather than a COAS calibration check at the end. We used Regulus and it appeared right in the center of the AOT. We had no problem whatsoever on verifying our alignment. Our torquing angles were low and Rusty can give you those.

The star-angle difference was plus 00004, and the torquing angles were plus 0.089, plus 0.055, and plus 0.037.

McDIVITT After this, we had to lock the radar on and I used a visual lock verification. It certainly simplified the lock-on problem when I could see the target. We locked on at a range greater than 19 000 feet; I believe we took three marks before we reached this point. We then disabled the update until we had gone out to a range in excess of 19 000 feet, got three more marks, and were able to proceed out of this program and into the preparation

McDIVITT for the insertion burn.

The insertion burn was to be a PGNS burn under AUTO control. We had automatically done the maneuver to the proper attitude. Again we were using rough attitude checks. It was to be a posigrade burn; we knew this. We had a local vertical ball. ORDEAL was running. We had done a number of AGS alignments from the PGNS. AGS, attitude-wise, was staying very close to the PGNS.

With the number 1 ball running in orbit rate and with the number 2 ball running in inertial AGS (number 1 ball being in PGNS), we could compare all three of these inputs and determine onboard that we had indeed maneuvered to approximately the right attitude. We could look out the window and see where the earth was with respect to the Z-axis and make a rough judgment.

This time, we used X translation at 9 seconds; at 5 seconds, we enabled the engine firing. We did the entire burn

McDIVITT at 10 percent this time. The engine came on and went off, a good nominal burn. There was not an excessive amount of steering and very few jets fired. It was about as nominal a burn as anything I'd ever seen.

SCHWEICKART I thought that the jets were being fired during the insertion burn a fair amount. It's difficult to describe quantitatively, but my impression was that the errors were going back and forth perhaps 1.5 degrees on either side of center and was causing the RCS jets to fire rather than being taken out only by steering of the descent engine.

At the end of the insertion burn, the PGNS residuals were minus 0.9, minus 0.2, and minus 0.3 ft/sec. After these were burned out to zero, the AGS 500, 501, and 502 were plus 1, 0, and minus 1 ft/sec.

McDIVITT Dynamic responses were practically nil, very small attitude excursion. The acoustical environment was, practically zero level input to the ear through the hel-

McDIVITT met or the bunny cap that we were wearing. Visual effects of the DPS plume were essentially nil.

SCOTT At the phasing burn, I was monitoring the phasing burn visually through the rendezvous window; the RCS was clearly visible; it was at night. The DPS portion of the burn was not visible. I attempted to take movies with the 70 mm lens, but I doubt if there was any good results.

MCDIVITT 31. Maintaining RR tracking attitude: After completing the insertion burn, we once again had to lock the radar on to the command module. This was done without any problem. Throughout the rendezvous, I was running slightly higher on the AGC than my chart indicated, I wrote down some appropriate range and AGC readings. This particular one was 45 miles and 2.4 on the AGC.

31. Maintaining RR tracking attitude: We did an AUTO maneuver to the burn attitude and I might comment on the AUTO

McDIVITT maneuver of the LM. We were using 2 deg/ sec as a standard maneuver rate throughout the rendezvous. The digital auto pilot did an excellent job. It established this rate without an excess amount of RCS cycling. It maneuvered right on around, and when it got to its final attitude, it didn't seem to overshoot; stopped at the proper attitude without an excess amount of RCS firing.

The closest approach was 16 000 feet, and it was nice to have the radar locked on at sometime prior to the closest approach. Although the ground had called out our missed distance to us in simulations, we found that we sometimes had difficulty getting back to the right attitude and getting the radar locked on, verifying that we were really going to miss the other vehicle. In flight, it was done quicker and we had the information available to us previously. It is just awfully nice to know that you are not going to hit your friends out there.

McDIVITT

32. Targeting PGNCS and AGS for CSI and CDH: We targeted the CSI maneuver for the first apsidal crossing and went on through here. Rusty decided to call the ground for an affirmation of the first apsidal crossing. We had never used anything except a first apsidal crossing in any of our simulations and hadn't expected anything here. Unfortunately, the ground called back and said to use the second one, which we did later on; but we got the wrong solution. We changed it back to the first apsidal crossing and got the correct solution. This made it a little tight right at the CSI burn. At the appropriate times, we copied the range rate for our charts and did our marks. Then, we were going to do a rendezvous radar check when we got to a range greater than 50.8 miles.

33. Preparation for staging and CSI: We had 37 minutes between the insertion burn and the CSI burn. When we got to the rendezvous radar check which was

McDIVITT supposed to tell us that we had a cycle slip and a few other things, we decided to delete that part because of the limited amount of time and just continued taking rendezvous radar marks through this period. Rusty points out that somewhere along here we missed the recycle after 4 marks and reinitialization of the W-matrix. It apparently was at the time period of about 28 minutes when we were supposed to do that. This was caught by the ground and they reminded us of it. They took good care of us throughout our entire rendezvous. I think we proceeded to the 14-minute mark without any problem and certainly in a fairly nominal condition. The radar was working; the rest of the spacecraft was working properly. When we hit the final COMP at 14 minutes with the second apsidal crossing, we received an answer that was approximately 85 or 90 ft/sec, which we knew to be almost 2 times larger than what we wanted. We went back and put the first apsidal crossing in and got the right

McDIVITT answer out which compared very closely with the ground solution. In a case like this, if the first apsidal crossing hadn't solved our problem, we would have called P30 and loaded it with the ground solution; and then, we would have done the CSI burn. Because we were going to stage on this particular burn, we had to do some extra reconfiguration of the cabin to provide ourselves with the proper amount of 0_2 to breath in case we depressurized the spacecraft due to some staging problem. We also had to transfer to those systems that had their expendables located in the ascent stage. We also made an effort to deadface the electrical connections that ran to the descent stage so that we couldn't possibly get any shorts from a hot wire. When we finally put the first apsidal crossing in, our solution compared quite favorably with the ground. Once again, the decision as to whether to go with the ground or the onboard solution was an easy one.

~~CONFIDENTIAL~~

SCHWEICKART The first solution to the CSI burn following insertion came out to be minus 40.2 ft/sec with a DELTA-H of 9.9, which looked quite close to nominal. As Jim mentioned, this occurred slightly late on a ground reminder. We neglected to hit it at 4 marks. I believe that we actually got our reinitialization done and the recycle done at 7 marks. It was after this time that I asked the ground for their recommendation on apsidal crossing, primarily because I knew that the orbital parameters of the CSM were fairly different from what we had been simulating. I was not at all sure that the first apsidal crossing was the proper one. Prior to running the final COMP out of the PGNS, I had targeted the AGS with the proper times. I had input the second apsidal crossing to the AGS and had gotten a solution which read on the order of 85 ft/sec. At that time, I considered the AGS to be NO-GO based on getting a

~~CONFIDENTIAL~~

SCHWEICKART ridiculous answer from it. We had seen this type of behavior. I can't say exactly like it, but we had seen illegitimate solutions from the AGS in simulations. At that time with no time to troubleshoot, I assumed this to be the case here. However, on hitting the final COMP at 14 minutes for the PGNS, interestingly enough, we got the same answer. Then, the AGS came in as sort of a back door system in clueing us that we had a systematic problem which gave us the same wrong answer with both systems. This encouraged us to go on to the first apsidal crossing. However, this now had cut into our normal timeline because we had already gotten the final solution and prevented me from completing the chart solution. The first apsidal crossing gave us a DELTA-H of 9.8 miles and a TPI slip of plus 3 minutes 54 seconds. The horizontal component for the CSI burn was minus 40.0 ft/sec. This compared quite favorably with the ground solution, which was minus 39.3 ft/sec. Upon

SCHWEICKART working out the chart data postflight from the data taken inflight, the chart solution to that burn was minus 40.7 ft/sec. The reconfiguration of the ECS and the EPS prior to staging went as expected. There were no big drops in the bus voltages due to switching to the ascent batteries. As I recall, they were reading 28.4 or 5 volts following the dead facing of the descent batts.

McDIVITT The CSI maneuver is normally performed local horizontal, with the minus X-axis pointing in the posigrade direction. We were facing the sky, which was not much of an attitude reference. We maneuvered there from a position so that we were looking at the surface of the earth in local horizontal position and then pitch up about 90 degrees. We could tell that we were roughly in the right attitude. As I mentioned earlier, we compared the AGS, the PGNS, and the orbit rate information to make sure that we were in the right attitude. The CSI burn was to be

McDIVITT an RCS burn with staging shortly after we began the thrusting; it was to be 4 jet translation. We maneuvered to the burn attitude by using PGNS AUTO maneuver. Again, it was a good control system. We got there without an excess amount of thrusting, held in the right attitude, and configured the spacecraft for staging. At T minus zero, I began the plus X translation.

34. Staging and CSI burn: When I had verified that the spacecraft was controlling in the AUTO mode and that we were definitely getting thrust, I hit the stage fire switch. We staged in a cloud of debris and a big bang. We could see the debris being lit up by the thrusters, and it seemed to float all around the spacecraft. It did not perturb the spacecraft attitude excessively. I continued to thrust; and when I had assured myself that the spacecraft was indeed under control and that we could continue thrusting

McDIVITT as we were, I called for the APS interconnects to be open so that we could use APS fuel. These were open, and we did most of the thrusting — using the ascent propulsion system fuel rather than the RCS fuel. At a velocity to go of approximately 9 ft/sec, they were closed; and we were configured to the nominal RCS configuration. We burned the residuals to essentially zero without any problem at all; and during this period of time, we called the burn to the command module to let them know that we were accomplishing it as programmed. There was some RCS activity in addition to the translating activity, but I didn't feel it was excessive. One would always expect some because there are perturbing forces, but it seemed like a reasonably nominal RCS plus X maneuver. I should add that we were looking at the black sky, and it was pretty black everywhere. Yet, I found that the RCS activity, which seemed to create a much brighter flash around the spacecraft than anything

McDIVITT else, was not in any way blinding. We did not have to configure the interior lighting to any particular mode; we just had it the way we had been using it at night. It certainly was not optimized for viewing out the window, but everything was not full bright, and it seemed to work pretty well. During the burn, the ascent interconnect worked as expected with the exception of the closing of the ascent feeds at the end of the burn. At this point, there was some momentary heart failure when I closed the ascent feed because the number 2 talkback in system A remained gray. I hit the switch a couple of times before recalling that there was a sticky talkback in that location. When I rapped the panel, it went back to barber pole.

On those talkbacks, when any of the switches associated with the talkbacks on the parker valves is activated, the talkback goes to a gray condition regardless of whether the valve is opened or closed.

McDIVITT Thus, if a valve is closed and the talkback is gray and one positions the switch to a closed position to ensure that it is closed, the talkback will nonetheless display gray while the switch is out of the neutral position. This characteristic is something which future flights should be aware of to keep from misinterpreting the display.

Following the burn, and the burning of the residuals to zero in the PGNS, the AGS 500, 501, and 502 read plus 10 and plus 1 ft/sec.

After CSI, we again had to lock the radar onto the command module, and I was unable to see him at this time. When we were out at a range of about 85 miles, I could no longer see the light. I did not try to dark adapt or anything as exotic as that. I had noted the AGC reading prior to breaking lock for the CSI. It was running about 2.2. Then, I went back and did a lock-on. We put in the VERB 95, which prevented updating of the PGNS. I

McDIVITT checked the AGC. It was reading 2.19 at a range of 85 miles, which is above the AGC signal strength that I had on the card. I was assured that I had the right target locked on. We allowed the radar updates to continue and proceeded on through to CDH. Shortly after this, the CMP called and said he didn't see us in his telescope. We started checking to see if we had a tracking light. We looked at the quad, which had been lighted by the flashing of the tracking light earlier, and did not see any flashing light off of it. We considered the possibility that the light we had seen on the quads had been a reflection from something that had been on the descent stage. Because we had already jettisoned the descent stage, we thought, or maybe I should say hoped, that the tracking light was operating and was not just reflecting on the quads. Subsequent to this, we found out that the tracking light was indeed not working and had apparently failed at staging. With

McDIVITT our lock-on, we proceeded through the checklist as we were supposed to and picked up the range rate for the charts.

36. Preparation for CDH burn: We had a little trouble establishing the time for CDH with the ground. We had a little communications problem that we'll let Rusty discuss here in a minute. We did get these range rates out, and as we went through the maximum range of approximately 98 nautical miles, my AGC was reading 2.17 on the radar. With the ascent stage only, the pulse mode was still a very effective mode. It gave a little snappier response than it did when the descent stage was hooked on. It compared quite favorably with the response of the simulators, but at this point, I began to notice even more the lack of fidelity in the rate needles that we had onboard. Earlier when the pulse input was causing a lesser DELTA rate change, I could watch the needles and see how the spacecraft was actually behaving. If I saw the thing

McDIVITT deviating, I had plenty of time to stop it. With the higher rate changes per pulse without the descent stage, I really got so that I had a stronger and stronger desire for a set of accurate rate needles. I finally had to give up almost completely on the rate needles. I went to the radar error needles and upon watching the rate with which they changed, I used them as my rate indicators. I just almost completely forgot about the rate needles as displayed on the FDAI. It's unfortunate that they weren't more sensitive and more accurate, because we did a lot of pulsing back and forth across the correct attitude trying to get these needles to stop when we could have used the rates; and with that information, we probably could have stopped it a little better. As we approached the CDH maneuver, we again had very good agreement between the onboard solution and the ground solution. As throughout the previous portion of the mission, it was easy to decide which one

McDIVITT to use, that is, to use the onboard solution and go with its answer.

SCHWEICKART Immediately following the insertion burn and during the AUTO maneuver for the initiation of P20 tracking, VERB 06 NOUN 31 was called to obtain the PGNS burn time for the CDH burn maneuver and PGNS ignition time for the CDH maneuver. This turned out to be 96:56:29, which we then biased upward 1 minute 45 seconds to 96:58:14 for the actual TIG. This was passed to the ground; however, due to our normal COMM problems over Tananarive, we had no success in getting this word to the ground. This was later passed down on first contact at Carnarvon. The recycle after 4 marks gave us a 10.1-mile DELTA-H and a DELTA-T TPI slip of minus 3 minutes 56 seconds, which corresponded very, very well with the 4 minute TPI bias which we had put in during the CSI program. I might mention that the normal TPI bias was 3 minutes on TPI, but due to the trajectory that we were in, the ground recom-

SCHWEICKART mended using 4 minutes. This worked out very well indeed. On the final solution at 14 minutes, the DELTA-H came to 10.0 (right on the money), the DELTA-T TPI slip was minus 3 minutes 30 seconds, and the NOUN 81 came out at minus 39.2 plus 0.1 and minus 13.7. This compared with an onboard chart solution of minus 39.5 for X and minus 14.5 for Z, or less than 1 ft/sec difference all the way around. The ground also compared at this point with a minus 38.1 and a minus 15.3. Interestingly enough, for this burn, the AGS solution came out to be minus 40 ft/sec in X and minus 14 ft/sec in Z; so we had 4 independent solutions all within 1 ft/sec of each other.

McDIVITT CDH was obviously to be done with the ascent propulsion system. We did an automatic maneuver to the attitude. Once again the DAP proved to be a fine attitude control system. There was no excessive jet firings which was of some concern to me. I wasn't sure with the lighter weight

SCHWEICKART vehicle just how these autopilots would perform, but they were very, very good.

37. CDH burn and parameters: We maneuvered to the attitude and again checked the attitudes as I mentioned earlier. At minus 3.5 seconds, we got AUTO ullage. The burn started. It was just a big jolt — a very short burn of 4 seconds. It was almost impossible to see whether or not it steered. It was a big jolt, a little noise, and a shutdown. The whole thing was over before we really had a chance to evaluate the steering. The noise wasn't enough to cause any concern. We could almost feel it more than we could hear it. It was certainly of no concern to the pilots as far as being able to communicate with each other or to hear information from the ground. I guess I should say that the dynamics were practically nonexistent in this short burn. We used a 4-jet ullage for the burn.

The residuals at the end of the CDH burn were minus 2.4, plus 0.8, and plus 0.1.

SCHWEICKART These were burned to 0, and the 500, 501, and 502 read minus 1, plus 1, and 0.

MCDIVITT 38. Operation of PGNCS and AGS: I'd like to review the control systems again. I felt that the pulse modes, both PGNCS and AGS, were very good modes. We used them predominantly through the orbit periods, the nonthrusting periods. The DAP operation was smooth with no overshoot. It appeared to be a very fine control system, both for attitude holding, automatic maneuvers, and manually commanded RATE COMMAND. The AGS appeared to attitude-hold properly, and I felt that the RATE COMMAND just had too much authority and could not be used without overcontrol. During our coasting phases between burns, I noticed no tendency of the LM to trim to any particular attitude, and there didn't appear to be any drag or any external effects influencing our attitude. When we put it some place, it stayed there. I think that the rate needles in the LM certainly need improving. I think that

McDIVITT we could have saved a considerable amount of fuel if we had just known what our rates were. I doubt seriously if we ever get them to be comparable to the 1-deg/sec rate read-out that we have in the command module with its accurate gyros; but if we could, it would certainly be a worthwhile effort.

SCOTT 38. Operation of RR, AGS, and PGNS for TPI: After the CSI maneuver, the P76 with the LM DELTA-V's, and the time bias for the burn time, P20 maneuvered the Gumdrop to what was supposed to have been a preferred tracking axis. There was no light visible in the sextant. This could have been due to several reasons, one of which could have been an improper P76. I checked the registers, and the P76 had been loaded properly. I called the LM to check on the light. They no longer saw any flash off their quads; but we still could not be certain, so I left P20 running to maintain preferred tracking axis pointed at the LM for the radar. Because CSI had been per-

SCOTT formed shortly after sunset, the entire tracking period prior to CDH was in darkness. I could, therefore, expect no opportunities to take any marks prior to CDH. A comparison of range and range rate at the horizontal crossing with the LM was very good, indicating that the state vector was still being carried fairly well in the command module. I had about 96.63 miles, and the LM called 98 miles. I ran a number of checks through the systems, and everything seemed to be running well except the LM light. I spent some time deciding what to do in case I could not see the LM at daylight after the CDH burn. I guess the only solution would have been to pick up 2 more state vectors from the ground, which we had done in simulations; so I knew they were prepared to support that type of operation. I followed the normal preCDH procedures and targeted the CSM with the mirror image burn 1 minute after the LM burn, adding the DELTA-V bias that we had calculated

SCOTT preflight. After the CDH burn I took the components that the LM had burned and entered them into a P76 per normal procedure.

McDIVITT In the postCDH procedures, I checked the rendezvous radar to see what my range rate was. The range rate just postCDH was reading 107 ft/sec. As we went across the bottom of our track, approaching TPI, the range rate stayed at 107 for a long time and very gradually dropped off to about 105 shortly before TPI, which indicated that we were almost perfectly coeliptic. We did the rendezvous radar lock-on. Once again, we were unable to do it visually, we had to do it with the AGC readings that I mentioned earlier. They proved to be adequate, and I had great confidence that we were indeed locked on the main lobe when we allowed the radar to start updating the computer state vector. We did our recycle at the right time and had a fairly long period of time across the bottom between CDH and TPI.

McDIVITT It gave us plenty of time to take marks and to update the AGS through the rendezvous radar, which we did at intervals. We had a pretty good feeling that the AGS had all the good information from the radar. As we came back in, I checked the AGC signal strength again, and at 52 miles, I read 2.39. On the way out at 45 miles, I read 2.40; so I once again felt that the radar had not degraded because it was reading approximately the same at the same ranges. We were plotting our relative position on a polar plot beginning at about 45 miles and found that we were very close to the nominal line. We were getting solutions from the CMP, who was able to see us again once we passed into the daylight. Also, we were getting solutions from the ground, and we had our own solutions. We got the ground solutions well in advance of the TPI time. They called us back later and told us they weren't going to give us an updated one. The one we had was fine. All of the solutions

McDIVITT converged until they were practically on top of each other. I think this was the easiest decision of all to make, because there was practically no difference between any of the solutions.

SCHWEICKART 32. Operation of PGNCS and AGS for TPI: Looking back over the rendezvous, I think that the only item worthy of comment at this point (rather than in the systems debriefing) is that the AGS performance, as compared with the simulations in the LMS, was a bit of a surprise in that the solutions to CSI, CDH, and TPI were not as definitive as one would be led to believe through the training. The LMS tends to give a positive response to these programs or these computations; whereas, in actual flight, the AGS solu- and the solution you get for a burn is highly dependent upon what you decide is the average of all those readings. In a burn where the solution is 40 ft/sec, the total excursions might go from 36 to 43 ft/sec, depending upon when you look at the data. I think that this is something

SCHWEICKART which ought to be modified in the simulators so that this behavior is expected.

39. Targeting PGNCS and AGS for TPI: The time of the TPI burn in the three solutions that we ran, after four marks and just before the W-matrix reinitialization were as follows: we ended up with 97:57:56 after the reinitialization, after 10 more marks, we had 97:57:33; at 16 marks, we had 97:57:41; and the final solution gave us 97:57:59. This compared with a nominal TPI time of 97:56:23, well within the limits that had been set preflight. The final NOUN 81 components were plus 19.4, plus 0.04 and minus 9.7; or forward 21.7, right 0.5, and down 0.3. This compared with a chart solution of forward 20 and down 1, so the chart also came out very close to the PGNS solution.

McDIVITT Our final time out of the PGNS of 97:57:59 compared very favorably with the CSM solution of 97:58:08, a difference of only 9 seconds. The updating of the rendezvous radar into the AGS was physically a

McDIVITT relatively easy task to do. I thought that it was slightly easier than it appeared to be in the simulations; however, the apparent effect of the updates in the real AGS did not appear to have the same power that was demonstrated with the radar updating in the LMS. The range and range rate did come in to what was displayed on the range and range rate tape; however, the AGS state vector began to degrade more repidly than what occurred in the LMS. The final solution out of the AGS, after 2 series of radar inputs, was an elevation angle at TPI time of 23.46 degrees, a DELTA-V at TPI of 20 ft/sec (which was alright), and a total TPI plus TPF of 49 ft/sec. The DELTA-V, therefore, compared very well with the PGNS; however, the angle disagreed by 4 degrees at that TPI time. In support of the TPI burn, the AGS was loaded with external DELTA-V inputs; but 404, 405, and 406 were also run to 0. Because we burned along the Z-axis, rather than called the 500, 501, and 502

McDIVITT displays, 472 was used to support the PGNS burn.

40. Preparation for TPI and TPI burn performance: TPI was to be an RCS maneuver. We had procedures for both plus X and plus Z thrusting. Plus X thrusting procedures would be used if we were running low on fuel. We had plenty of fuel, so I elected to do the thrusting in a plus-Z direction, which meant that we did not do an automatic maneuver. We were already at the burn attitude, so we just went to ATTITUDE HOLD — PGNS ATTITUDE HOLD, VERB 77. I maneuvered so as to center the radar needles to be in the proper attitude. As we were doing this, we had the only anomaly that I noticed on the rendezvous radar all day long. We were at the right attitude. I hadn't changed it for quite some time. I was watching the AGC signal strength when, all of a sudden, it started dropping. It dropped from about 2.6 down to 1.6. My first impression was that the command

McDIVITT module was maneuvering, and we were not going to have the kind of transponder performance that we wanted. Then, it dawned on me that he wasn't maneuvering that much, because he was going to be pointing the X-axis at us; and he probably had been pointing fairly close to that anyway. We stayed in the TPI attitude for some time. The rendezvous radar signal strength began to increase again slowly. It gradually went back up to about 2.5 or 2.6, to whatever it had been prior to this incident. I have no explanation for this whatsoever. We were not maneuvering, and I doubt seriously that the command module was maneuvering through any gross attitude at this time. This phenomena began sometime between about 6 or 7 minutes prior to TPI, it dropped down to a low of 1.6 around 4 or 5 minutes prior to TPI, then it climbed back up slowly after that. In some discussions we've just had, we discovered that the command module was not maneuver-

McDIVITT ing until after TPI minus 5, so I doubt seriously that this had any effect. As I mentioned, the burn was performed in PGNS ATTITUDE HOLD, VERB 77. We waited until we got the flashing 1685 and then burned the components to 0 without any problem. It is interesting that when burning in the three axes, as we did, that burning up and down with respect to the man does not affect them or did not affect me. Burning fore and aft did not affect me, or my positioning within the spacecraft. But when burning left and right, I had a sensation of a moving within the spacecraft. I didn't feel as firmly fixed in the left-right position as I did in the other two. It was a nominal RCS burn.

42. PostTPI systems status: Because we had done the TPI burn in the plus Z direction, we did not have to search for and find the target and then lock the radar on it because it remained locked on throughout this time. We did have to

McDIVITT call P20, reinitialize the W-matrix, and start through. We got our radar data for our charts at 5 and 8 minutes. We hit the final COMP at 7 minutes to perform a maneuver at 10 minutes. All went exactly as planned. We did the thrusting at 10 minutes, keeping the Z-axis pointed at the command module; it was a little aft. We then reinitialized the W-matrix, called P35 the way we wanted, and copied the data for the charts at 17 and 20 minutes as normally planned. We did the proceed for the final computation at 19 minutes for a 22-minute burn. We burned a little forward at this time. We left the radar locked on, got in a little bit closer, went to P00, called VERB 62, stopped updating the state vector with the radar, cross referenced the tape meters with the VERB 62, rendezvous radar self-test data, and came on in using that. In the meantime, I called program 47 to get the thrusting information into the state vector.

4.5.2 LM Rendezvous

SCHWEICKART

44. RCS midcourse corrections: The PGNS solutions to the first midcourse correction were as follows: NOUN 81 was minus 1.0, minus 0.3, and plus 0.9 which amounted to an aft 1.4, left 0.4, and up 0.1. The chart solution there came out aft 6, and a zero up/down, so we were 4-1/2 ft/sec different from the chart. On the second midcourse, NOUN 81 was plus 0.2, minus 0.9, and minus 1.8 which converted to a forward 1.8, left 0.9, and the chart came up with a forward 1 ft/sec. Following the second midcourse, the cameras were set up again in the LM to record the final braking and station keeping. The VERB 62 self test of the radar was called, and displays agreed very well with the tape all the way in. Following the final braking and station keeping and return to P00, VERB 83 was called and agreed very well with the actual conditions. I believe that the velocity was less than 5 ft/sec, and it was sometime

SCHWEICKART after going into station keeping mode that we called it. I believe that the range was out to a mile or 2 miles at that point.

MCDIVITT 45. Rendezvous: I also would like to comment on the restraint system in the LM. I had the feeling that the restraint system was trying to pull me into the forward left-hand corner of the LM, and because of this, I spent most of my time leaning to my right and to the rear. I sort of felt that when we were in a level attitude, the front left corner of the LM was pitched down approximately 30 degrees. I felt as if I were standing on a hill the whole time. I believe that the restraint system is optimized to provide a restraint for looking through the window during the landing phase. Obviously, it can't be optimized for landing and for orbit operations at the same time. It wasn't impossible to work with it. It's just a comment on what it tends to do to a crewman.

SCHWEICKART The operation of the right-hand side of the vehicle, with respect to charts and graphs and handling of those during the rendezvous was that operation with the gloves and the helmet on was a difficult thing at best. I found that I could not plot points with any degree of accuracy on the polar plot or on any of the mid-course charts without removing a glove. I ran most of the flight, with the exception of the burns, with both gloves off. However, I did leave the helmet on rather than continually put it on and remove it for the burns. The restraint system affected me the way it affected Jim. It did tend to pull me forward and to the right-hand side of the cockpit. I did not feel this was overly objectionable, but a reduction of the forces on the restraint system would seem to me to be highly desirable. For a large part of my operation on the right side, I tended to lean back against the Z27 bulkhead and

SCHWEICKART then forward so that I could operate on the data table. The restraint system did not interfere with this maneuver to any large extent. One other item that I think is worthy of mention here, as well as in the discussion of systems, is that the window heaters on the LM were considerably overdesigned to the point that one became uncomfortable if he got his helmet or head too close to the window. The heat radiating off the windows was very strong. On the rendezvous day, we requested f and received from MSFN approval to open the heater circuit breakers to keep this heat source from bothering us. I have a feeling that the temperature of the windows might have affected the item that Jim mentioned earlier on the window shades — where they did not tend to roll up in the small curl that they exhibited prior to flight when they were taken off the windows. There is no question that the heat definitely affected the window shades. They tended to be wrinkled a bit, and at

SCHWEICKART: some points during the flight, with the helmets off, you could actually smell the window shades because of the high temperature that they reached when they were rolled up with the window heaters on. During the rendezvous, there were several times when, to see, work with, and handle the data properly, I had to roll up the window shade on the right-hand side to keep the sun and the very bright earth from interfering.

McDIVITT: 47. Formation flying; attitude control: When the command module broke out into the sunlight, it appeared as a little white silver blob and then sort of formed a crescent shape. The sun was shining from my right, and I could see the right side of the spacecraft first. As I got in closer, the sort of crescent became larger and larger until I could see the command module very well at approximately 1500 feet. We had no trouble stopping. We just coasted right up in front and stopped at about 25 or 30 feet; and at the

McDIVITT time, we had something like 60 percent fuel remaining.

48. Braking: We arrived at 6000 feet at just about 30 ft/sec, and this was our first braking gate. No braking was needed. We coasted right on through. At 3000 feet, we braked to 20 ft/sec, and I felt that it took just a little bit longer to take out the Delta-V in actual practice than it did in the simulator. We then braked to 10 ft/sec at 1500 feet and 5 ft/sec at 500 feet.

51. Docking: While we have demonstrated that you can dock with the LM as the active vehicle, which was one of the DTO's that we were supposed to accomplish in this particular mission, I personally recommend that all the dockings be performed command module active because of the much better visibility and the much better target that the command module has and because of the sort of standard configuration where you are thrusting in the direction in which you are looking and

McDIVITT where you don't have to make a coordinate transformation before you hit the control handle everytime. I think that we have demonstrated a backup system here, and I personally feel that in the future all the dockings ought to be command module active and the LM used only as a last ditch kind of thing. In the lunar orbit mode that we were supposed to be demonstrating, I think that when the command module has accomplished the docking, has the probe inside the drogue, and there has to be some thrusting, he can call thrust and have the LM do the thrust maneuvering and let that be its part of the docking maneuver.

SCHWEICKART 53. Tunnel operations: After the docking, the tunnel was cleared out in a nominal manner. After the couch was reinstalled and on first inspection of the probe, the extend latch indicator was out, which indicated that the extend latch had not (the hook had not) completely hooked onto the roller on the probe piston. It required

SCHWEICKART about four strokes of the preload handle to get the extend latch to engage completely. In removing the drogue, there were no additional marks apparent caused by the docking. The docking ring angle was minus 0.2 degree. All the latches had mated properly and were completely engaged.

55. LM closeout and APS interconnect: In preparation for the transfer, all the LM data were transferred into the ISA. The PLSS LiOH cartridge was transferred into its container and then into the command module. The OPS's were stowed on the floor as planned. The probe and drogue were stowed on the right-hand side, also as planned. The PLSS was stowed against the commander's side of the cockpit. However, rather than lying at an angle against the side wall, it was laying flat on the floor on the left-hand side to make room for a bag of garbage which was transferred to the temporary stowage bag from the command module. This was placed directly on top of the PLSS on the left-hand side. The

SCHWEICKART

two helmet bags were stowed as far forward as possible, one to the left and one to the right of the OPS pallet. All of the planned transfer items were transferred from the LM to the CSM as planned. In the final LM switch closeout for jettison, another change was made to the effect that the system A RCS was left on the line. Normally, as opposed to running the interconnect on system A, the interconnect with the ascent fuel was run only on system B. The maneuver to the final attitude for ejection was done in the LM again by using the ACA for yaw control and the TTCA for pitch and roll. This proved to be no particular problem as far as maneuvering was concerned. When we arrived at the LM attitude for the burn, the CSM was informed and took over attitude holding at that point in narrow deadband. The LGC was configured to wide deadband ATTITUDE HOLD. At this time, the AGS was updated, aligned, and put into configuration to support the APS burn to completion. During the docked alignment,

SCHWEICKART

the second star that was selected was occluded by the earth before we were able to take marks on it, and a third star had to be selected mark on. Unfortunately, the way the alignment program is set up, there was no way to get the mode 2 error needles for this star. As a result, there was no assistance for the maneuvering other than calling for pitch up/down or yaw left/right by the commander who was looking through the AOT. This did make attitude control more difficult during that alignment. After the final switch closeout, the upper hatch was closed on the LM, and I reentered the command module in preparation for the LM jettison.

56. Preparation for LM jettison and LM jettison: In preparation for the AGS burn to depletion, we received from the ground a P30 update which was inserted. Prior to pressing on with the checklist, we did a docked alignment, active from the LM side. For this alignment, we used LM attitude control for yaw. For pitch and

SCHWEICKART

roll control, we used the horizontal thrusters with the TTCA to keep from firing the vertical thrusters toward the CSM. This made the rates of the vehicle during alignment a bit higher than was experienced using pulse mode with the LM alone. However, the star angle difference came out to be all zeros again, and the torquing angles hopefully are recorded on a tape somewhere. I don't happen to have them here now, but as I recall they are all quite low. At no time during the alignments that were performed in the LM did the radar antenna tend to drift into the field of view. A special procedure was sent up from the ground to investigate the AGS warning light which was on all through the rendezvous day. That procedure was executed but the light came on again during activation of the LM AGS. It was tentatively concluded that the problem was a caution and warning problem as opposed to an AGS problem.

4.6.2 Preparation for SPS Burn 6

SCOTT For burn 6, we loaded the DAP for the ullage, probably about 10 minutes before the burn, and proceeded into the burn. At 18 seconds prior to initiation of ullage, we got no thrust.

We did not perform the burn at that time because of the lack of ullage but did perform it on the next revolution after rechecking and reloading the DAP.

We don't understand exactly what happened, but the numbers were loaded into R2 to enable all four quads, and for some reason it just didn't get in. We had two other occasions in which we suspected some anomaly with entries into the DAP or into the DSKY for configuration. One occasion was on the last night when we powered the DAP down by inserting a zero in the first digit of register 1 of NOUN 46 for no DAP, and then after the DAP load of VERB 46 to enable no DAP. Apparently, VERB 46 which was confirmed by all three of us was not accepted by the DAP,

SCOTT

and the DAP continued to run. We were notified by the ground that it was on and did another VERB 46 which did, in fact, put it to sleep.

4.6.2 Preparation for SPS Burn 6 (Retrograde)

SCOTT

It was a minimum impulse burn of 1.4-second and 38.8 ft/sec which was very close to the minimum impulse type burn that you would expect during a CSM rendezvous. It was a good solid boot in the back, and it was off about as fast as it came on. The residuals were relatively small — 1.2 in X, minus 0.3 in Y, and minus 0.3 in Z. DELTA-V_c was in minus 13.0. as minus 13.0.

4.6.4 IMU Realign

SCOTT

The alignment on day number 6 was nominal, and we prepared for burn number 6 which was a minimum impulse burn. At the time, we were attempting to save propellant by utilizing various configurations of the SCS and the DAP. In the process, it was

SCOTT

necessary to reload quads and the DAP for ATTITUDE HOLD in maneuvering and different quad configurations for ullage.

4.6.6 High Gain Antenna Tracking

SCOTT

Another apparent anomaly occured after the conclusion of the tracking of the ascent stage in the last day. The P20 that was used to track the ascent stage was turned off with VERB 56, which should have stopped the W matrix. Approximately 3 hours later, we got a master alarm on the computer which turned out to be a W matrix overflow and indicated that W matrix had been running for the whole time or since we had concluded the tracking. Another VERB 56 turned the W matrix off, and we had no further problem with it that night.

4.6.6 High Gain Antenna Tracking

SCHWEICKART

The CSM high gain antenna test was run at approximately 193 hours into the mission and was modified quite extensively from what we had in the procedures book.

SCHWEICKART We were to establish a PTC mode of attitude control prior to coming up on Carnarvon AOS; the high gain antenna was to be switched on, manually slewed to a pitch of minus 45 and a yaw of plus 90, and then placed in the reacquire mode. The behavior of the antenna was to be observed at Carnarvon LOS and again at Hawaii AOS and LOS. We were supposed to observe the signal strength and, more particularly, the behavior of the antenna as regards the reacquisition mode. We got started late in setting up the PTC, and as a result, we were well into the Carnarvon pass by the time we had everything configured. This apparently did not effect the test in any way as there was no observation to be made at Carnarvon AOS. When we first locked on at Carnarvon after having things set up, the antenna slewed from the REACQ angles to a yaw of approximately 360 and a pitch of minus 60. As we passed over Carnarvon and proceeded

[redacted]

SCHWEICKART with the barbecue mode, those angles changed very gradually from 360 to 270 in yaw and from minus 60 to plus 30 in pitch with essentially constant signal strength well up on the upper end of the meter. At Carnarvon LOS, the yaw angle jumped from 270 to 235 and the pitch angle from plus 30 to plus 45. This happened just after the S-band became noisy and the signal strength dropped down near zero. There appeared to be no tendency for the antenna to return to the REACQ angles that had been set in. After arriving at these angles of 235 and plus 45, the antenna stayed there with no drift whatever until we began to pick up Hawaii. On the first sign of signal strength at Hawaii, the antenna appeared to slew right back to the REACQ angles. However, at just about the time that it arrived at the REACQ angles, there was enough signal strength, and it went right past the REACQ angles and locked on to Hawaii.

[redacted]

SCHWEICKART — The antenna tracked Hawaii smoothly until approximately 1 minute and 15 seconds prior to the predicted Hawaii LOS, at which time it broke lock on Hawaii and slewed immediately to the REACQ angles. Our assumption at the time was that the reason we broke lock 1 minute and 15 seconds early was because the PTC had taken us into such an attitude that the spacecraft was between Hawaii and the high gain antenna. I am sure that this can be verified by the downlink data. In summary, it appeared to us as though the antenna worked properly at Hawaii LOS but not at Carnarvon.

4.6.8 Necessity of Additional IMU Alignments

SCOTT — The normal alignments, P51 and P52, were performed by using the standard checklist. P51 took an average of approximately 10 minutes, depending on the availability of stars. Once stars were available, it took little time to identify two stars to make the P51. P52 took approximately

SCOTT

3 to 4 minutes, again depending on the availability of stars. If the spacecraft was in a position where stars were available, it took 3 to 4 minutes. Our standard technique to verify the alignment was to proceed on the fine align check and either allow auto optics to select a third star or manually to insert a third star and have auto optics drive to confirm that the third star was, in fact, selected properly. Prior to each major maneuver, we performed an attitude check relative to the stars by calling VERB 16, NOUN 91, positioning the optics manually on the PAD star that had been passed from the ground, and comparing shaft and trunnion with the PAD values. Most of the time, these values were within 2 to 3 degrees. We performed a P52 by using the celestial body vector option on Jupiter, and auto optics performed as advertised once we got the proper vectors loaded into the NOUN 88 value. The tables that we carried onboard required inter-

SCOTT polation to get the proper one-half unit vectors to load NOUN 88.

It was noted during the process of taking marks that in using auto optics, NOUN 88 must be loaded prior to the auto optics driving on the mark. Subsequent to the mark, the NOUN 88 values have been written over, are no longer available, and have to be reloaded. A recommendation is that the subsequent programs retain the NOUN 88 preload prior to the auto optics in drive.

In marking on the planet, which in this case was Jupiter, it was noted that Jupiter filled the inside of the center of the reticle, which made it slightly more difficult to position the planet in the exact center. The star-angle difference between Jupiter and a star was 0.04. Normally, the star-angle differences had been working out to 0.01 or less. This could be because of the interpolation of the unit vectors or the lack of accuracy

SCOTT in positioning Jupiter in the center of reticle.

The values for the half-unit vectors used for Jupiter were minus 0.49425, minus 0.02730, and plus 0.00310. The GET was 144:16:43.

At approximately 187 hours, we performed a P53 and P54 by using the COAS to align the platform. The calibration of the COAS was from the rendezvous day, and the COAS had been removed from the left window several times. When the COAS was in the right window, it didn't appear to be aligned properly. P53 was performed according to the checklist by using the values 359.74 and 57.167 for the COAS calibration. With the use of stars number 11 and number 12, the star-angle difference was 0.07. The technique was to position the star relatively close to the center of the COAS reticle and allow it to drift through while the right hand was placed on the inner button. The inner button was pressed when the star

SCOTT

was in the center of the reticle, which was a relatively easy task. P54 was performed according to the checklist using stars number 11 and 15. The star-angle difference was 0.03; and the gyro torquing angles were minus 0.080, minus 0.13, and plus 0.183. To evaluate the accuracy of the alignment, the platform was aligned by using P52 with the sextant. The star-angle difference there was 0.01; and the gyro torquing angles were plus 0.073, plus 0.060, and minus 0.084, which indicated that the COAS had done a good job in aligning the platform. This occurred about 4-1/2 minutes after the COAS/P54. A quick check was made to determine the drift rates with a sextant alignment; the star-angle difference of 0.01 produced torquing angles of plus 0.003, minus 0.025, and plus 0.002 after 5 minutes. To compare the telescope capabilities, we performed an alignment with the telescope which was concluded about 6 min-

~~CONFIDENTIAL~~

SCOTT

utes later and which produced a star-angle difference of 0.05. This was primarily because the sun was coming up and the second star was Menkent which faded at about the time the mark was made. It was difficult to place Menkent in the center of the telescope, which wasn't really a fair trial of this telescope; but the gyro torquing angles were minus 0.070, plus 0.169, and minus 0.133. I performed another telescope alignment approximately 1 hour later after doing a P52 of the sextant and got a star-angle difference of 0.02 and gyro torquing angles of 0.000, minus 0.059, and minus 0.003. This was at 188:39:00, which indicates that the telescope does have a good capability for accurate alignments (probably better than the COAS as indicated by the gyro torquing angles). This second telescope alignment was performed after torquing the platform from a sextant alignment to ensure that we had a good platform right at the beginning. A back-

~~CONFIDENTIAL~~

SCOTT

up GDC alignment was performed with the IMU powered up to evaluate the procedures and capability of utilizing the telescope in a fixed position to align the GDC; this occurred at 197:45:00. The South Star set was used, and the ground had provided some IMU angles for comparison after the completion of the GDC alignment and maneuvered to the 180/180/0 attitude. The alignment angles put into the attitude set dials prior to the GDC align were 246, 315, and 051. The spacecraft was aligned on the stars Atria and Acrux, the GDC aligned button was pushed, and then the spacecraft was maneuvered to 180/180/0. The following values were read out of VERB 6 NOUN 20 on the DSKY to get an IMU comparison: 180.36, 236.10, and 359.78. Had the GDC align been perfect, these values should have been 180.4, 237.5, and 000.5, which indicated that the GDC alignment was very close. It might be noted that the IMU and the GDC were not aligned at this point since we were utilizing a

SCOTT

previously defined REFSMMAT in the IMU. The technique used to perform this alignment was somewhat different from the technique described in the checklist primarily because the checklist technique does not utilize the reticle in the telescope as it was designed for backup alignments. The checklist calls for a telescope shaft of 180, trunnion of 7.5, and the utilization of the 50-degree mark on the telescope reticle. The telescope reticle has a point at zero degrees which is designed to enable the user to place a star in the center of a small cross at that point. At the 50-degree point on the reticle, there is no such mark and no indicator to provide a vertical alignment along the vertical reticle line. To use the small cross at the zero-degree point, it is necessary to leave the telescope shaft at zero and move the trunnion to minus 7.5 or 82.5 on a DSKY read-out. This not only takes less time in movement of the

SCOTT telescope reticle but also provides a better point on the reticle to align a star to. Because of the drift in the shaft and trunnion, it was necessary to have another crewmember maintain the telescope shaft and trunnion at the proper values during the maneuvering of the spacecraft in GDC align.

4.6.9 Landmark Tracking

SCHWEICKART To point the S065 cameras directly vertical with an orbit rate drive in the spacecraft, we utilized the pitch orbit rate maneuver technique as described in the checklist. The pads that we had set up preflight did not provide us with the numbers necessary to load into the CMC for the ORB rate drive. Other than that, the pad was adequate. Again, the numbers on the charts that we carried on board had to be interpolated for the rate drives that we experienced in each particular orbit. The loading of the computer went according to the checklist with no problems, and it was noted that the ORB rate drive would start

SCOTT

from 5 to 20 seconds after the ENTER button was pressed to initiate the drive because of the position of the spacecraft within the deadband at the time. The drive was smooth and very few jet firings were observed. The rates could be observed on the pitch needle and they were exactly the same as or, as nearly as we could determine, comparable to the values that were preset into the DAP.

4.6.9 Landmark Tracking

We performed landmark tracking a number of times. Overall, it proved to be successful; however, it was significantly more difficult in earth orbit than it will be in lunar orbit, primarly because of the rates at which the spacecraft goes across the ground. Our general technique was the yaw roll procedure with P22 and several alterations to P22 to enable it to perform in earth orbit. The first comment might be made on the landmark tracking update form. We found that, in addition

McDIVITT

to the time at which this landmark would come over the horizon, we needed the time of closest approach to enable the crewmen flying the spacecraft to position the spacecraft properly for the pass over the site.

We used the standard in-plane alignment for all the landmark tracking, even though the spacecraft ended up being pointed perpendicular to the plane of the orbit. After we received the pad messages, we determined whether the landmarks were going to be to the left of the track or the right of the track. I'll discuss only one direction. If the landmark were going to be to the left of the track, I would align one of the balls with the orbit rate torquing on it, yaw the spacecraft around to the left, and position the X-axis so that I was just outside of the red circle on the FDAI which indicated gimbal lock. Then I would bank the spacecraft so that the telescope would be

McDIVITT looking in the direction in which the spacecraft was actually traveling. It took constant looking after the spacecraft because the spacecraft tended to trim back into the plane of the orbit. Therefore, after I had maneuvered around into a position where I was pitched down approximately 20 degrees, I would be banked to the left approximately 60 degrees. I would hold the spacecraft in this attitude until Dave said that the optics had tracked up to the horizon and then started tracking down on the part of the land mass that he could actually see.

As Dave had mentioned earlier, the PAD was changed from the initial PAD times, when we received only the time when the landmark would appear on the horizon, to include the time when it would be directly underneath us or when we would have our point of closest approach. I set the digital event time up so that it counted down to this moment of closest approach and then called the times to Dave and

McDIVITT tried to establish a slow roll rate so that, when we arrived at the time of closest approach, the spacecraft would be essentially wing's level pointed directly out of plane, to the left and pitched down approximately 20 degrees. As the target passed underneath us, I would continue to roll around so that we could track it out the rear. The roll rate had to change as the target approached us when it was out near the horizon. It was very low, and as it passed underneath us, it required about 0.6 deg/sec if we had the time of closest approach correct and had maneuvered properly. The time of closest approach was very critical, and if we were off by approximately 30 seconds, so that I still had the spacecraft rolled to the left waiting for the time of closest approach and the target actually passed underneath us, it required a very high rate (almost more than 1 deg/sec) to keep the optics off the stops. It took a little bit of coordination between the

McDIVITT man in the optics and the man guiding the spacecraft to make sure that the roll rates were such that the optics drive modes did not have to be continually changed. It was possible to make two landmarks, and I think we could have made three landmarks across the dayside pass. It required approximately 10 minutes to do one landmark tracking — approximately 7 minutes prior to the time of the landmark and approximately 3 minutes after the point of closest approach to get set up for the next one. I did all of these landmark trackings with only six jets operating, two for pitch, two for yaw, and two for roll. Even though I had only two for roll, I still had plenty of roll control. I do believe that some of the attitude excursions that occurred in pitch and yaw were the result of firing only one jet in roll, because as the c.g. moved back and forth, we were contributing some pitch or yaw by firing the roll thrusters.

McDIVITT I did not have any trouble at all establishing the roll rates and maintaining the ones that I wanted with only one thruster firing in each direction. I used minimum impulse throughout the entire time. In placing the spacecraft out of plane, it was necessary for us to pitch down rather than pitch up because some of the landmarks were fairly close to track; but we did pick up some landmarks as far out as 78 miles, I believe. We were still able to handle landmarks directly underneath us and out to a range of approximately 80 miles by pitching the spacecraft down 20 degrees. We never seemed to have any problem with the landmarks being too far out. I think that if they go out at distances greater than that, it may be necessary to pitch up above the gimbal-lock point rather than down below it.

SCOTT The program flow worked as advertised with two exceptions. In one exception,

SCOTT

we found that we had a 121 alarm which indicated that the roll rate was too high in that the ICDU's were allowed only 0.6 deg/sec. We disabled that by going into erasable and found that the state vector was not being updated properly because of the lack of a proper W-matrix, since the programs had not been set up to do the landmark tracking preflight. Therefore, by going into erasable with the W-matrix load, we were able to provide ourselves with the proper W-matrix to update based on landmark tracking. The P22 AUTO optics worked very well; however, it never seemed to point the optics closer than approximately 30 miles of the landmark. Tracking was relatively easy when the spacecraft roll rate was proper. The resolve medium control mode was used, and the sextant was used after acquisition with the telescope. The desirability of having at least 15 seconds between marks was difficult to achieve because of the short duration of the pass where marks could

SCOTT

be made with a sextant. Normally, there was only 45 seconds to a minute during which the landmark was properly identified and marks could be made. Therefore, to get five marks on a known landmark, the time duration between marks will probably have to be shorter. The maps seemed to work well, except for earth orbit where the high rates and rapid approach to the target become a significant factor. It is apparent that we need an acquisition or run-on map of a larger ground coverage to enable us to identify points prior to reaching the landmark.

Another major problem throughout the landmark exercises was the amount of cloud cover that we had this time of the year. Not only was it difficult to identify the landmark, but sometimes we just couldn't find it at all. If the day had been clear, the probability of identifying the landmark earlier and providing a longer pass would have been much higher;

SCOTT and I am sure that the tracking would have worked much better. On the first few landmark-tracking exercises, we still had the telescope problem; and after switching out of AUTO optics, the telescope hung up and the manual tracking with the telescope was impossible, although the sextant was still available and worked all right. However, it was difficult to acquire the target with the small sextant field of view. The final procedure that the ground came up with for evaluating the state vector updates seemed to work rather well; and it might be considered for future use in evaluating landmark tracking. The procedure was to update a good state vector in the LM state vector storage, to use the old degraded state vector in the command module storage and update that, and then compare the two with the VERB 83. There were eight separate landmark exercises during the flight with a different target for each.

4.6.15 Performance and Post Burn Parameters

SCOTT

SPS 7 was another nominal type burn. It was 25 seconds long, which was considerably longer than the OT. It was a good, smooth burn with constant acceleration and no chugs and with residuals of minus 1.3, plus 1.0, and minus 0.2. DELTA-V_c was minus 17.5. During the period for SPS 6 and 7, we had no further difficulty with the optics. All the alignments were nominal.

One comment which might be made relative to both SPS 6 and 7 is that everything should be securely tied down in the spacecraft prior to a burn of this acceleration. The burn feels like a much higher level than 1g because of the previous zero g state. Also, it is significantly greater than the docked maneuvers in which the masses are much greater. At this time, the vehicle weighed about 27 000 pounds.

4.6.16 Additional Experiments or DTO's

SCHWEICKART The S065 experiment worked very well. The mounting of the Hasselblads was precise and easy to perform. The electric Hasselblads worked in sequence as advertised. The only anomaly incurred throughout the S065 procedures was that, on the first run, the platform alignment was retrograde because of the previous burn and we had the complement of the values loaded in the DAP for the ORB rate drive which started driving the wrong way. However, this was corrected on subsequent passes. The exact times of each picture are recorded in the Procedures Book under S065.

4.6.16 Additional Experiments or DTO'S

McDIVITT The ground sent us a set of gimbal angles to fly to at the time of appearance of the Pegasus satellite. The two times that we did this, we were able to see the other satellite go by right on time. Both times we used the diastemitor in the left-hand window because it provided an 8-power magnification. The field of view is only

McDIVITT about 2 degrees; in each case, the target went right through the 2-degree circle on the diastemitor, and we were able to identify it without any problem at all. It was also visible through the right-hand window with the naked eye on both of these occasions. I think that the really significant thing is that in each case the target was exactly where it was supposed to be and was going in the direction it was supposed to be at exactly the time it was supposed to be there. It gave you a really warm feeling that everybody knew where everybody was.

SCHWEICKART At 222 hours, we had the opportunity to track the ascent stage with the sextant based on a state vector update from the ground. At this time, the ascent stage was in an orbit 3742 by 128. The ground passed in an initial roll angle for the spacecraft, and P20 was utilized with an automatic maneuver according to the checklist to position the spacecraft in pitch

SCHWEICKART

and yaw for initial acquisition. The W-matrix as utilized during the rendezvous was used. The initial range and time passed by the ground for acquisition was approximately 1000 miles at 222:35:30. The closest approach was estimated to be 652 miles at an R dot of 32 ft/sec. The platform was aligned at 222:19:30, and the spacecraft was maneuvered and AUTO optics was initiated shortly thereafter. The first sighting occurred at 222:25:55, approximately 10 minutes prior to 1000-nautical-mile range. We have not received the data yet as to how far that was. It was a very small illuminated dot which appeared occasionally from about half the distance out on the right-hand line of the sextant reticle. This first sighting was verified by both the CMP and the CDR. The image did not remain visible in the sextant long enough to initiate a series of marks until 222:39:40. At this time, it became clearly visible as a point source of light. Marks were made for 6 minutes at 1-minute inter-

SCHWEICKART vals (a total of 6 marks); and at 222:45:40, the target disappeared as it went below the horizon. It might be mentioned that the sextant does have two lines of sight, and we look through both of them simultaneously. This caused the double image of clouds, although there was only a single image of the target. The target appeared periodically for several seconds until 222:51:43, which was the last visual sighting. However, during this period, it was not visible long enough to switch to a manual drive and to take an accurate mark. The AUTO optics tracked very well throughout the exercise. The initial pointing was to within 0.2 degree, and throughout the exercise, AUTO optics would point to within 0.2 to 0.3 degree of the target. The mark incorporation updated the state vector so that the DAP maneuvered the spacecraft sharply to a new attitude and continued a rate drive adequate to maintain track on the target. These pulses

SCHWEICKART were approximately 0.5 deg/sec in rates and much sharper than any of the P20 maneuvers during the rendezvous, which were all low rate and very smooth. The entire exercise was a rather impressive demonstration of the computer optics DAP capability to track a target based on ground-provided state vectors, and again it gave us confidence that everybody knew where everybody else was. The W-matrix was checked just to see what its value was approximately an hour later at 223:30. At that time, we did not know that it was still running. However, the values were plus 00328 and plus 00087. This size is probably because the W-matrix apparently had been running from the time that we terminated the exercise.

4.6.20 Final Stowage

McDIVITT For reentry, we stowed McDivitt's and Scott's suits in the L-shaped bag underneath the center seat. We didn't put anything in the top compartment. We took

McDIVITT Schweickart's suit and laid it across the LEB, right next to the lithium hydroxide canisters, and tied it down (with two of the helmets inside of the suit and one of the helmets underneath the legs) with the PBI cord that we had available. We then used the sleep restrainer underneath the right-hand couch for stowing the temporary stowage bags, which were full of garbage. The rest of the spacecraft was stowed pretty much as it was during launch. The lithium hydroxide canister from the LM was in A-1, and the LM data that we brought back with us were in A-8. We had filled the first food compartment (which, I believe, is B-1) with garbage. The two left-hand-side food compartments were full of loose food that we hadn't eaten. We took some things out of A-5 (rope, heel restraints, and things like that) and stowed the tools, the tool kit, and some of the odds and ends that we had left over in A-5. We sort of used it as

McDIVITT a last place to put things. We ended up with the flight plan in the L-shaped bag because we didn't have any other place to put it.

Okay, to summarize, the stowage for re-entry was nominal except for where we put the suits, the helmets, and the data that we brought back from the LM.

4.6.21 Systems Verification

SCHWEICKART Starting with El-1, vehicle PREP, we followed the checklist all the way. The only places that we deviated from it were those things which were updated by CAPCOMM earlier in the morning concerning the configuration of the command module rings. They wanted RING 1 on MAIN A, RING 2 on MAIN B, and the A&C roll on MAIN B. The SPS heaters engaging circuit breakers MAIN A and B open because of the problem we had had with the PUG system. There were a few other relatively minor things such as a change in the DAP; but aside from those things, which were called up

SCHWEICKART as updates to the flight plan, we went through the checklist as advertised. We initiated the cabin cold soak, as I recall, about 3 hours before the deorbit ignition. Up until that time, we had been running with the cabin fans off, and the cabin temperature was indicating close to 68 or 67. Then we turned the fan on, and the true cabin temperature which was indicated to be close to 72 or 73. As the cold soak progressed, I think just before the deorbit burn, we were back down around 67 or 66 degrees in the cabin. At that time, it was an honest temperature. The only thing that surprised us was that, when just prior to the final preparations I looked at the waste water quantity, it was down to 55 percent. I called it to Dave's and Jim's attention, too. Then we realized that it was going into the secondary water boiler. We were boiling because of the cold soak. That was something which I

SCHWEICKART had not really thought about ahead of time, the waste quantity is called out to be 90 percent, or greater than 85 percent, depending on where you look on the checklist; and there we were, sitting between 50 and 55 percent at the time of the deorbit burn. Therefore, that was a bit of a surprise. Aside from that, the systems verifications went right down the line.

McDIVITT I guess I should have summarized before we started discussing reentry just where we were and how we started our configuration. On the night before the retro, we had done most of our final stowage. We had placed the suits and worked out the whole stowage system so that, when we got up in the morning, we had very little to do. We had the suits tied down and stowed away.

We awoke at approximately 233:30 for a retrofire that was to take place at 240:30. We had 7 hours of time to pre-

McDIVITT pare for the deorbit. We had plenty of time and were always 2 or 3 hours ahead of any sort of a timeline checklist. We worked our way down to the T minus 1 hour point at about 3 hours prior to the actual retro time.

SCHWEICKART I'd like to go back very briefly to systems verification. I noticed in my checklist that there were a couple of things that did not follow the checklist. We added a few steps under the Systems Checks in the vehicle PREP. One was to attach the X-X strut lockout lanyards so that Dave could unlock the X-X struts before splashdown while on the main chute. That was not in the checklist. Also, there was nothing called out to don the Mae West, and we penciled that in. We also penciled in to check the Y-Y strut to make sure that it was locked. That wasn't in the checklist. Also, even though we carried heel restraints, there was nothing in the checklist which called

SCHWEICKART out donning the heel restraints, so we wrote that in.

SCOTT Two other things that were not in the checklist were verification of the hatch configuration relative to the pump handle being in neutral, and ensuring that the shear pin and the counter balance are installed.

SCHWEICKART On the EPS checks, the DC volt-amperage check, it turned out that BAT B was below what was called out in the checklist. The checklist called out 34 to 38 and less than 3 amps. A check of the two BAT BUSES and BAT C indicated that BAT BUS B was down at 33.8, which really wasn't surprising. I think that the checklist is probably in error there. We ought to have more tolerance on the low end.

When we made the command module RCS checks, the helium pressure limit (checklist was 4000 to 4450) system 1 read 3920 and number 2 read 3810. I have

SCHWEICKART a feeling again that the system was probably okay. It was just a little bit of overoptimism on the part of the checklist as to what the lower limit ought to be. We were also low after pressurization by just about the same DELTA that we were off before activating the system.

SCOTT After the CM RCS pressurization, the helium pressure was 3225 in CM 1 and 3215 in CM 2, whereas the checklist called 3300 to 3750.

SCHWEICKART On the EMS deorbit check, I had a note here that the scroll was not tracing during the test. Jim will comment more on that. In regard to the caution and warning system operational check that calls for the caution and warning power to be turned off and then to verify that you have a caution and warning power light on, the caution and warning light did not come on. Again, I don't know whether this was an anomaly. It never

SCHWEICKART did come on all through the flight when the caution and warning power was turned off. In the simulator, it comes on; and my understanding of the system was that it should have. Aside from those comments, everything followed the checklist right down the line.

4.6.22 Final Entry Preparations

SCOTT The power-up on the platform on the first alignment was performed at 235 or in the dark period beginning at 235:18. We tried to allow three nightsides to make sure that we had the platform aligned properly. We had a good check on our attitude because we had problems with the telescope, and we wanted to ensure that we could do a backup alignment of some sort if the telescope didn't work when we powered it up on entry morning.

The first alignment was done to a nominal at a rough deorbit burn time that we'd gotten the day before in order to get the platform in plane and do a fine align on

SCOTT the first available nightside pass. The nominal time of T align was 240:30:08. The time of the first alignment, fine align, was 235:34. Then, on the next nightside pass, I did an alignment to the desired REFSMMAT that had been sent up from the ground; and that was at 238:31:30. Then we maneuvered to the burn attitude to get a star check at the attitude and run through the complete spacecraft alignment checks to ensure that the spacecraft was at the proper attitude one revolution prior to the deorbit burn. The last alignment was performed at 237:05:30; and we maneuvered to the burn attitude. The star for the deorbit burn was Sirius. It was about 2 degrees from the center of the sextant, and the spacecraft was off about a degree. It looked pretty good, and we got the ground update on the DSKY. We were sure that we were at the proper attitude at more than a full revolution before the deorbit.

SCOTT The alignments on the last day worked very well. The telescope did not hang up at all, and everything seemed to be working nominally. There was a slight bit of slope in the deadband in the center of the sextant, which had been occurring the last several days, but it was not enough to prevent getting a good mark. The spacecraft had just a little bit of rate to put you on the edge of the deadband.

McDIVITT One thing that is worthy of note here has been commented on by previous crews: when you arm the command module RCS propellant system, you can hear the fluids flowing through the line to the thrusters, and it's quite obvious that you've armed at least one of the systems. By checking the gages, you can tell whether you've armed one or both of them. In the command module RCS checkout, it was very obvious that we were firing command module RCS engines rather than

McDIVITT service module RCS engines. When we went back to service module, you could be convinced quite easily that you had switched back to the service module.

SCOTT As a matter of fact, you could hear the transfer click when you threw it from command module to service module.

I'd like to go back and correct the alignment times of the platform. The initial P51, P52 to the nominal was 235:34:00. We did a realign to that nominal initial alignment at 238:31:30. Then we received the desired REFSMMAT from the ground and did the initial P52 to the desired REFSMMAT at 237:05:30. On the nightside when we did the star check, we did a final realign P52 to the desired REFSMMAT at approximately 238:28. At that point, we maneuvered directly to the burn attitude and did the star check. All four alignments were with a star angle difference of zero.

4.6.23 CM RCS Preheat

SCOTT We found that there was no need to preheat the CM RCS injectors because of the temperatures that existed at the time we checked them. All of them were just about off-scale high. The temperatures had been almost off-scale high throughout the flight for all six, so it never did appear that we'd ever need to preheat the CM RCS.

McDIVITT When we performed the first EMS test, we did the DELTA-V test, and it worked alright. Everything on the EMS had been working fine up until this point. As a matter of fact, I thought it did an outstanding job. We had no glitches whatsoever in it. However, when we did the scroll test (we had many ground checkout patterns in the spacecraft scroll that were still available to us), I just moved to the first scroll pattern and we did an EMS check; and it checked perfectly. Then we moved the thing down to the first

McDIVITT flight check pattern. It was supposed to be scribing across the top of the scroll. All of a sudden, the line disappeared and went from test pattern 3 or 4, whatever it was, to the first flight test pattern. It didn't scribe most of the way down. Therefore, I thought I'd better do another check. I put in one of the flight test patterns and did another check, and it scribed partially during this particular time. It alerted us to the fact that we may not have an EMS during the reentry. When we finished that test, we ran it down to the B-zero for reentry, which was 25996. During its trip down there, it didn't scribe across the top of the scroll either. Therefore, I pretty much concluded that the EMS as an entry monitoring device was going to be semiuseless. It looked like the drive and everything on the tape worked properly, and I could expect the scroll to scribe across. I just couldn't expect the stylus to scrape

McDIVITT the emulsion off the tape, which meant that by roughly looking at the g meter and then trying to correlate it with the little black mark on the bottom of the EMS, I would be able to approximate myself on the scroll. It was very crude, and I found that during reentry this is indeed what happened.

As we started the reentry, the EMS failed to scribe. To the best of my knowledge, it did not scribe at any time during the entry until after the drogues came out, at which time the vibrations caused it to start scribing across the face of the EMS. At no time during the useful portion of the flight did the scribe ever scribe. The range counted down properly and seemed to agree with the DSKY at all times.

SCOTT In general, the EMS DELTA-V counter worked very well throughout the flight. On the final day, we ran two sets of DELTA-V tests — both the drift test and the standard DELTA-V test. On the first one, SCOTT we had 0.3 foot per second and 100 seconds on the drift. The DELTA-V test counted down to minus 20.5. The second one was 0.2 foot per second and 100 seconds and minus 20.5 or 20.7.

4.6.24 Maneuvering to Deorbit Attitude

SCOTT We maneuvered to deorbit attitude manually to 180, 180, and 0. Then I did a VERB 49 to that particular position to get the thing there for the star check. We did these tasks quickly. Then we called P40 to make sure that it was calling for the same angles, and it was within tenths of degrees.

As we went across that nightside pass, prior to the retrofire, I knew we were going to retrofire just a few minutes into the sunlight. This meant that the horizon probably was going to be in that never-never land where there really isn't anything that you can see. Sure enough, as we came across the horizon 1-1/2 hours before retro, I made all of the retro

SCOTT attitude checks that we were supposed to do - the T minus 12, 8, and 5. You could see the T minus 12 check where the horizon is supposed to be — essentially at zero, zero, zero. I still had the night horizon out there; but by the time we got down to around 8 minutes, the sun was beginning to shine through the left-hand side window — window number 1, and the horizon was beginning to disappear. As we approached the retrofire time, there was absolutely no horizon. So, we were unable to make any horizon checks except that we had turned all the lights down in the spacecraft 1-1/2 hours before the retro and checked the attitudes as we went through; they looked pretty good. We knew we were within a few degrees; certainly good enough to get us out of orbit. But it just happened to be at that one time when it was impossible to make all those nifty little checks that we had worked out in the data priority meetings.

McDIVITT Dave makes a point here that he could see the horizon through the center hatch window better than I could through the rendezvous window. However, we did not have any lines scribed on the center hatch window. We would have had to go back and do a line scribing session on the horizon in the daylight, and we did not feel that we wanted to do that. But I had great confidence that we were in the deorbit attitude, which later proved to be correct.

4.6.25 SPS Deorbit Burn

McDIVITT The deorbit burn was a typical lightweight command and service module SPS burn. When it comes on, it hits you in the back like a sledge hammer. It was about 12 seconds long, and sure enough the thing counted right on down and shut off. The DELTA-V counters and the DSKY residuals were nominal. I will have Dave give you those. I think he has them written down.

SCOTT — The residuals at the end of the burn were in X, Y, and Z — 1.6, plus 1.1, and minus 2.3, respectively. Jim nulled them out to zero. The EMS DELTA-V counter was minus 18.2 at shutdown. The apogee and perigee were 240.0 by minus 2.0; the burn time was within one-half second of the predicted value.

SCHWEICKART — I have just one short comment on the deorbit burn. At TIG minus 30 seconds, we had received an update to go tape recorder to record HIGH BIT RATE in forward, first and then UP TELEMETRY command to RESET and back to NORMAL. Everything was already in configuration except for the telemetry bit rate switch which was in LOW. I moved that to HIGH and then hit the UP TELEMETRY to reset NORMAL, and the talkback stayed barber pole on the tape, which puzzled me for a few moments. However, I had to give it up because the burn was coming up, and we were counting down. The next time I looked back at it, SCHWEICKART after the burn, it was gray; and I just let it go and never asked. I was never sure whether there was a time delay which prevented it from going gray immediately or whether the ground had picked up the fact that the tape recorder did not start and sent up a command. I don't know exactly what happened there.

4.6.26 CM/SM Separation

McDIVITT We followed the checklist, and it was probably the best simulation we have ever had, as Dave said after we got down on the carrier. Everything went according to the checklist. There wasn't any problem. We yawed right to 45 degrees, got everything set up, and boomed off the service module which went off with a big bang. There wasn't any doubt about the fact that it was gone. We set the switches up single ring — number 1 on MAIN A, maneuvered back around to the zero yaw attitude, rolled over and pitched up to put the horizon on the window at the right spot (-32.5 degrees), and

McDIVITT

tracked around. That part of the checklist and that part of the maneuver went just the way it was supposed to go. I used single ring pulse, maintaining the -32.5 degree attitude line near the horizon until we got down near 0.05g. As we approached 0.05g I tightened up the control of the attitude and put the line right on the window as I was supposed to do. The attitude errors were down to practically zero at 0.05g. Dave points out that, as we went around, the G&N needles were driving us to a point that did indeed put the 32.5 degree line on the horizon and that we had a real good confirmation that the G&N was steering us in the proper attitudes through this portion of pre-reentry.

One thing that might be worth pointing out is that the single ring pulse is a real nice control system; it is snappy. You can really hear the thrusters banging, and it gives you real fine control of the spacecraft. It is not an over-control situation, but you do not have to wait

McDIVITT

there very long for it and it will bring you right where you want to go.

I guess we should point out that the command module RCS thrusters are much more audible than are the service module RCS thrusters. Sometimes I had difficulty telling whether or not the service module engines were firing, but I never had any trouble with the command module.

4.6.27 Passive Thermal Control

SCHWEICKART

The passive thermal control procedure described in the checklist was evaluated at the end of the flight with a number of different deadbands. It seemed to work very well. The roll rates were as indicated by the checklist, and the mode was smooth with very little jet activity. The roll rate was 0.1 deg/sec, and the initial deadband was 10 degrees. Subsequent to that, we changed the deadband to 20 degrees and 25 degrees. At two points during the procedure, we turned off the PTC. One point was when we initiated

SCHWEICKART POO at 221:05:00. It was turned off and reinitiated at 221:16:00 with a 20-degree deadband. Again, it was turned off at 221:18:30 and reinitiated at 221:21:30, and finally the PTC was terminated at 222:10:10. The sequence of establishing the PTC and loading the deadband was to follow checklist page 3-17, initiate the roll rate, and then go into ADDRESS 3255 and set the deadband in sequence without changing the CMC control mode after the initiation of the roll.

McDIVITT We did a couple of other little tracking experiments which were not very significant for our flight but, I think, might be significant for future flights.

4.7 Reentry

4.7.1 Reentry Parameters

SCOTT

The first thing that was noticeable as we approached the 0.05g point was the time of freefall out of VERB 82 of the computer. It was approximately 27 seconds early. The ground had given us 15 plus 27 for RET 0.05g. The TFF was almost constantly 27 seconds early, putting us there at 15, until we were approximately 2 minutes prior to the 0.05g time; then it started to converge. At the ground pass of RET 0.05g, which was then 15:25, we arrived within 3 seconds of the 0.05g indication on the DSKY. The comparison of the two was very good when we actually arrived at 0.05g. P61 worked properly and was properly loaded. NOUN 61 had the correct latitude and longitude when it was initially called. NOUN 60 was plus 0.81 on the g's, plus 25896 on the velocity, and minus 1.73 GAMMA. NOUN 63 was plus 12688 for the range and plus 25982 for the velocity

[redacted]

SCOTT The postburn number that the ground had passed up was 325.6, and the display at 0.2g was 311.2. So, we were well within the 100-nautical-mile tolerance. At that time, we accepted the G&N as go.

The next monitoring parameter on the G&N was the bank angle command which was supposed to occur between minus 6 and 0 miles down-range error. It did, in fact, occur exactly as it should. We got a minus 6 miles and then got a bank angle command immediately thereafter on the next cycle which was another indication that the G&N was in good shape.

McDIVITT When we handed over the control of the spacecraft to the CMC at 0.05g, it performed just the way I had seen it do in simulations; and just the way I had expected it to do. There wasn't a single anomaly.

The only interesting thing is that once you have handed over control to the CMC and it starts making maneuvers, you then lose some of your backup reentry schemes

[redacted]

McDIVITT which did not compare too well with the ground values, particularly in range. The ground had passed 1201 miles for the range to go. This was approximately 67 miles difference, which surprised me a little. I thought that COLOSSUS had been corrected to have the proper range to go value come up in that display. Then postburn update for the range to go was 1209, so it was still approximately 60 miles off.

P62 and P63 worked nominally; and, as I mentioned, we dropped into P64 within 3 seconds of the ground predicted time. The entry monitor system range started counting and was well within the tolerances of 40 miles plus or minus 10 seconds. As a matter of fact, I think it was something like 45 after we hit 0.05g, and Jim initialized it manually at the 0.05g time. The 0.2g display of NOUN 66, which was our down-range error comparison to accept or reject the G&N, was well within tolerance.

McDIVITT (for instance, the bank-bank techniques and so forth) because the G&N starts steering you one way and then another way. It is steering without regard to the bank in one direction -- bank in the other direction scheme. Because my EMS had failed to start scribing, I was sort of without a real good backup, except for the fact that I could read my g meter. I tried to take that value of g and run up the non-existent line from the scribe on the bottom to a point on the EMS and to extimate my range potential. This was very, very crude, especially when we were up at high ranges -- high range potentials (600 or 800 miles). It was almost impossible to tell within 200 miles what my range potential was; but, of course, it is not too critical up there. It became a little easier to use when I got down around 200 or 300 miles, because the difference between the lines is considerably greater. I could estimate probably within 100-mile range potential at this point; but, it was still a very, very

McDIVITT crude scheme. Once we were committed to the G&N (although we were all very well assured that the thing was operating properly), failure midstream would have been a very poor place to have one because our ranging capability was really crude.

4.7.3 Ionization

McDIVITT We could see the ionization sheet start at about 0.01g or so. It was nominal, and we took a picture of it on the way down.

4.7.4 Sounds, Sensations, and Observations

McDIVITT The Sounds, Sensations, and Observations were as I had expected. The spacecraft did not exhibit any really abnormal conditions on the way down. The rates ran about 1 deg/sec all the way down, even when we were doing some of the weird gyrations that the thing goes through when it banks from 80 degrees right to 80 degrees left; and it goes in a big arc instead of a roll. I could actually feel these

McDIVITT weird motions. At no time did I ever feel that the G&N was going to lose control of the thing, either in rate damping or in attitude control mode.

4.7.4 Sounds, Sensations and Observations

SCHWEICKART I recalled that I had a very distinct impression at drogue deploy of a pulse of hot smelly gas in the cabin. It was a very sharp onset, almost as if part of the exhaust gas had blown right into the cabin. I would guess that it was part of the thrusters from the apex cover or the motors themselves going off. But, it was a very distinct heat pulse; and it had a rather pungent odor to it. I noticed even at MAX g that, although it felt like about 8 or 10 g's, I could reach up and manipulate the S-band on the antenna switch. I was doing that all the way down; so I was aware by moving around that I was not really up at 8 or 10. But, as far as the way it felt on the body, it was up in the high numbers getting close to 10, as far as

SCHWEICKART I was concerned.

4.7.6 Attitude Control Mode

McDIVITT We flew all the way down in G&N attitude control mode. I had the rates scale set to 55. There was no problem.

4.7.8 Drogue Chute Deployment

McDIVITT When we got on down towards drogue chute time, everybody was estimating the drogue chute time. We had about a thousand different checks, and they all came out very well. There seems to be some discussion here among the three of us when we aren't on the tape about the significance of the steam pressure duct as an altimeter. It came out within about 17 seconds, which I personally feel is probably a pretty good check. There are a lot of other checks that I have on the left side which the other guys don't have. One is the way the g's are falling off; another is looking at the range to go off the EMS and also off the DSKY. I could tell roughly that I was getting to the point

McDIVITT where I should be getting the chutes out. I could not use these things as altimeters, but there is a leeway of a few minutes there. I think that one must be aware of the fact that he is getting down to the point where something should be done. The thing that has to be done is to place the ELS logic to ON and the ELS to AUTO, which then establishes another set of barostats that would also have to fail before one gets into trouble. So it seems like, in my opinion, the check was adequate in that it gave us the clue that we should arm up these systems. A couple of seconds either way does not seem to be that significant, but we will let the other people express their opinion here.

SCOTT In simulation, we had established a technique of correlation between the DSKY and the steam pressure gage to get a hack on the time at which the altimeter should come off the peg. Rather consistently in the simulations at 5000 ft/sec on the DSKY, you could expect to standby to watch

SCOTT

the steam pressure gage; and at 4000 ft/sec on the DSKY, it would come off the peg. This was an indication. I would normally call this to Rusty so he could be watching the steam pressure gage; and in simulations, it would be within several seconds of 4000 ft/sec indicated which normally was at approximately 65k. I think we may have been putting too much emphasis on this as a check, or else we have a bias somewhere or some uncertainty that we are not exactly sure of.

SCHWEICKART

About a week before the flight, we coordinated with EECOM to get the most accurate numbers that we could for the time from steam duct pressure increase, coming through 90k, to altimeter off the peg at 55k — also, to 40k and to drogue deploy. The times for our mission and entry parameters were 61 seconds to altimeter off the peg. As it turned out, in fact, when Dave gave me the mark from the DSKY as to when I should expect the steam pressure to begin rising, nothing happened on the steam

SCHWEICKART: pressure for another 15 or 20 seconds. When the steam pressure started to rise, it had been hovering down around the 0.12 to 0.13 area; as it started fluctuating and went up positively to 0.15, I started my watch. When my watch read about 44 seconds, Jim said the altimeter was coming off the peg. That figures out to about 16 to 17 seconds ahead of the time-early on the times that were given to us by the EECOM. Whether this is a random error or whether it is a bias in the computations that we are making is a question in our minds; and depending upon how you weigh this as a backup system, we either should give it up or try to pin it down a little more accurately.

SCOTT: The comparison of EMS range to go and DSKY range to go was pretty good all the way down to within about 30 miles.

McDIVITT: During the reentry, the maximum g-level that I saw was about 3.2 and typical of reentries. I guess, when we got up to

McDIVITT 0.2g, everybody felt like they had an elephant standing on their chest. Our sensations seemed to indicate to each of us that we had many more g's than what the g-meter said, but I believe this is typical of most reentries. During the reentry, we could see the ionization sheet start at approximately 0.01g; and it was considerably different from what I recalled it being in the Gemini mission. It was almost exclusively orange color; and it just varied in intensity, from what I could see of it. In the Gemini mission, the ionization had more red and green and other various colors. We took some pictures of it during reentry. The camera was started at approximately 0.02g and was still running after main-chute deployment, although we are not really sure if it took pictures all the way down. The drogue-chute deployment was performed automatically with the barometric sensors. The apex cover went off with a bang and the drogues came

McDIVITT out; they operated the way they should. There was considerable debris. It was my impression that the longer we were on drogue the more we oscillated, although the oscillations were not bad at all. It looked as though we had a DELTA angle between the centerline of the spacecraft and the centerline of the drogues that built up to probably plus or minus 20 or 30 degrees.

4.7.9 Main Chute Deployment

McDIVITT The mains were deployed automatically and were deployed properly. When the mains deployed, it looked as though we only had two chutes. The one on the left side came out, and we could see that it was one chute. The one on the right side looked as though it was just a single chute, and I am not sure where the third chute was. To me, it looked as though it was almost up inside of the chute on the right. When they came to the reef position when they started

McDIVITT filling with air, the third chute sort of magically came out of the second chute on the right side. We had a single chute on the left and two chutes very close together on the right in the reef condition. Then when they disreefed, they opened up; and we had the typical three-chute blossom. It looked very normal. Prior to the time we dumped our fuel, I noticed that there were a couple of the small squares torn out of the chute which was on the left-hand side at the time. I could notice that one small square was gone. Then after we dumped the propellant I noticed that the chute which was over my head then had three small panels torn out of it. I am not sure whether that was a result of the fuel dump or whether the chutes had rotated. I personally think that the chutes had rotated and I was looking at a different chute or a different part of the same chute that previously had been over my head. There was not any

CONFIDENTIAL

McDIVITT major damage to the chutes. As I said, I saw one small square panel out on one chute and three small square panels out on another one chute, or possibly the same one. Once the main chutes were out, the spacecraft stopped oscillating and rode down very smoothly. There is not much else to comment on the chutes.

SCHWEICKART I was on the right-hand side looking out the window at the deployment. I did not pay any particular attention to the drogues; but when the mains came out, I also had the impression that we had two at first. From my view on the right, it appeared that the third chute was obscured by the two outside chutes. It was up between them. Then, I had the same impression as Jim when they began to fill with air, before the disreefing. As the two outside chutes began to fill, I saw the third chute come out from between them. It was almost as though it were on longer shrouds than the two outside ones and was just sort of wedged

CONFIDENTIAL

SCHWEICKART — up between them so it could not be seen. I do not think there was any anomaly at all associated with it. I did not notice any holes in the chute, I was so happy to see those big things that I did not really get down to the nit-picking details.

SCOTT — At the time the G&N switched to NOUN-67 at the 1000-ft/sec point, relative velocity, our indicated latitude and longitude were plus 2326 and minus 6801; the desired latitude and longitude loaded into P61 was plus 2325 and minus 6800. The range to go at that time was minus 1.1 miles; so we had, at least by the DSKY, reasonable confidence that we were close to the landing point.

4.7.10 Communications

SCHWEICKART — For communications during the entry, they had recommended sticking with antenna C, as was called out on the checklist. Antenna C seemed to work pretty well except that we were beginning to lose

SCHWEICKART lock after the blackout was supposedly over. The signal strength was fluctuating around the half-way point, which is about the point where we began getting a significant amount of noise on the S-band; I switched back and forth through all four antennas, but none of them really seemed to lock up very strong. Antenna A and C seem to work the best, but none of them put the signal strength up to the upper end. We really did not get a good strong S-band lockup, as I recall, until after we were on the drogues. At about the time we got the drogues out, one of the antennas — and I must admit that I'm not sure which one it was — locked on good and strong, and I left it there. Dave gave his latitude and longitude on the S-band at that point, and we did get communications with Houston at that point.

SCOTT I called Houston once but got no answer; so I gave the latitude and longitude in the blind. Then, I called Houston one

SCOTT more time and got a response; so I gave them the latitude and longitude but received no reply. That was the last time I heard from Houston.

McDIVITT When we were doing the command module RCS fuel and oxidizer dump, we got the great big red cloud at the end of the dump. It went swirling up through the chutes very gracefully and then we went ahead and did the purge. We eliminated the big cloud. It's quite obvious when the dump finishes, because the noise from the thrusters firing just ceases very abruptly.

4.7.11 ECS

McDIVITT The cabin stayed cool on the way down. We picked up some odors I guess, slightly before we got on the water, the typical odor that you get from the burning heat-shield. We didn't install the vents because we didn't feel that we needed any. We never turned off the suit loop. We had it blowing all the time. We had the cabin fan on.

TABLE 4-I.- SUMMARY OF RENDEZVOUS MANEUVERS/SOLUTIONS

	MSFN	CSM	PGNS	LM AGS	Charts
SEP[a]	0, 0, +5.0				
Phasing	+0.9, 0, -90.7				
TPI$_0$	-20.2, +0.4, -1.5 A16.8, [illegible], U11.3	[b] +19.6, +0.6, -3.3	[c] -20.1, 0, +1.8 A18.5, L0.1, U8.2	[d] 20, 44	
Insertion	+43.1, 0. +0.8				
CSI[e]	[f] -39.3, +0.6, 0		[f] -40.0, 0, 0	(g)	[h] -40.7, 0, 0

[a]Preplanned.

[b]Elevation angle at final computation was 28.75 degrees.

[c]Elevation angle at final computation was 28.85 degrees.

[d]DELTA-V TPI, DELTA-V (TPI plus TPS).

[e]TPI time bias for CSI computation was plus 4:00 because of off-nominal initial conditions.

[f]DELTA-V_3 bias of plus 0.7 ft/sec was to inserted manually into NOUN 81 to account for shortening of burn time because of staging.

[g]Wrong apsidal crossing was employed in obtaining AGS solution.

[h]Because of confusion regarding the apsidal crossing, the minus 10-minute data were only estimates and final computation was done postflight.

CONFIDENTIAL

TABLE 4-I.- SUMMARY OF RENDEZVOUS MANEUVERS/SOLUTIONS - Concluded

	MSFN	CSM	PGNS	LM AGS	Charts
CDH	-38.2, -0.9, -15.1		[i] +1.3 -39.2, +0.1, -13.7	-40, 0, -14	-39.5, 0, -14.5
TPI	[j] +19.6, +0.1, -10.5 F22.3, R0, U0.3	[k] -19.5, -0.5, +9.0 F21.5, L0.6, D1.0 [l] -19.4, -0.0, +8.8	[m] +19.4, +0.4, -9.7 F21.7, R0.5, D0.3	[d] 20, 49	F22.0, D1.0
MCC_1		[n] -0.6, +0.5, -2.3 A1.2, R0.5, D20	-1.0, -0.3, +0.9 A1.4, L0.4, U0.1		A6.0, D0.0
MCC_2			+0.2, 0.9, -1.8 F1.8, L0.9, U0.0		F1.0, U0.0
TPF		29.3	27.8	29	

[d] DELTA-V TPI, DELTA-V (TPI plus TPF).

[i] Plus 1.3 DELTA-V_y was VERB 90 input to NOUN 81 which was not used.

[j] T_{ig} for MSFN update was 97:57:45.

[k] T_{ig} at final computation was 97:58:08.

[l] Solution based on LM T_{ig}.

[m] T_{ig} at final computation was 97:57:59.

[n] Solution obtained with no marks after TPI because of loss of LM tracking light.

5.0 LANDING AND RECOVERY

5.1 Touchdown Impact

McDIVITT — We came down, and I called off the altitudes as we approached zero. We hit, I guess, at approximately minus 100 feet, just as we were told we probably would.

5.3 Postlanding Checklist

McDIVITT — When we hit, we had a strong desire not to turn upside down; and we had our procedures sharply tuned. Rusty punched in two circuit breakers, I popped off the main chute release, and we stayed right side up. We went through the postlanding checklist without any difficulty.

5.4 Temperature and Humidity

McDIVITT — The temperature was fine. The humidity was good. The only thing I did not like was the smell which is never very pleasant.

5.5 Communications

McDIVITT — We established communications with the recovery forces while we were still on the chutes and had no problem with them.

SCHWEICKART One additional thing, before we leave the recovery, was the communications with the swimmers on the swimmer umbilical. There was no adequate communications with the swimmers. I think that all of us felt that we heard the swimmers trying to communicate with us, but it was unintelligible; and there was no evidence that the swimmers had any success in hearing either. They looked through the windows, and we were giving thumbs up, okays, and things of that kind with hand signals; but it didn't appear that we were getting out to them any better than they were getting in to us.

5.6 Spacecraft Status

McDIVITT Spacecraft status was good; there wasn't anything abnormal at all about it.

5.7 Battery Power

McDIVITT We had battery power.

5.8 Postlanding ECS

McDIVITT We activated the postlanding ECS system.

5.9 Ventilation

McDIVITT We got the ventilation going.

5.10 Seasickness

McDIVITT Nobody got seasick.

5.11 Internal Temperature

McDIVITT There were not any internal temperature changes.

5.12 Stable I

McDIVITT We stayed in stable I. We did not plan to put the float bags out until 10 minutes after we had landed so that the structure would cool down. By then, the swimmers were in the water and had the sea collar around it; and we decided not to deploy the uprighting system because we were liable to hit the swimmers with it.

5.13 Couch Position

McDIVITT We left the couches in the position that we had landed in except for the center couch. We lowered the seat pan of the center couch so that Dave could get down into the lower equipment bay.

5.14 Initial Sitting or Standing

McDIVITT — We found no problem with standing or sitting except that we were a lot heavier than we had been 30 or 40 minutes beforehand.

5.15 Internal Pressure

McDIVITT — I felt no internal pressures.

5.16 Recovery Operations

McDIVITT — Recovery operations were interesting, and they were documented on film and television tape for the whole world to see.

5.17 Grappling Hook Deployment

McDIVITT — We did not deploy the grappling hook.

5.18 Spacecraft Power Down and Procedures

McDIVITT — We powered the spacecraft down according to procedures.

SCHWEICKART — We did follow the checklist through to the point where one would power down for conservation of battery life in case he was going to be on the water for a long while. But, there was nothing in the

SCHWEICKART postlanding checklist which said anything about completely powering down when you leave the spacecraft to get out into the raft. As a result, we sort of played that one by ear and just pulled all the breakers off the flight and postlanding bus. Rather than leaving BAT BUS A and B tied to the flight and post-landing bus, we pulled those and decided that was the quickest way. But, it seems to me that it would be worth while to add another section to the postlanding checklist as a final power down or perhaps to add something in the training which says don't power down. For example, it was not immediately clear to me whether or not we should have left the VHF beacon on, although, in this particular case, they happened to request it off because they thought that it might have been interfering with the swimmer communications. But it was not clear whether or not we should have left that small amount of power on the flight and postlanding bus when we got out the door, or whether we should have pulled the breakers. So, by using our heads for what that was worth, we pulled the breakers and powered down completely.

5.19 Egress

McDIVITT: We egressed the spacecraft after inflating our Mae West, got in the liferaft, and were picked up by the helicopter in a Billy Pugh net. It was a little exciting at times, but I don't think we need to comment on that here. It is well documented.

5.20 Survival Equipment

McDIVITT: We did deploy the sea-dye marker, as we were supposed to, to get the telephone out; although I was never able to hear the swimmers talking to me except in a very, very low background.

5.21 Crew Pickup

SCHWEICKART: On the crew pickup, it was obvious that the helicopter crew was having considerably more trouble in positioning the

SCHWEICKART

Billy Pugh net than what we had seen in the Gulf during our training with a Coast Guard helicopter. It was not until 24 hours or more later that I remembered one difference in the geometry of the situation, which may or may not be significant; but it was the only thing I could think of which gave any possibility of a difference. By the way, the water was at least as rough or rougher in the Gulf than it was in the actual recovery; so, that was not a factor. But, in the Gulf, after we all got into the raft, we stood off from the spacecraft at the end of a line. When the helicopter picked us up in the Gulf, we were probably 30 feet, I guess, away from the command module; whereas in the actual recovery, we were still lashed to the flotation collar right up next to the spacecraft. I am sure that had some effect as far as downwash was concerned and the behavior or lateral motion of the Billy Pugh net. Now, whether that was the full answer, SCHWEICKART — I don't know; but that is the only thing I could think of that was an actual difference in the procedures used.

6.0 COMMAND MODULE SYSTEMS OPERATION

McDIVITT — If the behavior of the system was as we had expected, we won't discuss it at all.

6.1 Guidance and Navigation

SCOTT — To lump the G&N systems together at the beginning, it should be noted that we powered down and then powered up the IMU, the CMC, and the optics completely for the first 5 days. Then the IMU was powered down and powered up again for the last 5 days with the CMC and optics remaining in OPERATE each of the last 5 days. No problems were encountered at any time in the power-up or power-down procedure. The CMC was left powered up during the last 5 days to provide a constant power level for the fuel cells, and the optics were left powered up the last 5 days to prevent any further difficulty with the telescope drive.

6.1.2 Optical Subsystems

SCOTT — The eyepieces on both the telescope and the sextant tended to rotate and come off, and we had to retain them with tape through-

SCOTT out the flight.

In addition to the eye pieces, the focus was a problem and tended to change based on the vibrational rotation of the eyepieces. The tape was also necessary to maintain a constant focus.

The sextant reticle was not clear and it hadn't changed since the chamber. It was fuzzy and had a halo around the outside. We complained about this prior to the flight, and when we got in the flight, it was exactly as we had seen in the chamber. The reticle was fuzzy and not clear. There was no place to stow the optics covers for the eyepieces, and we just stowed them back in the optics stowage point. Occasionally, they would drift out and would have to be located again.

The star chart and VERB/NOUN list on the GNC panel worked very well once we got the VERB/NOUN list out. That took about 5 days because it was firmly in place for launch and there was no easy way of pulling

SCOTT

it out at zero g. The tolerances on the VERB/NOUN list or the size of the list must have been somewhat larger than the star charts because it was jammed in its mount, and we had to use a screwdriver to pry it out. The two star charts worked very well. They were easily installed and removed and were excellent aids in identifying the stars. The long eye-relief eyepieces worked well; however, they required far too many turns of the screws to mount, which would be a very difficult task in a hard suit if the eyepieces were needed. The quick disconnects on the eyepieces were excellent and were used anywhere from two to ten times a day. Each time that we completed an alignment, we would restow the two eyepieces to prevent damage, particularly when we were suiting and unsuiting or going through the tunnel.

The prism split and the telescope was most annoying throughout the flight, particularly during the rendezvous when

SCOTT the reflection from the sun or the earth was picked up. The target was obliterated completely from the center of the telescope, and it occurred on alignment probably about 20 to 30 percent of the time. This prism split appears as a band across the horizontal line of the telescope reticle and covers about one-third of the field of view. It varies from a light brown stripe to almost a complete white brilliant band, depending on the intensity of the reflection. The eye guards on the eyepieces were small and dark and come off easily. Once they came off, they were difficult to find; and it's recommended that some better method of attaching them be discovered. Towards the end of the flight, the sextant deadband appeared to grow in that, if the spacecraft rates were very low or almost zero during alignment, it was difficult to position the star in the exact center of the reticle because it would slide from one side of the deadband to the other. It was determined that with low spacecraft rates it was far easier

SCOTT

to mark on the star in the center of the sextant reticle.

For daylight alignments, it might be useful to provide a sextant field-of-view outline of stars relative to the navigation stars because it was noted that a number of the navigational stars have characteristic features and prominent secondary stars near them in the sextant field of view and can be identified very easily in daytime if the sextant is pointed automatically. As an example, Regor and Acrux are very easily identifiable in daytime because of the nearby stars.

The sun filters worked very well except that the sun filter for the sextant, which was used on the long eye-relief eyepiece, was far too loose and had to be held on manually. The filter for the long eye relief on the telescope seemed to work fairly well. During the evaluation of the sun filters, we looked at the sun through the sextant and were able to count approxi-

SCOTT mately 15 sunspots, most of them located in the first quadrant. This was at about 174 hours in the flight.

The major anomaly during the flight relative to the optics was the hangup of the telescope drive. This has been mentioned previously in the debriefing, but it occurred on the second day when Jim noticed that the mechanical drive read-out on the talkback had hung up in shaft at 64 degrees. There was no apparent hangup in the electrical drive at that time. On the third day on the first alignment, the telescope hung up at approximately 64 degrees with the electrical drive. It was necessary to take tool E and manually drive the telescope and shaft away from the point of hangup and then reposition the mechanical drive for electrical drive to enable it to work electrically. However, on a number of subsequent occasions the telescope hung up again, and each time the procedure was to detach the eyepiece and mechanically release it from the point of

SCOTT hangup. In this process, a rubber grommet came out of the mechanical drive tool fitting. We still have the rubber grommet. Whether it was an extra or the grommet that was supposed to be there was difficult to determine at the time. Actually, we have only three-fourths of it; the other quarter is missing. Later in the flight, the telescope hung up at other angles. Sometimes, we had one hangup at approximately 15 degrees and another at 37 degrees as determined by the OCDU read-out on the DSKY. The first indications were that it was hanging up at multiples of 64 degrees, but apparently that was not a continuing situation. Finally, after a number of exercises with the telescope and after leaving the optics power on, it performed without any problems; and this continued throughout the last 5 days of the flight.

6.1.3 Computer Subsystem

SCOTT — The only problem that we had with the computer throughout the flight was the apparent nonacceptance of an instruction or the lack of the proper input by the crew. The first occasion was prior to SPS 6 when the DAP was loaded, or the DAP was changed from two-quad operation to a four-quad operation. The second occasion was on the last day — on the last night when the no-DAP configuration was loaded and activated by a VERB 46, which apparently was not accepted or didn't get in. The third occasion was the completion of the ascent-stage tracking when P20 was terminated by a VERB 56 and the W-matrix continued to run until CMC light and a W-matrix overflow alarm occurred. A subsequent VERB 56 was entered and did terminate the W-matrix. The rest of the computer subsystem worked very well.

6.1.4 G&N Controls and Displays

McDIVITT — Prior to flight, we had a few changes in the techniques with which we were going to use the entry monitoring system; but they

McDIVITT weren't major, and we followed the new procedures. The EMS in the orbit mode worked extremely well. The drift on the accelerometer was very small. Throughout the flight, we tested it, and it varied somewhere between 0.2 and 0.4 ft/sec per 100 seconds. Whenever we did a DELTA-V test, the DELTA-V test was about as good as it could be and always came within a couple of tenths of a ft/sec of the middle of the band. In each case, I always felt that we had probably the best entry monitoring system that had flown to date, and certainly better than anything that we had ever seen in any of our simulations. However, when we got around to doing the entry and really were going to use it for entry monitoring, we ran through a ground-test pattern to see how the thing was going to work. Then we were going to go through the flight check-test pattern. On the ground-test pattern, it worked exactly as it was supposed to work. At the completion of the test, I had concluded that the

McDIVITT test was successful; and at the time, I sort of decided not to even bother to run through the flight test-check pattern. As we started slewing the EMS down towards the 37 000-ft/sec line, I noticed that the scribe stopped scribing across the top of the film; therefore, I elected to do one more EMS test on the flight test-check pattern close to the beginning of the entry scroll. When we performed the check, it scribed reasonably well, and I figured that maybe we had just had a slippery piece of film between the two test patterns. However, when we slewed down to the entry interface velocity of 25 996, it failed again to scribe across the film. Throughout the entire entry, the EMS scribe failed to scribe a line on the film until we were down very low. I believe that it was at a drogue deploy that we finally got the thing to start scribing; it looked as if it needed a good bang to get the stylus back down through the emulsion. It didn't render the EMS completely unusable because, McDIVITT by looking at the other accelerometer, I could estimate what the g's were, estimate a position on the EMS, and approximate my range potential to the nearest 100 miles, at least. It certainly made it a difficult task, and the EMS will have to be fixed before we proceed to any more lunar reentries.

The FDAI's operated as they should throughout the flight. I might comment on the FDAI 1-deg/sec rates scale. I think that this is an extremely useful scale to perform as a rate gyro. As the scale made the maneuvering of the very large full-up vehicle (CM/SM/LM) a very precise task, I think that we saved a considerable amount of fuel by having this excellent display available to us.

The rest of the G&N controls and displays operated nominally except for the rotational hand controller. It operated fine electrically, but the mechanical interface between the controller and the seat was one of the sloppiest that we had seen. I think that

McDIVITT it was even worse than the one that we had in our simulator which we were required to fly by stabilizing the controller with our knees. It didn't make it an impossible task to fly the spacecraft, but it certainly wasn't as desirable as a good tight-fitting mechanical interface between the hand controller and the seat.

6.1.6 CMC SPS TVC

McDIVITT I have one little comment on the CMC/SPS TVC relative to burn number 5, where we had about a 40-second burn and picked up large cross-axis residuals. We had expected this from preflight simulations and, I think, maybe as a result of some auto pilot improvements, we may be able to tighten up the loop a little bit and improve this cross-axis steering.

6.2 Stabilization and Control System

SCOTT One additional comment to the SCS was that the MASTER ALARM light that came on every time the BMAG's were powered down.

SCOTT

and we always wanted to maneuver the spacecraft at very low rates to save fuel. We did a lot of preplanning to get to the right attitude at the right time and to start the maneuver as much as 45 minutes or 1 hour beforehand. I did find that when the spacecraft was in full-up configuration (full command module, full LM), it was sometimes better to go to the ACCELERATION COMMAND to get a reasonably sized rate.

In SCS ATTITUDE HOLD, we got into some limit cycles. I think that the classic one was just prior to retrofire when we were as light as we ever became and when all the thrusters were enabled. We got into a classis example of limit cycling, banging back and forth at a fairly high frequency in roll. We turned the LIMIT CYCLE switch ON, and it damped the rates right down to zero. From that moment, we had very few jet firings that I would consider to be the nominal for that particular ATTITUDE HOLD mode.

SCOTT We had a power-up and power-down checklist that we used for the SCS. It went very well. For the first 5 days after that, we only powered the SCS electronics down at night and back up in the daytime. Each time we went to bed at night, we disabled the hand controllers in a direct mode and the hand controllers in a normal mode. We turned off all 16 switches for the AUTO RCS SELECT and we turned off the translation controller, so that we always had a good feeling that the flight control system was powered down and that I wasn't going to have to spend too much time worrying about a stuck-on thruster while I was sleeping.

On the control modes preflight, we went through a number of exercises to try to determine which DAP configuration would be the most efficient and which SCS configuration would be the most efficient. During flight, we did use the adjacent-quad procedure in the DAP for attitude holding and it seemed to be very efficient.

SCOTT There were few jet firings, and for maneuvers, even though it hadn't been recommended for maneuvers, it seemed to work very well. Normally, maneuvers should have had a couple on each axis to be most efficient; but at the times we made maneuvers, both with the LM on and the LM off (with only adjacent quads enabled), the maneuvers seemed to be smooth and efficient. When we switched from a MAX deadband to a MIN deadband on the DAP, such as after a VERB 49 maneuver to a burn attitude in a subsequent entry into P40, and unless we were in the center of the the deadband or near the center, we would have a very sharp maneuver from whatever part of the deadband we were in to the center of the deadband, which was not efficient in fuel usage. The LIMIT CYCLE was also very good with the LM on. This was illustrated during the EVA attitude holding in which we did a complete SCS hold with the BMAG's uncaged, and MAX deadband low rate, six jet in that we

SCOTT — turned quads A and B off electrically and turned D roll off and the LIMIT CYCLE ON. The holding seemed to be very smooth and very efficient.

6.2.1 Control

SCOTT — I found that the MINIMUM IMPULSE was the most used motor control for the spacecraft. We used this because it was a fuel saver.

6.2.2 Thrust Vector Control

SCOTT — The MTVC on SPS number 3 was as expected with the exception of the difficulty in stopping the error needle movement. It was easy to fly and easy to hold the error needles in a position, but the needles didn't appear to stay in a fixed position as long as they had in the simulations.

6.3 Service Propulsion System

SCOTT — The SPS helium tank pressure indicator onboard went to zero at lift-off and remained zero throughout the flight, and the ground data were okay.

6.3.8 PUGS

SCHWEICKART — The propellant utilization gaging system appeared to behave in what could only be described as a very erratic manner as long as it was powered up. On SPS 1, just at the end of the burn, the SPS PU sensor caution warning light was illuminated and the oxidizer unbalance read full scale DECREASE, which was what caused the light to illuminate. This system was used for the next several SPS burns and behaved very erratically. The system was switched from NORMAL to AUXILIARY after the light lit up on SPS 2. The auxiliary

SCHWEICKART system also behaved in an erratic manner with the oxidizer unbalance fluctuating in an erratic manner between full-scale HIGH or full-scale INCREASE to full-scale DECREASE. Following SPS 3, the ground recommended disabling the SPS PU sensor. At a subsequent point in the flight, a special test procedure was sent up and carried out with the read-outs for the test appearing to be normal, except that the oxidizer and fuel quantity displays were not balanced and never returned to a balanced condition. However, the test 1 and test 2 slewing of the system appeared to work in a completely normal manner. The PUGS was again activated for SPS burn 7 and the PUGS mode switch at this point was in PRIMARY. Once again in this burn we obtained the SPS PU sensor caution and warning light. It was then deactivated for the last time and it was not used during the deorbit burn.

McDIVITT This was a burn that took place after we had a 6.5-minute negative acceleration on the service module. There was some concern about some very terrible things happening within the propellant retention tanks and within the engine as we started the engine again, and we went through this burn. I'd just like to say that the burn was perfectly nominal. I did not see any change in the chamber pressure. We did not experience any chugs, bumps, or thumps. The engine burned, on this burn, as it had on all the previous burns. I guess it should be pointed out that we used 18-second, four-jet ullage prior to this maneuver; but that was the only thing that was not standard in the whole maneuver.

6.4 Reaction Control System

SCOTT We noted at lift-off that C quad was less than 100 percent in propellant quantity. It remained the low-indicated quad throughout. When it came time to switch

SCOTT

to the secondary propellant system, the values passed up from the ground for the switchover were 44 percent indicated, and 170 psi. The quantity went down to 40 and the pressure never went less than about 172 psi which indicated that the secondary propellant valve had already been opened at some point. Because these switches are spring loaded, it seems like it might be a good idea to guard these particular switches if you wanted to be certain that you did have switchover at the proper time, or that the secondary switching was available. On the propellant isolation valves, prior to transposition and docking or the separation from the S-IVB, they all indicated gray. Subsequent to the separation and the turnaround, in discovering we had no left translation, we found that the primary and secondary quad C isolation valves were closed as indicated by barber pole talkbacks and that the secondary quad D isolation valves were

SCOTT closed as indicated by a barber pole talkback. We are reasonably certain this did not occur because of any manual contact with the switches, and this may also be an indication that the quad C secondary propellant valve had opened prior to the point in the flight when we expected the quad C primary system to deplete to the point where we were to open it manually. After discovering the barber poles during transposition and docking, the switches were activated to open the isolation valves and all performed normally.

6.4.2 CM RCS

SCOTT During the descent on the mains at the conclusion of the CM RCS dump, a large red cloud engulfed the spacecraft. The CM RCS injectors remained at a relatively high temperature throughout the flight and I believe we never got less than 4.8 volts indicated on the systems test meter.

6.5 Electrical Power System

SCOTT

The condenser exhaust temperature on fuel cell 2 exceeded the caution and warning limits early in the flight. They remained high throughout the daytime activities when we were powered up, and went down during the night when we were powered down after the O_2 purges. Finally, after two long H_2 purges, after day 5, the entire fuel cell seemed to get well and operate normally throughout the rest of the flight. During this later portion of the flight, we kept the power level relatively constant throughout the day and night cycle.

SCHWEICKART

On one of the first fuel cell purge cycles, the O_2 flow on fuel cell 2 increased to a much greater extent than nominal. The fuel cell 2 warning light came on. It was noticed that the DELTA in the O_2 flow, for the purge on fuel cell 2, was indeterminately high — indeterminate because the gage was pegged at the top of the meter. We couldn't

SCHWEICKART determine how high the flow was, but this phenomenon exhibited itself through several cycles on the O_2 purge valve. However, on all subsequent purges, the purge flow was completely normal. So this remains as an unknown.

6.5.10 Cryogenic System

SCOTT The primary problem was in the H_2. We spent a considerable amount of the flight time changing switch configurations and adjusting the pressure on the H_2 tanks, purging, and a number of assorted techniques, to try to maintain the H_2 tank pressures within the limits. And one problem was that the normal operating range of H_2 tank 1 was below the caution and warning limit which provided a number of periods with the caution and warning light on. This necessitated going to an acknowledge situation and a caution and warning panel which further complicated malfunction detection. Another associated problem was the occasional interruption of sleep cycles to

SCOTT — adjust or turn off a caution and warning light. The first time we got a cryo light on the H_2 was 40 minutes into the flight. We had one off and on for the rest of the flight. The entire operation of switching heaters from AUTO to ON and fans from AUTO to ON for the H_2 systems should be automatic.

6.6 Environmental Control System

SCOTT — Early in the flight, it was noted that the surge tank pressure was low, and upon checking the turn-on valve it was found that it had to be turned approximately 30 degrees past the ON position to fill the surge tank. In other words, the looseness and the sloppiness in the valve turn-on resulted in our thinking that the surge tank had been filling or was on, and it actually was not.

6.6.2 Cabin Atmosphere

SCOTT — We found that it was necessary to locate the hoses properly to provide adequate circulation throughout the cabin and

SCOTT maintain an even cabin temperature. The screens on the hoses worked very well. There was no need to detect any glycol, but we did have a quantity of water on the floor after the SPS burns number 5 and number 7. There was a considerable amount of water on the center of the floor. The source was the ECU. We never had the opportunity to open up the panels and get in the ECU to find out the exact point at which the water collected. It looked like the amount of water was 4 ounces or so.

McDIVITT I looked at the ECS plumbing lines, probably five or six times during the flight. They were always wet, not all of them, but the ones that were cold were wet. There was only one time that there was an excessive amount of water on any of them. I think that was probably on the day before RETRO. There was a great big gob of water on one of the lines. I took the little vacuum cleaner and sucked it off and looked at the rest

McDIVITT — of the lines, which had little droplets too small to vacuum up.

SCOTT — The cabin seemed to have considerably more particles after we had opened the hatch and gone into the LM on each of the LM days. After the EVA, the cabin had cleaned out considerably. But still, on getting into the LM, we had more floating particles. After the LM was gone, the cabin seemed to clean up much better and we had a lot less lint and fewer particles on the screens. Toward the end of the flight, the amount of debris picked up on the hose screens seemed to increase although the amount of debris on the suit circuit return valve screens seemed to decrease. But overall, the cabin got cleaner as the flight went on. Odor removal seemed to work well and the cabin seemed to clear out in 5 minutes. One other item in the ECS was the cabin fan failure which occurred at approximately 153 hours in the flight. We had cabin fan number 2 on, and the cabin temperature

SCOTT had risen to 75 degrees. We turned 2 off and 1 on, and apparently cabin fan number 1 did not work. Jim reached in and felt that the housing around the fan was hot. After about 3 minutes, we turned fan 1 off and pulled the circuit breakers. We did not use it any more during the flight. On visual inspection of the fan, we saw a piece of Velcro webbing in the fan blades. It looked like it was a piece missing off the DSKY table in the LM. It looks like the particles that got into the fan must have entered through the front, the exit point of the fan. It is recommended that perhaps a screen be placed over the exit hole to prevent pieces from drifting in.

6.6.3 Water Supply System

SCOTT Associated with the waste tank servicing valve was the necessity to gather a number of parts and pieces to dump the waste tank, which was a time-consuming, inefficient, process, particularly because of the

SCOTT storage locations of all these pieces and different boxes throughout the spacecraft. It was noted at about 175 hours that the captive wire on the waste tank servicing port cap came off the cap. It remained attached to the panel and got in the way of the cap when the cap was replaced. On chlorine injection, it is recommended that the chlorine be put in the water system at night prior to the sleep period to enable it to mix with the water so you don't have a slug of chlorine when you try to drink it. Even when this was done at night a number of hours later, we did get a high concentration of chlorine from several squirts out of the water systems.

McDIVITT I'd like to discuss the food preparation and the drinking water together. Early in the flight we were drinking water out of the water gun and it was coming through with a large amount of gas in it. As soon as I had had a good drink of water, I could begin to feel my stomach rumble.

McDIVITT

It felt like I was blowing up like a balloon. We used the water gun for a while at the beginning of the flight because we did not always have time to fill a bag full of water and try to separate the gas out that way. During the early parts of the flight, I think we were all bothered by the gas in our stomachs. Throughout the flight when we were preparing food, we got great gobs of gas into the water bags. On a number of occasions I managed to fill a food bag with hot water so that it was a fairly hard cylinder with only two squirts from the food preparation gun. Normally, if you're putting just pure water into the thing, you can get 7 or 8 squirts at least. It was an indication of the amount of gas we were getting in. Sometimes the bags were at least half filled with gas. For the last 4 or 5 days of the flight, we attempted to drink only from drinking bags. We found that this, in some way, alleviated the

McDIVITT the gas problem, although it was a far cry from what I would consider to be even a semidesirable situation.

6.6.4 Water-Glycol System

McDIVITT Prior to launch, we were alternately hot and very humid. I shouldn't say hot, I guess very humid, warm, or cold in the suits. This was a repeat of what had happened during countdown demonstration tests except that we started using the suit heat exchanger bypass valve earlier, and did not get quite as cold as we had during CDDT. It turned out that the CDDT changer bypass valve could not be modulated in small increments. It was required that we modulate the valve in 20-second increments which I believe was changing the valve from full open to full close. We were at one extreme or the other extreme and never really at a comfortable position on this particular valve. Once we got into orbit, we found that the modulation was not required when we had it in full flow

McDIVITT and we remained comfortable the rest of the time.

SCHWEICKART We had one anomaly with the ECS radiator flow control. One night, it automatically switched to secondary proportioning valve. Subsequent manual operation to the primary resulted in no further problems. After going manually to number 1, we later switched to AUTO and it quit running properly for the rest of the flight.

6.6.5 Suit Circuit

McDIVITT The suit inlet temperatures during flight and those experienced during operation on the ground were quite similar, but the sensation in the suit was extremely different. I should also point out here that the CDR and the CMP had a different sensation than the LMP, whose hoses were considerably longer. It is probable that the heat exchange from the hose to the cabin over this long run would tend to modify the flow that his suit actually received. Prior to RETRO, we cold soaked the cabin and actually detected the

McDIVITT decrease in the cabin temperature, although it was not a drastic decrease. It went down probably 5 or 6 degrees.

SCOTT Is a grounding strap really needed on the LiOH canister? It requires a lot of extra work.

SCHWEICKART The cabin air return valve had a sticky handle. It was very difficult to open and close. I guess we knew this prior to flight and it never improved any during flight.

McDIVITT Prior to the lift-off, I had some of our people check to ensure that the lithium hydroxide canisters were labeled properly, so we would not get them mixed up in flight. I was assured that each canister was labeled. In orbit, we started to perform our first lithium hydroxide canister change following the instructions in the flight plan which were quite specific in telling us which box to open and which one to pull out. We went down to the box which contained the requisite number of lithium hydroxide canister.

MCDIVITT After opening the box, we found that the lithium hydroxide canisters were not individually marked. They all had a bunch of useless numbers, like part numbers, drawing numbers, and things like that that were absolutely of no operational use to us. It turned out that each and every LiOH canister looked like every other LiOH canister. Now, this is fine if one has plenty of time to start painting canisters in orbit. We were extremely busy during the first part of the flight and had to take an additional amount of time to get the tape out and label the canisters as to which time it was used, when it was changed and stowed. Now it turned out that some of these canisters had to be reused at the end of the flight. Therefore, after we used the canister we couldn't afford to get it mixed up. When we placed it back into the suit loop, into the LiOH canister holder, we had to tear the tape off (because it was a foreign object) and try to stow the tape someplace

McDIVITT — where it could be found later to put it back on. It seems to me like there should be painted numbers on the LiOH canisters, as well as a decal or something so that we could mark when they had been changed, and what the PCO_2 was when it came out. This would certainly be worthwhile. It could really cause a problem if we had put a used LiOH canister in one of these things and had the PCO_2 quantity warning light come on during an EVA or a rendezvous. We would have had to go change the LiOH canister in a less than desirable situation. We could have had pretty bad results from a simple little mission like this.

6.6.6 Gaging System

McDIVITT — The gaging systems worked properly.

6.6.7 Waste Management System

McDIVITT — The waste management system left a little bit to be desired. The roll-on cuffs that we were supplied with in the spacecraft were of a number of different sizes.

McDIVITT In some cases they didn't match the ones that we were launched with in the suit — in other cases were too large or too small. It seemed like a little coordination between the people that placed the roll-on cuffs in the spacecraft would certainly alleviate some of our problems. It turned out that some people use only the UCD's because they had the cuffs that would fit. Other people use only UCTA's because they had the cuffs that only would fit. Therefore, we ended up with a management job on the waste management system that didn't necessarily need to be. As to operation of the plumbing portion of the system, it was certainly adequate and we had no operational or draining difficulty with the bladders. Of some interest is the fact that whenever we had a urine dump we could see the dump matter being deposited on the different windows and on top of the LM. After some time most of this dissipated; however, the left-hand (number 1) window began to

McDIVITT

accumulate particles. At the end of the flight, it had considerably more particles on it than it did at the beginning. I'm sure that this was due to the urine dumps. Prior to flight, we had some discussion about the size of the hole in the long underwear as to whether it should have a drop seat, a long slit, a flap, or one of a number of other things. In an effort to keep down the changes, we agreed to go with whatever size hole we had in our underwear. I must, at this time, say that they were indeed too small. The slit should have been another 6 or 8 inches longer than it was. I ripped mine early in the flight just to provide a reasonable size hole there and after that it seemed to operate properly. Some of the people feel that the removal of the underwear is the best attack to the problem.

6.7 Telecommunications

6.7.2 Individual Audio Center Controls

SCOTT — Audio center number 10 panel is very inconvenient to operate.

6.7.6 S-Band

SCOTT — On the S-Band volume amplifier, we had to switch to the secondary power amplifier during one of the rest periods at night. Everything appeared to work normally from that time on. The rendezvous radar transponder worked properly. The dump check was within limits and I got one data point at 97:19:00 during the rendezvous; the voltage was 2.3 and the range was approximately 50 nautical miles.

6.7.7 Tape Recorders

SCHWEICKART — There was a moment of hesitancy just prior to the deorbit burn when operation of the tape recorder reverted to manual control. According to the checklist as updated by the ground, I was to place the tape recorder to FORWARD, HIGH BIT

McDIVITT — RATE in RECORD and then position the UP TELEMETRY command reset switch to RESET and then back to NORMAL at which time the recorder should have begun operation. Although these procedures were followed, the tape recorder talkback remained barber pole. There was no time to troubleshoot it because the average g was already on and we were down to the point of ullaging for the deorbit burn. The next time I looked back at the talkback was during or very shortly after the burn and at that time it was indicating gray. I do not know whether it was commanded ON by MSFN or whether there was a time delay associated with starting the tape recorder.

SCOTT — I'd like to comment that the ground did a good job handling the tape recorders. With exception of the deorbit burn that was all handled by ground RTC's.

6.7.12 VOX Circuitry

SCOTT — The VOX circuitry worked very well except

SCOTT — for the time delay after the termination of the voice. Because of the long time delay, confusion resulted during the EVA portion of the flight. Because the CDR in the LM was not aware of the long delay time, the transmissions became confusing. It's recommended that perhaps the delay time be reduced to something comparable with the LM.

6.7.15 ARIA Aircraft

SCOTT — It is recommended that the ARIA aircraft be in a standby basis as they were during the later portion of the flight and be used only when requested. Several times when they were automatically up and transmitting, the noise was so loud that the rest of the communications between the two spacecraft was completely distorted. This made it very difficult to square away the COMM situation. This occurred even when the spacecraft was operating solo.

6.8 Mechanical

SCOTT — Most of this has been discussed within the context of the operational flow.

6.8.1 Probe

SCOTT — The only anomaly noted was on the probe; the extended latch was not completely over the roller at the completion of the LM docking and had to be closed with the preload handle. Prior to the LM separation and rendezvous, latches number 1 and 8 appeared to malfunction until they had been cycled. This is discussed in the rendezvous portion. It might be noted that the stowage of the probe, the drogue, and the hatch in the command module during intravehicular transfer worked out very well using the locations in the LEB. The probe was placed under the right couch seat pan, the drogue was placed on top of the probe and seat pan combination and held down with the probe retention straps.

6.8.2 Hatch

SCOTT

The side hatch worked very well with the exception of the counter balance arm connection roller. The piece on the hatch to which the counter balance is attached with a pit pin rolls along the hatch connection on two rollers. It is supposed to be captive and is not exactly optimum because one of the two rollers came out during the EVA. They slipped over the bar which is supposed to retain it in a captive position. And the hatch gearbox shear pin indicators are unacceptable and should be re-marked to enable a more direct interpretation of the position of the shear pin.

On the overall operation of the side hatch, if the gear box fails, there should be more information and descriptions on backup hatch-closing techniques and procedures relative to the gear-linkage disconnect and lockup. Also the use of the jack screws could be improved.

7.0 LUNAR MODULE SYSTEMS OPERATIONS

7.1.1 PGNCS

SCHWEICKART The LM inertial subsystem operated as expected. I think the only thing deserving of comment was that the IMU docked alignment (which had been developed to relieve the requirement for maneuvering the docked combination to obtain an attitude reference for the LM) worked as it had during the simulations. I think that the GYRO torquing angles, which were obtained with active alignment following the undocking on the rendezvous day, were good evidence that the docked alignment itself was very accurate. Following the last docked IMU alignment, and following separation and undocking, an active LM alignment was performed and the resultant gyro torquing angles were minus 0.09, minus 0.076, and plus .111 degrees. The star angle difference on this alignment was five zero's. These gyro torquing angles were obtained during about 2.5 hours between

SCHWEICKART the last docked realignment and the active LM alignment after undocking. I guess the primary point in bringing this up is that the docked IMU alignment procedures, in coordination with the ground updating of the gyro torquing angles, appeared to work very well. In fact, quite a bit better than we had anticipated prior to flight. I think this is a very powerful tool which ought to be employed in future missions for freeing the timeline from the constraint of having to do an alignment at night, and maneuvering the docked vehicles. This alignment can be done very rapidly and has no constraints other than that the command module platform be up and aligned, and that the LM platform also be up. The other obvious advantage of this type of alignment is that there is essentially zero fuel required to obtain a very good alignment of the LM platform. The only requirement preflight, to obtain this type of accuracy in the docked alignment, is that the relative geometry between

SCHWEICKART the two navigation bases be very well known. There have been techniques developed which would permit these measurements to be made at the manufacturing plants prior to the shipping of the vehicles to the Cape. However, these do involve some minimal time in the flow of the vehicles. In our opinion, this required time is well spent; however, this is a very controversial item.

McDIVITT I'd like to comment a little on spacecraft attitude control system here. We used PGNS in PULSE, ATTITUDE HOLD and AUTO. In each one of these modes the digital auto pilot performed up to my greatest expectations. There was no unnecessary limit cycling and I think that it's an excellent control system. The only reason I'm mentioning it here is I'm sure there was a lot of interest in finding out how it performed. Rather than just skip it and say it's nominal, I want definitely to say that I think it was a good control system.

McDIVITT Under Thrust Vector Control, one of the items that looked, preflight, like it might be very interesting — was the docked DPS burn without any RCS engines firing. This was much better than we had expected. The attitude excursions were down to a couple of degrees and the residuals were very low. It performed again — as good, or better than — I had expected, probably better than I had expected. All the other thrust vector control operations were good. The attitude excursions were usually less than a couple of degrees, and certainly within the realm of what one would expect with the RCS engines, throttlable DPS, or the fixed APS.

On the optical subsystem we found that, much to our surprise, we could actually see some stars in the daylight. The first alignment was made with the sun still shining on the LM. We took ten marks, five X and five Y marks on Sirius in the daylight. I was not only able to see Sirius, but could also see Canis Major and

McDIVITT identify it as the constellation with the bright star. We have made an AUTO maneuver to the star. We were able to do this because of the previously mentioned docked IMU alignment.

The dimmer control worked fine. I used the technique of dimming the reticle as the star approached the X and Y lines to ensure that the star was under the line and being blanked out by the line at the time I took the mark. The technique of dimming the reticle, and then brightening it up is a technique that worked very well for me. I might add that we only used the AOT in the forward detent for alignments, and it worked very well. The correlation between left and right, and up and down as viewed through the optics (and what one really had to do to make that happen) was very good. The field of view was what it was supposed to be — 60 degrees. When we placed the radar to the 283-degree shaft position, it was out of the field of view in the AOT. We pulled

McDIVITT — the circuit breakers and left it in this position and even though the spacecraft was maneuvering around, the radar stayed out of the field of view and was no factor whatsoever in alignments.

There did not appear to be any parallax in the AOT. In attempting to focus the AOT, I did have some difficulty focusing the stars and the reticle all together. Throughout the simulations, we had had trouble trying to get the image of the crosshair and the image of the star in the same place. I found that even in flight we had trouble — I had trouble — with positioning my eye so that I could see everything. Quite often, I would see the reticle and not stars, or the stars and not the reticle. I should add here, that I was not using the rubber eyepiece and that I had plenty of room to move my head. I'm sure that this was the reason. But it did become aggravating at times. It is also worthy to note, I guess, that we can see through the telescope with

McDIVITT our helmets on. When the radar was stowed, we could look through the telescope and see that it was stowed right in front of us. We also used the AOT to watch the radar come from the stowed position around to mode 1. One thing that I did find to be quite aggravating was that the reticle and the stars did not appear to be focused at the same point and that I could, in moving my head around, get the reticle in focus and the stars out of focus, or vice versa.

I found that in the time-critical situations we had — where we were trying to get these alignments in, just an absolute minimum amount of time — that I could get the star near the cross of the reticle; I also found if I moved my head just the very slightest amount that one of the two of them would disappear or would become dim or out of focus. While I'm sure we are not going to change the design of the AOT, I think it's certainly worthwhile for the people who are going to use it to be

McDIVITT aware of this. I found it to be quite similar to the way the optics operated in the LMS. To clarify I should also mention here that I think that in no way is it unusable. It is just that it takes a little bit longer to use them than I wanted to spend during the mission. It was a rather aggravating situation, especially on one occasion where we got a very nice star crossing on the Y line, and it turned out that just as the thing crossed, I lost sight of — I believe the star — because I managed to move my head a little. While I was doing these star sightings, I was not restrained to the floor; and I was holding on to the AOT guard, the pipe, the guard built out of the aluminum pipes that goes around it, and the control box. I had no difficulty whatsoever floating there and actually making the marks. In simulations we found that when I did this, I got in his way. We would end up folding up the table that went in front of the DSKY. Let's say we had some interference, McDIVITT but that we had expected it because we ran across it in the simulations. What Rusty did (and I did not see him doing it) was fold up the table on top of the DSKY, when we got the flashing VERB 54 (which indicated to start taking marks) and then he unfolded the table when we were ready to do our maneuver to the next star. One thing that might be worth mentioning here, and it's just an opinion; there has been much discussion about whether or not one could make a star AOT alignment on the lunar surface. We didn't, obviously, have the kind of environment that one would have on the lunar surface; but we did make the first alignment on Sirius, as I mentioned earlier, with the sun over our shoulder, the way you would expect it to be on the lunar surface. However, there were no objects in front of us to reflect light back into the AOT. The guard that we had around the AOT certainly kept the light from the sun, which was behind us, out of the AOT and there

McDIVITT — wasn't anything in front of us to reflect back. So I did see the star in the daylight and whether or not I could have seen it on the ground would, I think, depend entirely upon what the lunar reflectance into the AOT itself would be. I might also add here that here were a couple of pieces of debris on the AOT. I could see two black spots on it, one of them quite close to the center, and I think the other one was off to one side. They did not interfere in any way with the alignments. When we were looking down on top of the LM from the command module, we could see all kinds of white spots all over it. As the flight wore on there were a whole bunch of white particles that had collected on the left-hand (number 1) window on the command module. My personal opinion is that these particles came from urine and water dumps that we were making, and I wouldn't be a bit surprised if the debris on top

McDIVITT of the AOT were a result of one of these dumps.

When we unlocked the rendezvous radar and slewed it around to the front, we were able to monitor it with the AOT; it tracked right on around and operated just the way we had seen it in the simulations and in the tests on the ground. We were able to slew it left, right, up, down, and all the ways that it was supposed to operate. It operated properly under LGC control. We had mentioned earlier the problem that we had with the rendezvous radar self-test. When it was in the stowed position, we were unable to indicate a range input to the computer, except on one occasion, and we did the test a number of times. However, once we got the thing unstowed and operated it in a normal mode, we found that it operated very well.

In watching the AGC during the rendezvous, I was pleasantly surprised to find that the actual signal strength, when compared

McDIVITT to the card that we had (which was supposed to demonstrate the signal strength-versus-range data), was a little bit above it all the way through. I've got some numbers here that would be of some interest, I believe. At 45 miles, I read an AGC of 2.4; at 85 miles I read an AGC of 2.19; at 98 miles, which was our maximum range, I read an AGC of 2.17; and at 52 miles, I read an AGC of 2.39, which correlates very closely with the 2.4 at 45 miles. In all instances, I was able to determine from the AGC signal strength that I indeed had a main lobe lock-on. I did about half the lock-on verification optically and the other half using the signal strength. When we compared the shaft and trunnion readouts through the DSKY, and the display of the shaft and trunnion error needles, we found that they were in very close agreement.

When we also compared the range and range rate from the tape meter with that read

McDIVITT out in the DSKY, we found that they were in very close agreement.

In tracking, we used the pulse mode most of the time and were generally able to track and keep the vehicle within 10 degrees of the proper attitude and generally within 4 or 5 degrees of the zero on the Z-axis. Acquisition time was nominal; there was nothing abnormal about that.

One thing that was of some interest: when I did a couple of manual slews towards lockon, I noticed that we really had three lobes that I could see. We were at moderate range then. We had the main lobe, which was quite prominent, and then we had the first side lobe; then I noticed another side lobe. I didn't slew it out to see if we had other side lobes outside of that.

I believe the slew was in the plane of the orbit so that I would be slewing up and down while I was pointed at the target. I should say that we never really have seen anymore than the second side lobe in any of our simulations. It wasn't a factor; it was just an interesting

[redacted]

McDIVITT point. This was in the LMS simulations. I think I would like to sum up the operation of the radar here and say that it performed almost perfectly. There was only one anomaly that I noticed through the whole thing and I'd like to expand on that a little bit right at this time. I was using the AGC signal strength as a "howgozit" all the way. I checked it, probably every 30 seconds, for the 6 or 8 hours we were separated. It behaved just exactly as I had expected it to behave, except just prior to TPI. I'm not exactly sure of the time. I'm sure if we go back and look at the data we can get this from the downlink; but at approximately 6 minutes or so, the signal strength started decreasing from about 2.5 (or 2.6, or whatever it was) at that range of approximately 35 or 40 miles. It very gradually went down to 1.6 and then very gradually came back up again. The command module at this time was not making any maneuvers. It

McDIVITT was probably pointed right at the LM, at least until the TPI minus 5-minute point. The LM was not maneuvering because we were going to do Z-axis thrusting (which meant that we were going to thrust with the Z-axis pointed right at the spacecraft), and because we were already in that attitude, I didn't have to make any maneuvers. So for some unknown reason, the signal strength went down very smoothly from around 2.5 to 1.6 and then very smoothly back up to whatever it was. It took about 3 or 4 minutes for this transition to take place. At the time I thought, "Well, the command module was maneuvering and I may break lock because he's going to be pointing the wrong direction"; but 10 minutes later it dawned on me that he really hadn't done any maneuvering, or certainly no gross maneuvering, and that we had had an anomaly at that time.

It is also interesting to note here at the CDH maneuver because we had some

McDIVITT vertical component in the burn. When we maneuvered around to the burn attitude, the radar stayed locked on. It stayed locked on, I believe, all the way through the burn. After we finished, we were doing the postburn checklist and were just about to start maneuvering back to the tracking attitude, when the radar broke lock. (I think if we'd been 30 seconds quicker we'd have been able to get around without the radar ever breaking lock, and would not have had to go through the lock-on again, although the lock-on was no problem.) We locked on and were able to verify from the signal strength that we had indeed had a primary lobe lock-on. I might add that as we went through the zero-range-rate point, both on the maxi football and at 98 miles, we got the red light flashing on and off and the range rate tape — just the way the book says it will do when we have low range rates. I don't recall this light flashing on

McDIVITT

and off at any other time during the mission, although it may have. The radar stayed locked on as we came into very close range of the command module. As a matter of fact, when we were in at about 25 feet or so, we tried to break lock by manually slewing the antenna. We slewed it to both up and down limits, and were unable to make it break lock.

SCHWEICKART

I was monitoring the radar temperature throughout the rendezvous and from the several points that I plotted on our onboard chart, it appeared that the antenna temperature at all times was on the order of 5 to 10 degrees below the expected temperature curve.

The landing radar operated as expected; at no time during the various operations of the landing radar was there any tendancy to lock on to a spur, at least not one that could be detected visually on the cross pointers and the altitude/altitude rate tape. The landing radar antenna temperature during the docked

SCHWEICKART DPS burn had been reported earlier. Prior to the burn, it started out at 81 degrees, worked its way up to just about 100 degrees by the time the 6-minute burn was completed, and peaked out after the burn at about 110 degrees. The computer subsystem operated in a completely nominal manner. At no time did we experience any unexpected or unexplained program alarm or restarts. The only other comment that might be worthwhile mentioning was that on powering up the LGC on the rendezvous day we had expected to find the computer in standby after closing the LGC DSKY breaker (because we had powered it down in standby on the systems day). This did not turn out to be the case. After pressing the LGC DSKY breaker to CLOSE, the computer was witnessed to be in P06 with a flashing VERB 37 on the DSKY.

At no time in powering up or powering down the LGC was an LGC or CMC warning

SCHWEICKART light seen to appear on the panel 1 caution and warning. There were never any PGNS, caution and warning lights on during the flight with the exception of the VERB 35 DSKY light check.

SCHWEICKART All G&N controls and displays operated in the manner expected.

There were no anomalies on the rotation hand controllers or the TTCA's. The cold fire check which was run is an excellent check of all the switching and interface between the hand controllers and the computer. The check was performed very rapidly and in a completely nominal manner.

7.1.2 AGS

SCHWEICKART All of the AGS alignments were as expected. I had the impression at one point during the flight (and I cannot recall exactly where) that I did see the CDU glitch on attempting to align the AGS to the PGNS. When I compared the AGS and PGNS attitude display on my FDAI, there appeared to be about a 1-degree difference between them. I repeated the 400 to plus 30 000 several times and it did not appear to remove this 1-degree difference between the two displays. There was not time to investigate this further at that time and all

SCHWEICKART subsequent alignments were completely normal. I could not visually detect any difference between the AGS and PGNS total attitude.

Inertial reference appeared to be completely nominal with the single exception of the 407 switch jumping to its state of plus 10 000 prior to the ullage maneuvers. This was a considerable bother — if one wanted to compare the PGNS and AGS attitude errors coming up on a burn — because it required babysitting to insure that the 400 remained at plus all zeros prior to the burn.

The only automatic or semiautomatic maneuvering done under AGS control was the phasing burn and the ATTITUDE HOLD just prior to the phasing burn. This ATTITUDE HOLD mode in a local vertical attitude appeared to work as expected. There did not appear to be excessive RCS activity in working up to that burn, and the powered-flight control appeared to be at least as good as we had witnessed in the

SCHWEICKART simulations. The residuals at the phasing burn were very good: minus 0.9, minus 0.8, and minus 0.6 ft/sec at cut-off. (Those residuals were the PGNS residuals following the phasing burn.) As reported earlier during the rendezvous debriefing, at no time during the rendezvous was there greater than 1 ft/sec left in 500, 501, or 502 after burning the PGNS residuals to zero. The largest residual seen on the AGS were those following the docked DPS burn and the largest there was 5 ft/sec in Y, and that was after a 1740-ft/sec burn.

CSM acquisition was not employed under AGS control during the mission.

Under AGS initialization, we received quite a surprise, when in trying to initialize the AGS the first time, 414 did not jump back to its initial state of plus all zeros following the PNGS transfer of the vector. After a slight delay, we were advised by the ground that it was required that the PCM bit rate be in HIGH

SCHWEICKART to update the AGS successfully. This was new information to us. To our knowledge, no one with whom we came in contact through our training cycle was ever aware of this, or at least never advised us of this situation. We had experienced a similar problem in updating the AGS prior to flight in the LMS, but this was never related to the position of the telemetry bit rate, and always appeared to be an LMS problem in the AGS simulation. We did not receive a K-factor update from the ground for the AGS; that is, on initializing the VERB 47 AGS zero time, we used 40 hours on the systems day and 90 hours on the rendezvous day and did not receive any updating of that time. The AGS calibration worked essentially as we had simulated it on the ground. We found no difficulty, once the initial attitude was obtained by the CSM, in avoiding the CDU switching attitudes for the 5 minutes plus of the calibration. The accelerometer bias calibrations

SCHWEICKART appeared to be very, very consistent, with the only change being witnessed on the first calibration of the flight. Thereafter, the accelerometers never changed their bias. The gyro compensation numbers did vary up to 0.2 degree from one calibration to another. There did not appear to by any systematic shift in the gyro compensation.

Rendezvous radar navigation into the AGS (as was mentioned earlier) appeared not to work as well as we had witnessed this process in the simulations. The operation, as far as the crew activity was concerned, presented about the same degree of difficulty in positioning the Z-axis of the spacecraft to update the AGS. This was not a difficult task, although it did require precise control using MINIMUM IMPULSE mode on the part of the commander. The effect, or the power, of the updates did not appear to be as pronounced in bringing the AGS range/range rate into accord with the PGNS or range/range rate

SCHWEICKART readout on the tape meter (as we had witnessed on the ground). My own personal opinion on this, which doesn't have any substantiation yet, is that this is primarily due to the fact that the AGS model in the LMS has a greater word length than the actual AGS, and that this gives a false impression of the granularity of the AGS displays.

Engine ON/OFF commands under AGS control appeared to have worked at least as well, or better, than we had witnessed on ground simulations. The phasing burn was initiated with two-jet ullage and there was no hesitancy in the AGS startup. The initial thrust transient on startup of the phasing burn was fairly rapid. We did not see a delay of 4 or 5 seconds in the thrust buildup. It appeared to come on with no more than a 2-second-buildup time to 10 percent. There was no question of when the ullage, the manual ullage, should be released at ignition.

SCHWEICKART — As far as the DEDA was concerned, the only anomalies that were witnessed in handling the DEDA was the illumination of the OPERATOR ERROR light in conjunction with the pressing of the CLEAR button. This did not seem to be associated with a weak depression of the CLEAR button, but seemed almost a random occurrence. On several occasions, it was necessary to depress the CLEAR button three or four times sequentially before the OPERATOR ERROR light would disappear and further operations on the DEDA could be performed. As I say, this appeared to be almost a random occurrence, and I was never able to correlate it with any particular operations or mode of programming in the AGS. On the caution and warning alarms on the rendezvous day — from the time the AGS was powered up until the jettison of the LM for the APS burn at depletion — the AGS warning light on panel 1 was illuminated. Following the rendezvous, a short test was made by powering down the AGS and

SCHWEICKART repowering it, after resetting the caution and warning to see when the light came on in the sequence. The caution and warning light came on when moving the AGS status switch from OFF to STANDBY and did not disappear or would not in any way extinguish after resetting the caution and warning system.

The CSI, CDH, and TPI programs appeared to operate pretty much as expected. Although again the solution displays — the DELTA-V solutions — did jump around, fluctuate, to a much greater extent than was ever witnessed in the LMS. I had anticipated this, because I had run several simulations in the FEMS at Grumman using an actual AGS. In those simulations, I became aware that the actual AGS performance in displaying maneuver solutions was considerably inferior to the nice steady displays we saw on the LMS.

The external DELTA-V programming appeared to work in a completely nominal manner.

SCHWEICKART: The AGS followup during the rendezvous profile was as expected on all burns. The AGS was targeted with external DELTA-V from the NOUN 86 read-out from the PGNS thrusting program, with the single exception of the phasing burn, for which the ground pad values for the AGS were loaded. This was due to the fact that a throttle-up was performed. The NOUN 86 values were computed based on a 10-percent profile.

On TPI and the midcourses, rather than using the external DELTA-V targeting (AGS registered 404, 405, and 406) the AGS were zeroed. Monitoring was performed by reading out 472, 471, and 470.

7.2.1 Descent Engine

McDIVITT

The descent engine worked very well, a nominal kind of performance throughout the mission, except for the first start after the 40-second SPS burn. This was a phasing maneuver, and we had some rough combustion. We had about 20 percent, I should add.

Ignition and tail-off were nominal for all the burns. On the one rough combustion start, the engine went to 10 percent in its normal slow (but not too slow) manner. It was neither a step input nor a dribbling start. It was a nice smooth start up to 10 percent. We were supposed to start the throttle up at 5 seconds after ignition signal. It was approximately 5 seconds when I started the throttling and as I throttled from 10 towards 40 percent, we had a rumbling in the engine.

The acoustical environment was such that the descent engine could be felt more than heard at all times, even running at

McDIVITT 100 percent. There was no real noise in the spacecraft, but when the rough combustion started, I could feel it rumbling and I'm not sure that I didn't actually hear it. I stopped the throttle-up at approximately 20 percent. The rumbling stopped, and then I throttled up to 40 percent. It was smooth from that point on. The rumbling was very similar to a compression start on a jet engine, the rumbling kind. The rest of the operation of the engines were quite nominal. The helium regulators were shut off on a docked DPS burn 10 seconds before the shutdown, and we operated in a blowdown condition from that point on. When we started the engine for the other DPS burns, we had asymetric pressures in the oxidizer and fuel. At the beginning of the phasing maneuver, the fuel/oxidizer ratio pressures were such that the fuel was low. It was 12 psi below the oxidizer. The same pressure differential

McDIVITT was present for the insertion burn. The docked DPS burn, where we used the trim gimbal as the control method rather than any of the RCS thrusters, was excellent. The attitude excursions during this particular engine burn were very small, on the order of 2 or 3 degrees. The rates were low. We had no trouble at all with the attitude excursions as we figured we might have prior to flight.

When we got down to the throttling regions, we were able to throttle from 100 percent to 40, to 10, back up to 40, down to 25, and to 40 without any noticeable rumbling, chugging, or any other propulsion abnormality. There was one little bit of steering abnormality that we encountered. I guess it was a dynamic problem that we had about a minute or so before we started the throttling profile. We could feel a small pulsing occur; estimates vary from approximately 1 cps to approximately

McDIVITT 3 cps, which exhibited itself on the roll rate needle. There was just a tad of motion on the yaw rate needle, which I can't explain exactly, because it shouldn't couple into that direction. The prominent thing was the roll rate needle. It also could be felt and seen in the command module side.

The engine firing frequency that I saw in the rate needles was not matching that which I felt through my feet.

Shutdowns were made both manually and automatically. In both cases, they operated as expected. We allowed the engine to do an automatic throttle-up on the docked DPS burn. The throttle-up was at the appropriate time, and it was very smooth. Throttling rocket engine responses are quick, throttling is precise, and it's a very nice control system for thrust commanding.

During the insertion burn, we used the throttle position of 10 percent, and as expected, we had some RCS activity to

McDIVITT maintain the spacecraft in the proper attitude. We did use the RCS engines. We expected to use the RCS engines at this low throttle setting.

SCHWEICKART Regarding descent propulsion system operation when we fired the start bottle, it pressurized the system to 230 to 240 psi. At the start of the docked DPS burn, the pressure began to decrease, went on down to somewhere between 180 and 190. I don't have the exact number available here. It reached that point and started back up again. I hadn't seen anything like this in the simulator before. I should have been expecting it. I knew the pressure would drop, but I didn't expect it to drop quite so far. The first thing that went across my mind was that the MASTER ALARM switch, which I had placed back to OFF after the start, had been placed back to OFF before the pyros had fired. I started to reach over to turn it back on again, when the pressure started back up. But it did go down

SCHWEICKART a lot farther than I expected. It's interesting to note here that it decreased until after the engine had throttled up to the full throttle point, which means that it was decreasing from something on the order of 30 seconds or so.

The cyro pressure gage for the supercritical helium for the DPS engine was intermittent throughout the flight and would read the proper pressure for a time and then go to zero, and then it would come back and read proper pressure again. You could never tell whether you were going to have the proper pressure or the zero reading on it.

7.2.2 Ascent Engine

SCHWEICKART The ascent engine was fired for one time for 4 seconds. The start was abrupt, the shutdown was abrupt and there was no noticeable rumbling or any undesirable occurrences. The noise level during that 4 seconds did not seem to be too high in the spacecraft. I felt that I could have communicated if I had

SCHWEICKART anything to say. It was a little short really to evaluate the overall performance of the engine from a pilot's standpoint. The start was automatic and the shutdown was automatic.

After pressurizing the ascent system, our procedure called for cycling the interconnect valves to their already selected position to ensure that they maintained operation through the

SCHWEICKART pressurization transient. When the ascent feed valves number 1 were cycled to the open position, which is their normal position, I was able to feel and/or hear (it's difficult to say which) the Parker valve snap to the open position. This was not evidenced on the talkbacks, which remained barber pole. The Parker valves evidently had unseated themselves during the pressurization.

7.3.2 Translation Control Modes

McDIVITT The translation control modes have been covered earlier in the PGNCS and AGS sections. We were notified on the systems day that we had a failed thrust chamber pressure switch on system B, quad 4, the upfiring thruster. This was not a factor at any time during the flight.

7.4.1 Electrical Power Subsystem

SCHWEICKART The batteries behaved in flight as expected. The only deviation from

SCHWEICKART procedures is a recommendation from MSFN to shut off descent battery number 4 in the early part of the systems day. The ascent battery activation and checkout went as prescribed in the procedure that was developed immediately prior to lift-off, which verified the ascent battery feed paths without ever placing both ascent batteries on any one bus.

The pyro batteries maintained 36.8 and 37.5 volts all through the flight, from the first time they were read through all the uses with the EV system. All indicators associated with the electrical power system operated as expected. There was no noticeable sticking of the talkbacks on the descent BATS as we had anticipated from the chamber run. The switching of inverters from 1 to 2 and back did not cause the illumination of the master alarm light.

The power transfer from CSM to LM and

SCHWEICKART back to CSM worked very well. On ingress to the LM, the system could be verified on CSM power by observing that the caution lamp on panel 2 was not illuminated. Subsequent to transfer power to the LM, which was manifested by momentary dimming of the lights, the caution-and-warning power lamp was illuminated on panel 2, which indicated that the system was being powered by the LM. Exactly symmetrical behavior was observed on switching back to CSM power at the end of the day. All other aspects of the electrical power system in the LM operated in a completely straightforward and expected manner.

7.4.2 Explosive Devices

The explosive devices operated throughout the entire flight as expected. In all cases, we were able to hear and/or feel the selected device go. The single exception was the second activation of the landing gear deploy. The procedure

SCHWEICKART employed in deploying the landing gear was to utilize EDS B for the gear deployment. Following utilization of EDS B, logic power A breaker was closed, B was opened, and a second cycle was made on the landing gear deploy switch so that the A system pyros would fire. In this particular case, there was no sound or feel to the second activation of the landing gear deploy switch.

7.4.3 Lighting

SCHWEICKART All the interior lighting was adequate with the exception of the lighting in the aft cabin area for stowage of the OPS on the back wall and for tunnel operations. There was acceptable but less than desirable lighting in the aft cabin. One simply had to hand hold the utility light or coordinate with the other crewmen to illuminate the area of interest.

Concerning exterior lighting, the docking lights were not visible in any way

SCHWEICKART from within the LM and could not be verified. However, one of the docking lights and the running light on the minus Y extremity of the LM could be seen from the command module. The tracking light was detectable from inside the LM and from the command module while docked and appeared as a very weak flash off the forward quads on the LM. Following staging, the light failed. We were not able to see any reflection coming off the forward quads from the flashing light. We are uncertain at this time whether the reflection we saw while docked was a direct illumination of the quad from the light or whether it was secondary reflection off the porch. We're unable to say whether, after staging, the LM crew will be able to confirm operation of the tracking light.

SCOTT The LM tracking light was visible throughout the rendezvous. As the LM

SCOTT

would go into darkness or come into sunrise, the light would blend very nicely with the transition to a reflected image. As it went into darkness, the reflected image would disappear and the light would superimpose immediately.

The docking lights are very dim, very difficult to see, and poorly positioned. If they were brighter and moved forward, so that they both could be seen at the same time, they would enhance the acquisition of the LM at night.

The tracking light was easily visible at 50 miles, and I'm sure that it could be seen much farther out. It was a very bright object at 50 miles. In the daytime through the sextant, it was visible as a flash.

One possible use for the docking lights, if they were moved forward so that both could be seen from a front view of the ascent stage, would be in determining visually range of the LM in darkness.

7.5.1 Oxygen and Cabin Pressure

SCHWEICKART The oxygen supply and the indicators on the main display panels operated in a completely normal manner, as did the ascent oxygen system. The PLSS oxygen operation was as expected. On recharge on the PLSS following the EVA, the pressure dropped in the PLSS tank. The pressure had been only on the order of 100 psi, and the buildup after opening the PLSS fill valve was very rapid. The pressure immediately went up to 900 psi, which was completely adequate for any contingency operations subsequent to that time. Therefore, the PLSS fill valve was closed immediately, and PLSS doffing was continued.

The oxygen demand system worked as expected. The cabin pressure maintained itself at 5 to 5.1 psia all through the flight when under LM control. Cabin dump and repress times were in accord with what we had seen from chamber operations preflight. The forward dump

SCHWEICKART valve filter was used for the cabin dump prior to EVA to minimize the possibility of debris clogging the dump valve. The use of this filter extended the dump time considerably. I would estimate that from the time the LM depressurization was initiated, the hatch opening time was on the order of 6 minutes. It appeared that the bleed rate below 0.5 psia was very slow. The commander was unable to break the seal on the hatch for quite some time following the indication of less than 0.5 psia on the cabin pressure indicator.

The activation of the cabin repress valve for repressurization and during the regulator checks was as expected from both the IES experience at Grumman and the chamber operations at KSC.

There is no question whatever that the cabin repress valve is open and flowing. However, once the noise level has been experienced preflight, it's a very comforting, rather than an alarming

SCHWEICKART sound when employed inflight.

The LM oxygen hoses did not present any particular problem with their interfacing with the suit. There was a good bit of interference with the restraint system. Especially on the right-hand side, at least two hands were required to reattach the restraint system to the wall of the spacecraft and to keep the hoses out from behind the restraint system.

Caution-and-warning indications on the ECS were as expected. The primary stimulus of caution-and-warning alarms in the ECS was during the regulator check. On review of the regulator check, all of the warning lights which were called for appeared to come on as expected. The pressure regulation during this check was also as expected from the experience in the chamber at KSC; that is, both regulators in the egress mode were regulating on the order of 4 to 4.1 psi. During this check, there was

SCHWEICKART no question at all that the cabin fan also was going on and off in the various switching modes. Verification on that was audible. The noise environment caused by the cabin fans was quite high. I would put the noise level in the LM cabin, particularly with the helmets off, at a marginally high level. The suit water separator check and the suit fan check call for the illumination of the H_2O SEP component light when switching separators and switching from one fan to another. Evidently, both separators spin up to a fairly high RPM, especially with the dry system; and the wait time required to get the H_2O SEP light to illuminate was rather long. We waited at one point for more than 3 minutes and had no indication of the light coming back on. However, there was no doubt that the component light was working, because on powering up the system, the component light had o been on before activating the suit fan.

7.5.2 Cabin Atmosphere

SCHWEICKART — The cabin atmosphere itself was quite comfortable. There was no noticeable carbon dioxide abnormality. The indicated CO_2 level remained at zero for a considerable length of time, and the highest reading that I remember at any point in the flight (just prior to changing the canister) was approximately 2 millimeters of mercury. The humidity level in the suit loop and in the cabin was acceptable. I never noticed any tendency to fog on the inside of helmets and never felt uncomfortably humid in the suit loop.

The cabin atmosphere, after repress on the EVA day, was noticeably different only to the extent that the number of pieces of flotsam and jetsam were grossly reduced. Most of it had found its way out the open hatch during the EVA. The circulation within the cabin

SCHWEICKART

and the noise level of the fans, as already mentioned, were very high and made operation and communications with the helmets removed very uncomfortable. At points, the intercom intelligibility was severely affected in operation with the helmets off because of the high noise level. The removal and the replacement of the CO_2 canisters did present some problem for a time. However, after a period of several minutes of tinkering, the primary cartridge canister cover was replaced. The design of this closure is very poor. The markings, although very apparent, do not materially assist in the replacement of the canister cover, and a great deal of time and effort generally are required to close that canister reliably. This is design rather poor, but at this point in the game, I don't believe it to be an unacceptable design. Hopefully, only one canister change will be required during a mission. I think that

SCHWEICKART the system is reliable enough but extremely inconvenient.

The cabin temperature control valve never was moved from the normal position, and the suit temperature selector never was moved out of full cold. Sublimation and the heat exchanger did present some problem in activation of the DFI, particularly on the systems day. It appeared to dump enough heat into the glycol loop so that the glycol temperature worked its way above the caution-and-warning trip limit. On removal of power from the DFI, this temperature would work its way back into the green band, and the glycol caution light would go out. This same behavior was not exhibited on the rendezvous day. There was no evidence of glycol in the cabin at any time. Floating particles were manifested in considerable numbers. Their removal was facilitated by the EVA. The only noticeable odors were caused

SCHWEICKART by the very high temperature of the windows with the window heater circuit breakers closed. The effect of these hot windows on the window shades when installed, and to some extent, even with the window shades rolled down, caused an odor to be exuded from the window shades. It's a very difficult odor to describe except that there was no question that it was generated by high temperature on the Mylar window shades.

The other odor that was noticed came just prior to jettison of the LM during the final closeout on the rendezvous day. There was a sensation of some mechanical piece of equipment, either a bearing or a motor, getting quite hot. It was not the pungent odor that you get from a kind of generator. I would describe the odor as close to being hot metal. I was not able to locate the source of this odor, nor did I have the inclination or time to take

SCHWEICKART a lot of time to try to locate it. It was not what I would consider a normal odor. There was no irritation of the eyes, nose, or throat, with the exception of an occasional piece of lint getting into the eye.

McDIVITT Early in the flight, it appeared that the side and the hatch window were going to steam up as they had on previous flights. There was a circular area in the middle of the window where condensation began to appear. It looked like it was a function of the temperature on the windows. There were small circular areas of condensation that would appear and then disappear. Finally, in orbit, at the end of the flight, we still had a very clear hatch window and all the other windows were clear except for window number 1, which had a lot of particulate matter on the outside. I believe this was deposited there from the urine

McDIVITT

and waste-water dumps, the port being just about directly underneath that window.

Prior to entry, the rendezvous window and the left-hand side (number 2) window had a very milky-white coating on it. The density of the coating was much greater around the edge of the window. It wasn't much of a factor unless the sun was shining on the window; when it was, it was very difficult to see through. Rusty reports that he had just a very little bit of that milky-white film appearing on the upper portion of the number 4 window.

7.5.3 Water Supply

SCHWEICKART

The water supply in the LM was quite good. The bacterial filter, which was employed throughout the flight, did not materially impede the flow of water through the gun. It was quite comfortable to put the gun in your mouth, open up the valve, and take swallow after swallow consecutively. The water itself tasted only very, very slightly of iodine, was very refreshing in all respects, and was apparently without any entrained gas. All other aspects of the water system were completely nominal.

The waste management system was not employed in the LM. However, the one large bag was used in recharge of the PLSS.

7.5.4 Water Glycol

SCHWEICKART

The water glycol system operated as expected with the exception of the glycol temperature light coming on during DFI activation and operation on the systems day. The glycol pump operation was completely normal. The caution and warning was not triggered in switching from one

SCHWEICKART

glycol pump to another. The noise level of the glycol pumps was quite noticeable, but not nearly as objectionable as the cabin fans. On activation of the glycol pump on rendezvous day, the sound thereof suggested a small quantity of entrained gas at the glycol pump but this fluctuation disappeared after a few seconds of operation.

The sublimator dryout onboard appeared to follow very, very closely the expected shape of the glycol temperature profile. However, the temperature at initiation and all through the dryout was on the order of 8 to 10 degrees above that on the graphs which were carried aboard.

On transferring from one glycol pump to another, I would guess that the tail-off on the pressure indicator took less than a second, as did the buildup on the other pump. AUTO transfer from one glycol pump to another operated normally in the check of that system and was triggered at no other time than when it was called for.

SCHWEICKART Operation of the suit circuit was compeletely normal. The noise level due to the suit fans was noticeable but not objectionable.

7.5.5 Suit Circuit

SCHWEICKART The comfort within the suit circuit was adequate. At one point during the operation of the ECS, manipulation of the suit gas diverter valve and the cabin gas return valve was apparently reversed in the checklist. This caused the suit loop to pull down around us to a slight extent. Then it chugged until we got the suit gas diverter valve into the cabin mode. This is not a malfunction of the system, but a criticism of the procedures.

7.6 Telecommunications

SCHWEICKART — The operation of all the communications gear on the LM was satisfactory.

7.6.3 S-band

SCHWEICKART — There was, from time to time, unexplained noise and interference in both the VHF and S-band operation. This degraded performance was never correlated with any other systems operation or geometry of the spacecraft, or ground/LM geometry. It did not in general appear as clean as the operation of the TELECOM in the command module. The high-gain S-band antenna was never moved from its stowed location throughout the flight. Down-voice backup on the S-band, as mentioned earlier, presented some degree of mystery in that, with down-voice backup employed, the INTERCOM BUS would be transmitted live by S-band. This apparently was not the case during the test and no explanation of that is presently available.

7.6.4 VHF

SCHWEICKART

The PLSS EVA COMM worked very well, in fact, considerably better than we anticipated from preflight testing. While on the PLSS in the LM cabin, I was able to hear not only the VHF from the LM but also VHF from the command module, and on several occasions, VHF directly from MSFN. The converse was also true; the CSM was able to read communications from the PLSS directly radiating through the cabin. The CSM one-way relay, with the PLSS internal to the LM cabin, worked as designed and MSFN was able to read PLSS data prior to the EVA.

7.6.5 Audio Center

SCHWEICKART

Operation of the audio centers was again as expected with the exception of the LMP's audio center on the rendezvous day in which case the PTT capability had failed both on the ACA and also on the umbilical. Therefore, the VOX was employed in order for the LMP to transmit

SCHWEICKART throughout the entire rendezvous day, which brings up another good point, and that is that the VOX operation on the LM was excellent. The attack time and release time on the VOX is very, very satisfactory.

7.6.6 Flight Recorder

SCHWEICKART The onboard voice recorder apparently worked without any problem. The primary inconvenience or difficulty with a voice recorder is remembering to turn the recorder switch on and off in order to conserve tape. This proved to be a problem throughout all the simulations and the same inadvertent operation was witnessed during the flight, both in acts of omission and commission throughout the LM operation. Subsequent to the flight, we listened to the quality of the voice on the recorder. It is apparent that the noise level due to the cabin fans, the suit fans, and the glycol pumps significantly degrades the voice quality on the recorder when the recorder is left on

SCHWEICKART continually and these other systems are in operation. During the EVA portion of the flight, the cabin fans were off and the background noise levels were very, very low. The quality of the voice was excellent during that time. However, when operating the recorder in the VOX mode, the whole tape was (during the EVA) filled with beep, beep, beeps, and the first word or two of every conversation was clipped.

7.7 Mechanical

SCHWEICKART I would like to mention that the window heaters on all three windows were, in our opinion, overdesigned. The windows would get extremely hot to the point that the Beta cloth surrounding the windows and the window shades, the part touching the windows, would get so hot that they gave off objectionable odors. Also, when operating near the front windows with the helmets off, the closest analogy that could be drawn would be that of standing quite near an open fire. The radiation

SCHWEICKART from the windows was very noticeable on my face. Because of the high temperature that the windows reached, we asked and received approval for deactivating the heaters. Following the deactivation of the heaters, I did not notice any fogging or clouding of the windows. On first entering the LM on the rendezvous day, there did appear to be some moisture condensed on the window, but shortly after stowing the window shade, that moisture evaporated by itself. The windows throughout the flight of the LM appeared to be very clean. There was no noticeable fogging, milking, deposition of debris, or coatings on any of the windows.

McDIVITT In looking through the docking window, there were some noticeable pieces of debris as I had mentioned earlier. A washer between the inner and outer pane of the docking window floated back and forth across the field of view when I was trying to do docking. It was not a factor in any case.

McDIVITT There were a number of things in the LM that did not fit very well and proved to be a problem. The major one was the OPS pallet. It is supposed to fit on the aft wall of the spacecraft in a rack that has a large pin that goes through the rack and into the pallet. I could not get the pin to fit through the rack without the pallet in it. As I pushed it down, I couldn't get it flush so that I could turn it and lock it. The Beta cloth netting in the area was in the way, but even when I pulled the Beta cloth netting away, I was still unable to get it to fit. During the systems day, the OPS pallet was found floating loose after the docked DPS burn. On the EVA day and on the rendezvous day, I put it back in the same area and put the pin in and took the Beta cloth netting that was around it - around the handle - and draped it over the handle in such a way that it held the handle in and I was able to keep the pallet restrained to the back wall. There are

McDIVITT some snaps on the helmet bags that are there to stow the helmet on either the floor or on top of the ascent engine cover. The snaps pulled off, the little straps that fastened the helmet to the floor or the ascent engine cover, and while lightweight, they were certainly marginal for operation. I ended up with one helmet bag with either no snaps or no tabs to snap it to the ascent engine cover, and the other helmet bag had only one snap that was usable. The ISA didn't fit as well on the stowage area on the left-hand side of the spacecraft in zero g as it did in one g. The little hooks kept sliding out of the hole before I could get the next hook fastened, taking an abnormally long time for installation. The Beta cloth, as I mentioned earlier, fitted around the OPS pallet and over the top of the PLSS batteries in the back, but did not fit on the snaps very well. I got it unsnapped from around the batteries and was unable to resnap it. This was no

McDIVITT great problem, except it provided a hole for any loose equipment to slide back into the aft equipment bay, and once back there, it would have been impossible to retrieve. So I spent some additional time stringing the Beta cloth netting back together and trying to snap it where I could get it snapped to provide some sort of a covering to keep unnecessary equipment out of the aft equipment bay.

I might comment on some of the things that were extremely useful, one of these being the data file and the cards. The data file provided us the information that we needed. The instrument panel cards that were placed on the instrument panel on top of the Velcro provided an excellent source of information during critical periods, such as the docked DPS or during the rendezvous. We found that they stayed on the instrument panel very well and were a great asset. It also turns out that the little PBI straps, snaps and strap combination, with the little pieces of

McDIVITT Velcro provided an excellent place to stow checklists, pencils, gloves, and like items.

The restraint system appeared to be designed more for the lunar-landing case than it was for an in-orbit case. The anchor points for the restraints tended to pull the crewmember on the left side towards the front so that I ended up leaning to my rear and to my right at an angle of about 30 degrees from a perpendicular to the floor — during 95 percent of the mission. The only time that I did not do this was during the docking and during some of the burns when I had to have my hands on the translation controller and rotational controller at the same time. The Velcro on the floor and the Velcro on the bottom of the boots worked reasonably well. It was not sufficient to hold one down for any lengthy period of time but for short periods on the order of 15 seconds or so, it helped to hold you there.

8.0 MISCELLANEOUS SYSTEMS, FLIGHT EQUIPMENT, AND GFE

8.1 Cabin Lighting System and Controls

SCOTT — We had three malfunctions of the CSM flood lights. In the LEB, the variable lighting on the right-hand X-X strut, as you faced the LEB, failed OFF. The right-hand light on the left couch failed in the variable position. The left-hand light of the right couch got hot, got much hotter than the other lights and was turned off. This one was in the fixed position. This latter light got so hot we could actually smell it.

McDIVITT — The lighting underneath the couches was inadequate. Any time the coolant and control panel needed to be inspected, or a valve changed, it was necessary to obtain a flashlight and direct it to the point of interest. It is suggested that perhaps something like the lights used in the tunnel be provided in a strategic location to illuminate the points of interest under the couch.

8.2 Clocks

SCHWEICKART The clocks worked, at least as could be detected, without any failures or anomalies.

8.3 Event Timers and Controls

SCHWEICKART This is also true of the event timers and the controls. One small change we noticed in flight on the event timer was that we would lose 1 second on initiating the event timer. That is, if the clock were set up to 59:59 in simulations in the LMS, when the DSKY display reached 59:59, we would hit the start switch at that time and 1 second later, the DET would drop to 59:58. However, in the flight configuration, the display of 59:58 would come up immediately on starting the clock and this took a little getting used to.

8.4 Crew Compartment Configuration

SCHWEICKART The crew compartment configuration in the LM was not significantly different from what we had seen on crew compartment fit and

SCHWEICKART

function. The operation of the OPS pallet and transferring it from the floor to the aft-equipment bay and checking out the OPS's, in general, were slightly easier than we had expected from our training. The modified capture pins on the OPS were easily removed and replaced on the pallet which made the checkout of the OPS's quite simple. The mirrors in the LM were not employed at any time.

SCOTT

On the command module side, the stowage areas were adequate; however, the configuration of the stowage could be improved so as to facilitate the use of the equipment in flight. Many times we had to go to a number of different locations scattered around the spacecraft to accumulate the equipment necessary for the particular function of interest.

8.6 Clothing

SCOTT

The exterior of the PGA's were extremely worn on all three suits. The CMP suit was worn mostly in the arms and the el-

SCOTT: bows due to working in the tunnel. CDR's suit was worn primarily on the back of the shoulders, and the superinsulation could be seen poking out between the layers of Beta cloth.

McDIVITT: When I first operated in the tunnel and took the hatch out shortly after transposition and docking, I wore the protective visor over my helmet and I am sure that I did not damage my helmet then.

I took very good care of it until I got over in the LM and I had to thrash around in the back of the LM with that OPS pallet that didn't fit and tried to get it off the floor and back on the back walls, and then back down on the floor and move the helmet bags around and the PLSS and all these things. While I was doing this, I was bouncing around in the LM quite a bit. I was able to protect the front of my helmet quite well and it did not end up with very many marks on it. As you could see, we had it available for exami-

McDIVITT — nation. The top of my helmet was very badly scarred and I think that this was a factor in the rendezvous. There were some great big long, wide, quarter-inch wide or so, scrapes. I am not sure exactly where I got these things. If I had to guess, I would say I got them somewhere in the back of the spacecraft when I was trying to operate with the pallet, although I can't be sure of this.

My lightweight headset failed after 2 days, I believe. I was no longer able to transmit with it, but I was able to receive. From that time on, we operated with two lightweight headsets between the three of us.

SCOTT — Due to the bunny hat, I got some sort of skin irritation which caused the skin on my forehead and cheeks to get red and dry out. As soon as I quit wearing the bunny hat, after the first 5 days, it cleared up.

McDIVITT — When I launched with my UCTA, I had a

McDIVITT roll-on cuff that fit, and I thought that all the UCTA cuffs were the same size. However, after having used it the first and second day, I decided to replace the used one with a new one. I took the used one off and threw it away and put a new one on. After I had thrown the old one away, I found that the new one was considerably larger than the one I had launched with. I went back into the locker that had all my roll-on cuffs in it and found out that all of my UCTA cuffs were the same size and were way too large. Unfortunately, I did not have time to look around and find the old one because we were running late, as usual, and I elected to go with the one I had on, which proved to be semi-disastrous since the UCTA leaked all over the place for that day. Later, I was able to borrow one of the other cuffs and used that for the remaining days that I had to wear the UCTA. My UCD, on the other hand, had a set of roll-

McDIVITT — on cuffs that fit properly. I used the UCD with excellent results; no leakage, and everything worked the way that it should have.

SCHWEICKART — My experience with the UCTA and UCD was exactly opposite to that of Jim. That is, my UCTA cuffs were very adequate and the UCD cuffs were too large. As a result, and since we had aboard the special fitting to dump the UCTA's through the waste management systems, I elected to use the UCTA throughout the flight. The mode of operation I employed was to urinate into the UCTA and then dump it. I never did use the UCD.

SCOTT — Mine worked fine.

8.7 BIOMED Harness

SCOTT — The sensors on the BIOMED harness began to itch after about 5 days and were uncomfortable for the rest of the flight. The electrode paste on the CMP and the LMP dried out and had to be replaced. The CMP's dried out after about 5 or 5-1/2

SCOTT days. The LMP's dried out on about the 9th day.

8.9 Crew Couches

SCOTT The couch and everything worked as advertised. The only problem encountered was disconnecting the Y-Y beam or the center couch. The beam required a considerable amount of force to disconnect the first time it was disconnected. This probably could have been because of the forces during launch. Another problem we had was with the Y-Y struts. We had a great deal of difficulty locking and undocking the Y-Y struts. Finally, we were able to manipulate the struts with a lot of shaking of the whole couch and this occurred on both sides of the couch — the plus and minus Y-Y struts. Once we got them locked, the couch was firmly locked in place.

One more recommendation on the mechanics of the spacecraft — on the lithium hydroxide canister door. A spring-retention

SCOTT

clip, or something, could be provided to prevent the necessity of using tool E everytime that it is opened.

In the CSM side for an EV transfer, no restraints are really necessary. The hoses provide adequate tethering and you can move from the hatch to the couch and remain in the couch with no difficulty.

8.10 Restraints

SCHWEICKART

I'd like to mention that the golden slippers on the front porch of the LM functioned as expected from training. These were employed in the training in the WIF and functioned in flight as expected. They permitted good control of body position with no tendency for the boots to slip out of the restraints. The handrail which runs up the front of the LM for EV transfer was completely adequate for the job. In fact, the contingency transfer requires less concern over body position control than did our EVA and yet I had no trouble whatever in main-

SCHWEICKART taining complete control of body position through the mobility provided in the EV gloves and the wrist joint of the suit. The use of the tether as a transfer device for transporting equipment in and out the front door of the LM was judged to be quite good, with the exception of the case where it was employed with the sequence camera. In this case, the power cable for the sequence camera which is a telephone-type extension cable supplied enough force on the camera to cause it to continually contact the upper regions of the front hatch, thereby changing the positions of some of the controls on the camera and doing some slight damage to the camera in passing it in and out. In the case of the other equipment, there was no problem at all.

McDIVITT I found out the amount of Velcro in the area of the main display console, the window, and other areas that could be reached when a person is in his seat was

McDIVITT inadequate. Many pieces were in places where they were completely inaccesible unless you had a flexible object that could bend around corners. I suggest that maybe some of the useless pieces of Velcro that are around the edges of the floor and side panels and other inaccessible places be removed or certainly relocated to more usable places.

SCOTT The MDC bars that were installed prior to the EVA were very useful throughout the rest of the flight, except for the left one which covered a portion of the DSKY. The center and right ones were retained for the rest of the flight for protection against the switch panel. They also provided convenient locations for attaching data books.

8.11 Flight Data File

SCHWEICKART The flight data file in the LM was quite adequate. On opening the flight data file, there was no pronounced tendency

SCHWEICKART — for the data to drift out into the cabin. It all behaved in a very satisfactory manner. We anticipated some problem with this from our preflight work.

8.14 Thermal Control of Spacecraft

SCOTT — We did cold soak starting about 3 hours prior to reentry and were comfortable throughout the reentry.

8.15 Camera Equipment

SCHWEICKART — The use of the camera equipment in the LM turned out to be no problem. The large windows made handheld Hasselblad pictures out the front windows quite simple; however, operation of the 16-mm camera was a little more difficult in that there were no predesigned attach points or brackets mounted in the LM to facilitate this operation. The utility light universal bracket was used in conjunction with the Maurer camera on the crash bar over the LMP's window in order to take photographs along the Z-axis, and this proved to be satisfactory.

SCOTT We had a sequence camera problem during the EVA and the superwide-angle Hasselblad shutter timing was incorrect; both of those have been mentioned before. One small 65-frame Hasselblad magazine jammed and in the process of the magazine jamming, one of the standard Hasselblads got jammed.

9.0 VISUAL SIGHTINGS

9.1 Countdown

SCHWEICKART — There were no visual sightings in the countdown, during powered flight.

9.2 Powered Flight

SCHWEICKART — The only visual sighting I had was the ... boost protective cover of the LET. I was able to see the LET over the boost protective cover while the engines were still running. ...

MCDIVITT — During the countdown I saw very little since I had such a small window. I saw a little cable out the window, when they swung the swing arm back, it went away. During powered flight I saw nothing at lift-off except an object that came from behind the instrument panel and bounced off my helmet and down into the lower equipment bay. I don't know what it was. Somewhere during the powered flight, with the boost-protective cover on, I could

McDIVITT	see some smoke wafting across the left-hand rendezvous window between the glass in that window and the glass in the boost-protective cover window. Staging, ignition, S-IVB ECO, I didn't see anything. I was looking into the spacecraft almost all the way through the launch. I glanced out once or twice and saw the horizon going by, but no important sightings during powered flight.
SCOTT	I saw very little during powered flight because I was watching the DSKY most of the time. I did take one look at the BPC window at the horizon and noticed quite a bit of debris in the spacecraft at first-stage cut-off.

9.3 Earth Orbit

SCHWEICKART	In earth orbit there were no manmade objects sighted, aside from the Pegasus satellite. I did see a few geographical landmarks, and a few clouds. I was dark-adapted one night pass as well as possible. I drew a picture of the dimmed

SCHWEICKART

stars of Canis Major I could see. After correlating these with the Star Atlas it appears that the dimmest object that I saw was two stars very close to the sixth magnitude. Also one other star of the sixth magnitdue was located immediately next to the open cluster M41.

The other celestial sighting of note was the airglow. We were well dark adapted. Dave Scott and I were looking at the airglow. We observed the normal band of dim light several degrees above the earth horizon which appeared to be slightly reddish on the underside. Perhaps by constrast, it appeared slightly green on the upperside. We both noticed another more dimly lit white layer about twice as far or three times as far above the apparent airglow layer. It was a very, very tenuous layer and was just barely discernable.

It was positively identified by all three crewmen. This was observed 5 to 15 minutes prior to sunrise. At about 5 minutes prior to sunrise this layer disappeared, SCHWEICKART — or thinned out to the point where it could not be discerned; however, the lower airglow layer was still visible. The thickness of this upper layer was perhaps one or two degrees in vertical extent.

MCDIVITT — The most important ones were the sightings of Pegasus through the diastimeter and the sighting of the LM ascent stage throught the sextant, which we have already discussed here in some detail. Some of the data uplinked to us from the ground for the time of closest approach to a landmark seemed to be somewhat in error. When we took S065 photos, we occasionally took pictures of things that didn't look like were the targets, although they may have been. A couple of times we took pictures of the water after we crossed some beautiful landscapes. We were informed on one occasion that we were trying to get photos of oceanography. There were some times when we were doing landmark tracking when our time of closest

MCDIVITT approach, which was a critical parameter in the roll rate that was being established, looked to be almost 30 or 45 seconds in error and significantly influenced the performance of the landmark tracking at that critical time.

SCOTT Rusty discussed the airglow that we saw through the windows. The airglow through the sextant during a sunrsie appeared red, a slight red band at the top of the airglow as the sun came up.

9.4 Reentry

SCHWEICKART During reentry there was a considerable spray of debris at CM/SM separation which was seen through all windows. The ionization became visible as a nearly homogeneous reddish or pink glow surrounding the spacecraft at about 0.01g. This gradually localized to the point where there was an extremely bright orange trail behind the spacecraft from 0.2g on down through MAX g. I did not observe when it disappeared. The brightness of this ionization trail

SCHWEICKART was considerably stronger than the horizon which was covered with white sunlit clouds. The brightness was nearly strong enough to make the instruments difficult to see after looking out the window.

The drogue and main parachutes came out as expected. On main parachute deployment, the third chute, or one of the three chutes appeared to be hidden between the two outer chutes until after disreefing.

McDIVITT During reentry the color of the ionization sheaths was significant. I found it to be much different than the one I saw during Gemini. This one was all orange and I never did see any other colors in it except orange. It varied from light orange to dark orange and bright orange to dark orange, but I never saw any other colors like red or green — the colors I saw in Gemini. It was much, much brighter than the ionization sheath experienced in Gemini. I looked out the side window one time during reentry and

McDIVITT I could see fairly large particles passing by the window at a reasonably high rate, going back joining in the ionization sheath. I didn't spend too much time looking out the window, I was monitoring the reentry. When the drogues came out, there was a big bang and a bunch of debris. The two drogues went up and were easy to see. And when they went off, the mains looked to me like we had two mains rather than three. When they started to fill with air, the third one sort of popped out of the right-hand one. It was obvious then that we had three and they disreefed together. I saw three small squares missing from one chute and one small square missing from another chute. When we finished dumping the command module RCS propellant we had a big red cloud come out and envelop the chutes and then pass by.

SCOTT I took a couple of looks through the hatch window during entry and also saw

SCOTT the bright orange sheath. I had the impression that it was much brighter than Gemini. I noticed that just prior to 0.05g, when I looked out the left-hand side window there was a reddish-orange glow all around the spacecraft. I guess the ionization sheath started to appear somewhere around 0.01g or 0.02g, and I did get a pretty good view of the main parachutes through the hatch window.

SCOTT After the chutes came out, I had a real chance to look at the windows. I noticed the windows were coated with something, and the coating was burned and cracked and had started to peel up. After we got down in the water, the coating was still there and it was as if the windows had been coated with some clear substance and the heat of reentry had caused this clear substance to crack and curl up and peel off the window in a number of places.

9.5 Landing and Recovery Sightings

SCHWEICKART There were no particular visual sightings of note during landing and recovery.

10.0 PREMISSION PLANNING

10.1 Mission Plan

MCDIVITT

The basic mission plan was established about 3 years ago and stayed essentially the same. The basic mission plan was never changed, although is vascillated between two S-IB's and Saturn V and back to a couple of S-IB's and finally back to Saturn V. We had a double-bubble rendezvous in it one time, and then back out again. But the idea of EVA, systems A checkout of the LM, rendezvous, separated rendezvous, the demonstration of the docked SPS engine firings, all those things were exactly the same as we initially started with.

10.2 Flight Plan

McDIVITT

The flight plan evolved over the last year and was constrained by many things. The flight hardware, the availability of ground sights to support the inflight test and many things like that, that could really

MCDIVITT enter into the flight planning details would take about 4 or 5 months. I think the basic concepts were those that had grown up over the previous three years, and when we got in flight we found that the basic flight plan did not have to be changed drastically and we were able to follow it quite closely.

10.3 Spacecraft Changes

MCDIVITT The spacecraft changes were once again a matter of evolution. CSM 104 changed as a result of Spacecraft 101 and 103, and also many stowage exercises, EVA exercises, rendezvous exercises. The LM-3 changes were also dictated by many things, weight saving programs, different types of wiring, and schemes between LM-2, LM-3 and LM-4. Here again the change process is beyond description.

10.4 Mission Rules

MCDIVITT The mission rules for this particular mission were different than they had been on previous flights because we were faced with a problem of having one spacecraft

McDIV::TT separated from the other one. If either on had a problem, the solution wasn't necessarily to reenter at the next best planned landing area, as we had to get the spacecrafts back together. It took a little evolution, but we finally ended up with a set of mission rules that had the same concept. When the spacecraft separated, we did everything possible to get it back together. With certain pieces of equipment inoperative, we would still go ahead and do our separations and maneuvers. We tried to put priorities in the objectives. The highest one was the separation activities between the command module and the LM. I think the next one was the docked DPS burn to evalute the LM systems as best we could, since this seemed to be the pacing item in lunar landing, and we finally ended up with a consolidation of the mission rules all on one page of paper in a graph form we carried with us in flight. Fortunately, McDIVITT we were never faced with the problem of trying to intrepret the mission rules and apply them to an inflight situation.

11.0 MISSION CONTROL

MCDIVITT Before we get into any specific items, I'd like to say that Mission Control actually had to evolve a whole new concept of being able to control two spacecraft separated at the same time through sites that were S-band only equipped, VHF, and S-band equipped. Some were equipped with voice and others with TM. Some of the sites had command capability. It was a real complex mission facing the ground control team. I think they did an absolutely superb job sorting out all the out all the problem areas, and planning for the contingencies. Only through some very hard work, with long hours, were we able to sort out the ground and airborne situations so that we could run a reasonable simulation. Through these simulations, we were able to work out the techniques that we actually used in flight. Without the ground simulations prior to launch we would have been in absolute

McDIVITT shambles in flight trying to control these vehicles and do the flight as we had planned.

11.2 Updates

MCDIVITT We had a marvelous rapport with the flight controllers. We had discussed many times a bsic philosophy that we would use during the flight. This philosophy was to pass as much information as the ground could possibly pass without interfering with the mission that was going on at the time. And they were able to sort out the good pertinent information from some of the less pertinent, although I must admit there was very little less pertinent information.

11.4 Flight Plan Changes

MCDIVITT We had an understanding that real-time flight-plan changes would be more than welcome. I should say that the ground control team at the end of the first 5 days were able to work out a flight plan for

McDIVITT us that kept us entertained, busy, and gathering some extremely useful information that wasn't even considered, as far as I know, before the flight.

12.0 TRAINING

12.1 CMS

McDIVITT	We had assigned to us, at one time or another during our training for the flight, all three of the CMS's.
SCOTT	The simulation of separation might tie in with the difference that was noted throughout the flight concerning the pyros. Every time we actuated pyros in flight, we got a very large bang; whereas the simulation was sort of a soft beep. A loud bang might be somewhat more realistic. On the visual, it is recommended that the proper star patterns around the navigation stars be put in the sextant field of view for alignments in navigation. For rendezvous tracking, perhaps an image of the LM in the sextant relative to the range of the LM from the CSM and an image of the LM in the telescope would be an improvement. This is not quite as significant as the sextant.

SCOTT In flight, the telescope provided somewhat better light transmission than the one in the simulator in that, after proper dark adaptation, more stars could be seen through the telescope in flight than could be seen in a simulator. However, with 2 to 3 minutes of dark adaptation, the inflight view was very comparable to the simulator view as far as the number of stars available or visible.

The following concerns the relative size of the LM through the CSM windows, the telescope, and the sextant. The rendezvous timeline was laid out so that a visual tracking through the windows of the LM occurred only just after the separation burn and just prior to the braking maneuver. At these times the LM was visible in its complete form until it went into darkness at about 3 miles. The ascent stage of the LM was visible after it appeared at sunrise, at somewhat less than 3 miles during the braking phase.

SCOTT Through the sextant, the foot pads on the descent stage were still visible at about 50 miles; and the entire LM still made an image inside the sextant which was about the size of the double lines in the sextant reticle at 60 miles. During the terminal phase, as the LM appeared in sunlight after CDH at approximately 70 miles, it was a definite very small image; but it was more than a point source in the sextant.

Relative to the mission capability, the actual flight COMP cycles appeared to be somewhat slower than the simulator computer's COMP cycles. This was expected, based on evaluation of the CMS and the MIT hybrid prior to flight.

Another capability that might be improved in the CMS is the simulation of bending and slosh. These were not available for docked burns — CSM-LM docked burns. On the Mission Evaluator, the bending and slosh were significant factors in evaluating the stroker and MTVC. These were

~~CONFIDENTIAL~~

SCOTT	not available for simulation in the CMS. Relative to the availibility of the CMS, we decided that, for the complexity of the mission, it was not available enough to complete as much training as we would have liked — both in three-man operations, and one-man operations. There is a certain tradeoff between the time required to bring the simulator up to speed, and correct discrepancies versus the time available for crew training. We never did get to the point where the docking visual display was exactly right and where the COAS target alignment was exactly right. We continually had problems with that particular area. Also, we never had the capability to extract the LM from the S-IVB.
McDIVITT	On the CMS, there were a couple of items that really needed a little more fidelity than I thought we had. I thought the lack of a 504 boost tape until shortly before launch was an unnecessary problem. We did a lot of simulations, using the

~~CONFIDENTIAL~~

McDIVITT wrong time for the S-IC engine shut down; and everything was wrong as far as the times went. We did many, many, many simulations that way and very, very few with the correct times involved.

I also felt that the EMS and the reentry displays could have been a little more high fidelity and a little bit more operational. We didn't have that many hours set aside for practicing reentry. If the equipment wasn't operating when we did practice them, there just wasn't any way of coming back and picking it up at a later date.

As mentioned earlier, the availability of the simulators, especially in the last two months before the flight — or rather the lack of availability for certain times, put the major glitch into the training cycle. It caused the training program to be concentrated entirely on the prime crew for the last 3 or 4 weeks. Elimination of the training of the backup crew put us in a very poor posture, in case something

McDIVITT had happened to the prime crew late in the ballgame.

12.2 LMS

McDIVITT We had assigned to us, at one time or another during our training for the flight, both of the LMS's

McDIVITT In the LMS, I believe we could have had a little better fidelity in the docking and undocking presentations. We were never able to dock more than one day, I believe. The command module was always rotated so that we were docking with the COAS pointing into approximately the left-hand rendezvous window in the command module, rather than the right-hand rendezvous window. Considering the fact that we were operating in a very weird coordinate system — where the hand and the eye of the person doing the docking in the LM aren't necessarily pointing in the same direction — there's a need for some training here so that the coordination between hand and eye is better. We get this only through pratice, and we really weren't able to get

McDIVITT that kind of practice in the LMS. Forunately we had a docking trainer here in Houston that we used.

The right-hand visual display of the command and service module did not operate in LMS-2 until approximately 1 week before launch. The stowage of the LM was certainly adequate, and the availability of the LMS was very good. However, we had a few problems within the last two crucial months, but availability of the LMS prior to that time had been very good.

One major draw back on the LMS was the lack of authentic systems failures. We would have been a little bit sharper on our systems failures if the representation of these in the LMS had been a higher fidelity.

SCHWEICKART I would consider the visual simulation quite good with the exception of the AOT operations in performing alignments. It approaches the unacceptable region — because the chip mirror in the AOT simulation is located in the middle of the field of view and required very large

SCHWEICKART excursions in yaw and pitch in order to get an adequate mark on a star for an alignment. The effect of this in pulse mode is to prolong the alignment procedure to the point where it takes four or five times the actual time it took in flight. It also uses a considerable amount of fuel. This then severely distorts the picture of the time line.

12.3 CMS/LMS Integreted Simulation

McDIVITT We also managed to inegrate LMS 2 and CMS 3, LMS 2 and CMS 2, and LMS 1 and CMS 1. So, we spent a good part of our training time integrating the simulators and consequently lost a lot of valuable time working out the bugs in the simulators.

We finally wound up the last 2 months of the training phase with CMS 2 and LMS 2 integrated at the Cape. I think the simulation program that we had was considerably different than any of the previous

McDIVITT flights. It appeared to us that the most difficult portion of the mission, and the one that needed the most training, were those portions where we were doing the integrated spacecraft operation with the LM on the systems day, where the LM spacecraft and the command module spacecraft had to work together.

The rendezvous was another very important area where we had to have the two spacecraft work together and had many techniques that had never been tried before. We had to work these out, discard the unusable ones, go over the good ones, and modify them to make them even better. We had to work out the procedures that we finally ended up with in flight. So, we spent an abnormally large percentage of our training time, I believe, in the integrated operation rather than in practicing things like launches, reentries, and the other orbital operations that were less new, although not necessarily less critical.

As we approached the end of the training

McDIVITT — cycle, it became apparent that some of the things we had in the flight plan, such as landmark tracking and S065, we would not be able to train for in the manner that I considered to be adequate for flight. On the other hand, they had considerably less priority than the ones we figured were safety flight items and certainly extremely important, we elected to put these aside or to train only a very small amount on them. Fortunately, with good writeups and so forth, we were still able to conduct the orbital operations in an adequate manner.

12.4 Simulated Network Simulations

McDIVITT — As I had mentioned under mission control, our CMS/LMS/MCC-integrated simulations were an absolute requirement prerequisite for the flight. We were having a great deal of difficulty achieving any sort of success at all with these during our first month of integrated simulations —

McDIVITT integrated with MCC. Finally, they became the constraining item on launch. It became apparent that we might have to slip the launch date just because of lack of integrated simulations. However, about 2-1/2 weeks before the launch, we were able to achieve a successful rendezvous simulation and a successful systems day simulation. These particular simulations demonstrated the techniques that we had hoped would work, but we were never able to really demonstrate this in practice. After that week of simulations, we were able to proceed on with the procedures that we had. At least we had the confidence that we knew what we were going to do in flight.

The simulated network simulations are far and above the best training that we got. The simulations are much more realistic than when we're operating by ourselves, because the information that we got from the ground was an integral part of what was happening in flight. We have to know

McDIVITT what the ground input is or we are just fooling ourselves. When we were trying to run the rendezvous integrated simulations without the ground, it was only 20 percent effective, as if we had the ground. We were unable to make solution comparisons. We were unable to really find out what the problems would be in flight when operating only between the command module and the LM. But, as soon as we integrated the Mission Control Center, we were able to really get to the heart of the problems, and work out the details, and solve them before flight.

Launch, reentry, and other simulations with MCC are also far and above the best of that kind of training we got.

12.5 <u>DCPS</u>

McDIVITT The DCPS was a good training device for looking at specific launch vehicle failures, to see how the total launch vehicle responded to these, and to get the quick training that was necessary to make a good judgment in case anything had gone

McDIVITT wrong during launch. I launched with the feeling that I understood all the launch problems that I could get into. I didn't feel that I would be doing any inadvertant aborts nor did I feel that I would be letting the launch vehicle go through any regime whereby we could not abort safely. We had one session in the DCPS with all three crewmembers suited. We found this to be an excellent training device, but not something that needed to be repeated many times.

12.6 LMPS

McDIVITT The LMPS was a good training device. When we were working out the initial procedures for rendezvous, we were able to quickly reset and run through the procedures. As it says, it's a procedures trainer and that was exactly what we used it for. After we'd worked up the procedures, we went to the LMS and worked out the higher fidelity techniques on the LMS.

12.7 CMPS

SCOTT

The CMPS, was a good procedures trainer but only from the standpoint of initial procedures or familiarization. As far as an evaluation of capabilities of the computer or refinement of precise inflight time lines, it was not of high enough fidelity to do that. The computation cycle was not exactly the same as the actual CMC. In fact, the flow, relative to the GSOP, was not exactly precise. The solutions seemed to work out a little better than what we had experienced in the other simulators. In other words, it was easier to get a convergence of a solution in an acceptable burn. But, it was valuable as a beginning trainer on computer programs.

12.8 NR Evaluator, GAEC FMES

SCOTT

The NR evaluator was a good tool to evaluate the precise timeline that could be expected during the rendezvous. This was particularly true because of the

SCOTT

difference in the COMP cycles in the CMS and the core rope simulator. Because of the criticality of the timeline, from the command module standpoint during the rendezvous, it proved invaluable for ensuring that adequate time was available to perform all the functions included in the checklist timeline.

The NR hardware evaluator was used to evaluate the stroker tests in the MTVC. It proved to be a very good simulation of both tasks. One of the more valuable aspects of the hardware evaluator was its capability to fail pieces of hardware during a long automatic or MTVC burn; and after successful corrections of the failure, they could take the failure out and insert another one without having to reset or to start the problem over. The mission evaluator was also valuable in software verification relative to crew procedures and timelines for the COLOSSUS 1A program.

SCHWEICKART I thought that certain aspects of the FMES operation were more desirable than the LMS. In particular the AGS simulation also the 8-foot chamber runs in the CSD chamber. All were very useful in regards to familiarization with the EVA equipment. It also helped build confidence and familiarity with the various peculiarities of operation of the EMU. I thought these were very useful.

12.9 Egress Training

McDIVITT I thought the water egress training in the tank and in the Gulf were good exercises; however, I feel that this kind of training should be done early in the training cycle. I do not feel that it should be done in the last 3 or 4 months before the flight regardless of how important some people think this is. It's an important type of training, but not the kind of training has to be done shortly before flight. If we did it 5 or 6 months before flight, we could concentrate on those things that require a really high degree of skill and cunning towards the end of the flight and not so much on the procedures and that kind of thing. Our crew has had a number of water egresses. I believe we've had some from old spacecraft 12, and we did some from 101. I think we went through the water tank three or four times — at the pool at Ellington a couple of times, and in the Gulf a couple of times. I think that's

McDIVITT perfectly adequate egress training, and I certainly don't think it ought to be held until late in the training program. The pad and mockup egresses that we did down at the Cape wer of some use; however, I think that in doing these things close to flight time (running through the fire training and so forth), we were really wasting valuable time. If this kind of training is required, it should be done a year before the flight. The use of a carbon dioxide fire extinguisher or a powder fire extinguisher doesn't change. Once we have done that kind of training, we should not have to do it again. It should be moved as far from flight time as possible, so that we can use this time for developing those techniques that really require some skill and cunning. The last two months, maybe even a little longer than that, should be devoted entirely to CMS LMS training, really developing the required techniques. All of the gross training, planetarium, McDIVITT water egress, pad egress, wif, zero g, and those kind of things should be put early in the training program. All these should be moved as far from launch date as possible. There are some things, like the last minute systems briefings and maybe some software briefings, that have to be conducted towards the end. There just has to be some reasonable training period of 10 to 12 hours a day that the pilots are subjected to rather than this 16, 18, and 20 hours a day that we were faced with during the last 2-month period. This was an accumulation of a lot of little odds and ends, plus the lack of availibility of the simulators at the appropriate times. It created a hardship on the crew, having these long, long days without breaks. This should be avoided by moving whatever training that can be moved to as early as possible.

12.10 Planetarium

McDIVITT

Our planetarium training consisted of, I think, three trips to the Griffith Planetarium on about 6-month centers, with the last trip being approximately 6 months or so before the flight. These trips, I think, were very worthwhile. During our flight, we used a number of the south stars, and they are just not available flying around at night looking out of an airplane. We had a lot of other star training, using the star balls in the LMS and the CMS; but I think that the get together of the crews and really taking a big picture look at the skies and getting the little helpful gouges that help one person identify the stars was certainly valuable. I don't think we should ever eliminate planetarium training.

This also falls into the category of one of those things that you want to do maybe 6 months or so before the flight. Every individual has a different way of finding

McDIVITT a certain star. By getting five, six, eight, or 10 people together and discussing each person's gouge on identifying a star, we are able to spread a little bit of this knowledge around. We were able to pick up some of the other fellow's gouges.

12.11 MIT

McDIVITT The MIT briefings on the flight programs were an invaluable aid. There's no way of learning the programs by sitting down and reading the GSOP, which is a help; but this is not the best way. To discuss the programs with the people who are writing them — finding out what the intent of the program is and to see the different options that you don't necessarily always see in the simulator is a very worthwhile piece of training.

Having the MIT people available when we are doing the simulations is important because we continually run into problems, and we're never sure whether it's a LMS problem, a CMS problem, a program problem, or an interpreter problem in the trainers.

McDIVITT Unless we have the MIT people right there to get these notes, to go back to MIT, and to run on their hybrid, we never really get the answer. We discovered a number of significant items on the simulator and had them checked. Some of them, we found were really and truly in the flight programs; and some of them were just simulator problems. Tying the MIT system into the training in the last 6 or 7 months is certainly highly desirable. We had the MIT people available to us the last month, but I think earlier than that would be profitable.

SCOTT They were available during software verification, when we ran through the programs at North American. This was very helpful. They took notes, and we got direct answers immediately to almost all of our questions. It was a big help.

12.12 Systems Briefings

McDIVITT The systems briefings that we had on the launch vehicle and on both spacecraft are

McDIVITT a real time consumer. When you try to get a good systems briefing on all the systems in the LM, in the command module, and in the launch vehicle, you find that you're just completely overwhelmed with systems briefings. If we just spent one-half a day on each one of these systems, it seems to take weeks. If I had it to do all over again, I would move my systems briefings up earlier and try to get them out of the way by the time we got down to T minus 2 months. From there on, I would only go to the systems briefings people for specific questions. Then, I would have the same set of briefings that we had the last 2 weeks, where we find out just the anomalies in our own particular spacecraft systems.

12.13 EVA

McDIVITT The WIF exercises were far and above the most advantageous; we got more out of it from our training standpoint, at least for the zero-g part.

SCHWEICKART The EVA training that was the most useful was the WIF. After having experienced the body control in actual conditions, that the WIF and the zero g aircraft both give one a more severe body control problem than is the case in actual flight. The advantage of the WIF is the continuous time available as opposed to the 30-second increments available in the zero-g aircraft. It was quite useful for the EVA training associated with this particular mission. The other very useful element of training with the EVA was the chamber, both the SESL runs, thermal vacuum, and was what I would describe as signficantly different from the LMS. The FMES uses an actual AGS. It, of course, was far superior. If the LMS were upgraded in these areas, I do not feel that a significant amount of training time should be spent on the FMES for training on a D-type mission.

12.15 Mockups and Stowage Training Equipment

McDIVITT The mockups and stowage training equipment at MSC were a big asset to us in two major areas. One was the EVA, and the other was the tunnel equipment. The LM stowage training equipment was somewhat less than high fidelity as far as the knobs and switches were concerned. But, the stowage was high fidelity, and we were able to develop our own stowage techniques, as a matter of fact, 99 percent of our EVA techniques in the LM mockup.

SCOTT The CSM mockups were invaluable relative to training, particularly in the area of configuring the command module for extravehicular transfer for the actual EVA exercise, and also for training on the tunnel equiped with the counterbalance and the proper interior configuration. I think the procedures were developed to the point that they were absolutely optimal inflight. Based on the inflight experience that we've had, the mockups, SCOTT relative to tunnel exercises, are in an optimum configuration. The timeline that crewmembers experience on the mockups will be very close to the timelines they'll experience inflight.

12.16 Photography and Camera Training Equipment

McDIVITT The photography training equipment was adequate. We had sufficient number of pieces of equipment supplied to us early in the training program. We were running into a little difficulty at the end in getting enough 16mm camera support activities and real cameras to support activities in both the LM and the CSM. But, we managed to sort of double up on our efforts there and used what we had to some degree of efficiency. We were adequately trained in use of this equipment at launch.

12.17 Sextant Training Equipment

McDIVITT One thing which I would have liked to have had before I took off was a little more use of a real AOT, looking at real stars on top of a roof someplace at night. We had this in our schedule for one night

McDIVITT in Houston. We were unable to get back to Houston because of bad weather and never really got this training. I think it would be nice if this training were made available at the Cape, maybe up on top of the MSOB. We could spend some time looking out at the stars there. If we did that, we would not be so susceptible to weather problems. If the weather is bad one night, then we would have it there the next night, and the night after, and so forth.

SCOTT I did have the opportunity to go up on the roof of the G&C building one night and utilize a complete AOT sextant, telescope, and diastimeter. The flight operations people were kind enough to supply a helicopter which we used for evaluating closing rates and tracking with the diastimeter, sextant, and the telescope. It was a very valuable session. If we could have that type of equipment available at the Cape, it would enhance the training considerably.

12.18 General Support

McDIVITT I really can't say enough about the people who supported us during this mission. Dave and I were just sitting here talking, and he said, "If it hadn't been for the data priority meetings, we would still be up there looking around for each other." I think that was the type of support we had all the way through the whole mission. We had a very complex mission, and it had a lot of new things in it. Unless we had had people mobilizing the forces that are available to us here at the Manned Spacecraft Center and our associated contractors, and if it weren't for these people coming up with the answers for us, we would have never been able to even scratch the surface of this mission.

We had the support in a number of different areas. We had to have procedures support, and we had it. We had to have hardware support in preparing the two spacecraft for flight. We had to have support in all the other peripheral pieces of

McDIVITT equipment — the suits, the PLSS, the OPS, all those new pieces, and even the old standard pieces required looking after. Fortunately, I think we had the best group of people that could possibly be put together to support us for these things.

One of our biggest problems, for this particular mission, was to try to figure out the procedures that we would use with two vehicles instead of one. The discussions that we had at the data priority meetings, the conclusions that were drawn there from, and the dog work that went into digging up the answers to the questions that were always raised provided us with the knowledge of how to do the mission. When we actually did the rendezvous, it was almost like old home week. It wasn't really anything new. We had been going over it since the data priority meetings began, almost 2 years ago. That 2 years of training and meetings was really put to use inflight.

12.19 Planning of Training and Training Program

McDIVITT The planning of training in the training program was a very fluid thing, unfortunately. The simulators that we had kept changing from one configuration and mission to another. We spent, unfortunately, a large percentage of our training time checking out simulators rather than actually simulating in them. I think this is unfortunate but was just a fact of life. As the program and the mission requirements changed, the training had to be fluid to accept these changes. I think we finally arrived at a pretty hard and fast training package at 2 months to go.

As it became apparent that this training package wasn't being filled with the available simulator time and the available joint Mission Control/LMS/CMS simulations, it was necessary to make a rather drastic decision to start training only the prime crew during the last month. I think this paid off. There was no other way in the

McDIVITT world that we could have possibly flown the mission without coming up with this hard and fast training schedule and sticking to it.

13.0 PERSONAL HYGIENE AND HUMAN PERFORMANCE

13.1 Preflight

SCHWEICKART — I have no comments on the preflight section as regards food and water.

MCDIVITT — I think that the preflight medical care and procedures were reasonably adequate. The medical briefing that we had was good and covered all the aspects of what we encountered inflight. I think we were a little pressed for time to get in the proper amount of rest, exercise, sleep, and training.

13.2 Food and Water

SCHWEICKART — My hunger sensations in flight compared with 2 weeks preflight were considerably different. Until about the 7th day in flight, I had no particular appetite whatever. Up until that time, it was more an awareness that I should eat, rather than wanting to eat. Following the 7th day, my appetite began to return and approach normal responses with the exception that there were only certain foods within the selection available

SCHWEICKART that were in any way appetizing. And to a certain extent, I would say that a fair number of the foods available were unacceptable. This is in constrast to my preflight reactions to this food. Although it was not particularly appetizing, I had no particular objections to any of the food preflight. During the first 5 days, it was absolutely impossible to follow the eat periods, and we ate on a complete catch-as, catch-can basis. I did, on several occasions, use the spoon provided in conjunction with the rehydratable food and found that this made the food only somewhat more acceptable. I think that by the time I got around to using the spoon, my objections to eating the food were not associated with having to squeeze it through the tube. In the case of something like the sausage, is was simply easier to get to the food with a spoon than it was to force something that viscous through the tube.

SCHWEICKART I slept very well, much better than I expected to. This was true even in the early portion of the flight. On about half of the nights, I used Seconal. The primary effect of the Seconal was to cause me to drop off to sleep almost immediately after getting into the sleep restraints. Without using the Seconal, although I slept well, I tended to review the next day's activities in my mind before dropping off to sleep. I had no noticeable reaction to the Seconal other than drifting off to sleep almost immediately. Since I slept in the sleeping bag under the right-hand couch for the whole flight, I had no disturbances due to INTERCOM or anything of that kind.

MCDIVITT I thought that the food and water was a real problem during flight. The water in the command module had an excessive amount of entrained gas in it; and throughout the flight, it was a real problem. If we drank out of the drinking gun, the amount

McDIVITT of air or gas in the water seemed to be greater than when we took it from the bags. I guess the reason for that is we could better separate the gas from the liquid in the bags. When we were getting it out of the port on the bag, we tended to use our mouth as a separator to get the gas out. This was something we could not do with the water gun. I think the program we had for eating and drinking early in the flight was somewhat optimistic. We were unable to record the food and water that we drank and ate. We were forced, I think, to grab a bite of food whenever we could, rather than when we were hungry. There were periods of time when we went 18 or 20 hours without food during the flight because there wasn't enough time to work and eat. We weren't going to die if we didn't eat; but if we skipped what we were doing, it would work into the timeline on down the line, and we would never have been able to do the mission. On my previous space flight, I really looked forward to eating. I liked the food; and

McDIVITT early in this particular mission, I was hungry and ate whenever I could; but toward the end, I sort of lost my appetite. The food became less and less desirable and in the last couple of days, I found it a real chore to eat.

SCOTT I also had the same feeling about the food. It was fine for the first 7 or 8 days, but then it all got to taste like the same thing, and it just didn't seem desirable. I might mention that the three meals we had of "wet food" were very good once you got past the potatoes. If it's desired that the crew eat both potatoes and meat, it is suggested that perhaps they be mixed together. In the meals, we had the potatoes at one end and the meat at the other end. If you happened to open the wrong end, you ended up with potatoes first. I also felt the food was bland. I would liked to have had a salt shaker and some sort of spice. The food reconstitution worked fine when you could get enough water in the bag to reconstitute it; but again, our problem

SCOTT with the hydrogen bubbles sometimes made it difficult to get a complete reconstitution. Towards the end of the flight, we opened up all the food bags and put the drinks in one glove stowage bag, the rehydratables in another bag, the hard tack in a third bag, and just tried to sift through the food to find some thing that was acceptable to eat when it was time to eat.

MCDIVITT I promised Rita Rapp that I wouldn't say anything about her food, but I just feel obliged. Even with this technique, we found it very difficult to run across anything that looked really appetizing. I do think that we all felt that the drinks (orange, grape, and so forth) were by far the best. The cocoa was excellent and the puddings seemed to be good. Then, the next most desirable things were the rehydratable dinners, such as the chicken and vegetables, beef and vegetables, and salmon and tuna salad. Then, we worked on down to where the hard cube kind of

McDIVITT things were highly undesirable, I feel. Also, the bite size sandwiches made crumbs like I had never seen before. A number of times, we had packages open with these sandwiches, and we just could never capture all the crumbs that came out of them and weren't even able to eat them. We had to try to put them down, as far down as possible, in our temporary stowage bags, so the crumbs would not float back up to the surface.

The palatability of the water, I think, was affected by when we had last chlorinated the water. Early in the mission, we were so busy we didn't even get a chance to chlorinate the water. On one day, and we sort of let the whole thing slip until in the evening. After we did this, we found that it was by far the best technique to use. We used all the water that we wanted for that day, filled up a water bag with either water or some sort of drink (grape or orange), then chlorinate the

MCDIVITT — water, and went to bed. By the time it was time to get up in the morning, some of the chlorine had been dissipated in the system; and we didn't seem to have as much chlorine.

13.3 Work/Rest/Sleep

MCDIVITT — The next topic is work, rest, and sleep. I think the technique of having all three crewmen sleeping at the same time is far superior to any thing that we have had before. There was some difficulty in sleeping due to noise in the radio, which we solved after the first night and a few other minor problems. I think the real significant step was that we put everything to bed (including the spacecraft) at the same time, and got everything up the next morning at the same time. Even if you just laid there and didn't sleep, you were certainly resting; and you didn't have all the distraction of jets firing, transmissions on the radio, and people

McDIVITT scurrying around the spacecraft. I highly recommend this technique for all future flights.

SCOTT One thing I noticed that surprised me was the quietness of the spacecraft when everybody was sleeping. If somebody stirred or made the slightest noise it was very audible. We slept with light weight headsets on and with one ear piece in and the other ear piece out. I cinched myself down in the right-hand couch rather firmly and found that I didn't sleep too well. Subsequently, I loosened the restraint harness. I used the waist and shoulder restraints on the right couch; I loosened it to the point where I would float up about 2 or 3 inches off the couch and found that this was very comfortable. I got some real good sleep on subsequent nights.

McDIVITT I slept on the left-hand couch; I used the lap belt and the shoulder harness to

~~CONFIDENTIAL~~

McDIVITT

hold myself down, but I had them very, very loose. I also took the left-hand shoulder strap from the the center couch, placed it across my chest, and snapped it on the left-hand shoulder harness of my restraint system to hold me in. One gross oversight was that we had two sleeping bags in the spacecraft and three people trying to sleep simultaneously. It got quite chilly at night. The poor CMP had to put on a couple of pairs of long underwear and a bunch of other things. If we have three people sleeping at one time, I recommend that we carry the third sleeping bag. After the first or second night of being cold, I took the sleeping bag out from underneath the right-left hand couch and crawled into it. It provided enough insulation to keep me warm. I wasn't cold after that.

Something the psychiatrist will probably be very happy to find out is I got tired

McDIVITT of sleeping on my back, even though there wasn't any up-down or otherwise in zero-g. I found that, during the course of the evening, I had a strong desire to roll over onto my side, and I actually did this on most of the nights. I would roll onto my right side and put my head on the headrest. Even though I tended to float off, I got the sensation of lying on my side. I seemed to get my legs in a different position than what I did when I was lying on my back. I felt a lot more relaxed and felt that I could sleep better by actually being in different positions during the night. I even rolled from my right side to my left side underneath the restraint system and found that to be a different position, as far as I was concerned.

13.4 Exercise

SCHWEICKART I did no exercise until the 6th day due to the crowded workload during the first 5 days. On the morning of the 8th day when I went to exercise, I had

SCHWEICKART

the tension in the exerciser set fairly high. Unfortunately, I straightened out out a metal ring which fastened the foot loop to the rope. After straightening out the metal ring, it was apparent there was no way to hook the thing back together and that was the end of the exercise.

I felt that we certainly could have used some more exercise during the flight, not necessarily the first 5 days because we got plenty then but during the last 5 days. I also feel that the exerciser that we had with us inflight certainly was far from the desirable one. Any period of exercise caused the metal portions of the exerciser to become so hot that I almost felt it was a hazard to the flight, because we might catch something on fire with the tremendous heat generated by the friction — sliding the nylon rope back and forth across the metal bars. Unfortunately, when the exerciser broke, there wasn't any exercise machine of any type to be had for the last 3 or 4 days of the flight.

13.5 Inflight Oral Hygiene

SCHWEICKART Oral hygiene was no problem at all. It was a reasonably pleasant portion of the day when I decided to brush my teeth. I averaged one and a half brushing exercises a day. I did not use a dental floss.

McDIVITT I found that brushing my teeth did seem to freshen my mouth somewhat. I did not use any dental floss; the toothpaste was okay. As a matter of fact, the toothpaste tasted a lot better than the food sometimes. I had no problem using my toothbrush after it had been closed up in a container. The quantity of oral hygiene supplies was certainly adequate.

13.6 Housekeeping

McDIVITT I think that we have an awful lot of comments on this. Generally, we found that we always got to bed much later than at the beginning of the rest period because we were doing housekeeping. When we got up in the morning, if we got up at the right time, we found that it took longer to get ready to do the next real period of

SCHWEICKART activity in the spacecraft, because it took longer to do the housekeeping. The tasks were: change the lithium hydroxide canister, dump the waste water tank, chlorinate the water, urinate, defecate, brush your teeth, and get your food ready. All these things take abnormally long times in flight. I can get up in the morning 1 hour before I have to be at work and shave, shower, eat, and so forth, and still have plenty of time to get to work. But that's certainly not the case in the spacecraft. I think we'd like to discuss some specific items here. Generally, this period of getting ready to do something and regrouping after you've done it is considerably involved and should not be overlooked in flight planning. One of the things that was a continuous problem in the command module were the metal shades that we used to cover the windows. When they covered the window, they kept the light out and did a superb job; however, they did not fit. Early in the mission, we were

SCHWEICKART propping the shades up with checklists and trying to keep the light out with tape and things like that. Finally after a couple of days, we decided it would be better to adjust the locking mechanism every night when we put the shades on; so we got the screwdriver out. Every night, we loosened up the lugs, put the shades in, and tightened the lugs down so that the window shades would stay in. Unfortunately, when we took the window shades out in the morning, we were always in such a rush that we didn't have time to tighten them back down, and at least three or four times during the flight, we found screws and the associated locking lugs floating across the spacecraft. I think, on retro morning, we were not quite able to retrieve all the pieces; and we ended up missing one piece off the number 1 window. Dave says fortunately we didn't have to spend the night in the water, but this was a real problem with us. The other thing that was a continuous source of irritation

SCHWEICKERT was the lack of numbering on the lithium hydroxide canisters. I checked since I've returned to the ground and found that there were supposed to have been numbers on it; there was every indication that they were, except we couldn't see them. I'm going to have to check those lithium hydroxide canisters again to make sure that there weren't any numbers. We examined them at length in good light and never once saw any number that would distinguish one canister from another. A couple of other housekeeping (or, I guess they were medical problems) were: my noise was a little dry during the early portion of the flight so I thought I would open up the bottle of nose ointment and put a little on my nose. When I unscrewed the cap, it appeared that the bottle had been sealed at 15 psi; and all the nose ointment squirted out all over the cabin. Because it was highly aromatic, it certainly smelled up the cabin. I'm not sure that it wouldn't have been slightly corrosive to the eyeballs if we

SCHWEICKERT had gotten any in our eyes. We spent some time retrieving all the little droplets that had squirted out, putting them in a plastic bag, sealing it up, and depositing it in the temporary stowage bag. That was the end of the nose ointment. Then a couple of nights later, I decided I would use some nose drops. I took the cap off the nose-drop bottle and exactly the same thing happened. The nose drops went all over the spacecraft. When it stopped flowing out and the pressure equalized, I gave it a squirt but all the nose drops had already gone out. So, we had three bottles of useless nose drops. The very stiff black hoses were a problem that really complicated the suit-on portion of the housekeeping.

SCOTT There is enough Velcro in the spacecraft — it's just not placed in the most useful location. It seems that most of the operation take place either in the couch or in the LEB. We found that some of the most useful pieces of Velcro were those we had

SCOTT: put on the MDC for panel cards. It seems like the Velcro should be placed around the areas of operation rather than underneath the couches and buried in the bottom portions of the LEB where it is absolutely unusable.

McDIVITT: I think the really significant thing about the house-keeping in the suited mode is that, when the crewmembers do not have their pressure suits on, they're essentially free to maneuver where they would like. They can go down underneath the seats and back up on top and do all the things that they want. Once they put their suits on, they pretty much have to put their suit hoses on to provide cooling. Once they put the suit hoses on, they become very much restricted; and it's difficult to get down underneath the couches. Thus, you're much less mobile. Now, that is for one man. When we get three people in there with suits and suit hoses on, it becomes almost impossible for people to work in parallel. You almost have to work serially.

McDIVITT There is only room for one person to get up with the suit hoses on, to get underneath the couches, and to perform the kind of things that you need to do down in the lower equipment bay. I think the planning should be that, once the crewmembers are suited up, one man does all the operations. When you go to that kind of a mode, you have to put enough time in the timeline to take care of solo operation rather than three people. Instead of the other two people being an asset, they are actually a hindrance. I think one person by himself can operate in the spacecraft better with a suit on than with three people in the spacecraft. It should be mentioned here, that it takes longer to put the suit on when you are wearing the LCG than it does when you are wearing the light weight underwear.