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MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

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11.0 CSM CIRCUMLUNAR OPERATIONS

11.1 OPERATIONS OF SPACECRAFT

COLLINS In general, CSM circumlunar operations went smoothly, and there were no surprises. The spacecraft operated normally; it didn't have any failures.

11.2 NAVIGATION

COLLINS There wasn't much navigation to be done. I did use P21 several times to pin down the time of arrival at the 150° W meridian, which was the prime meridian on the map. It was a simple and easy thing to use P21 to get that information and update the map. The map worked fine with the time tick marks, as long as you are in an orbit of approximately 2 hours' time. The map is a useful tool in helping locate where you are with respect to the ground.

11.3 LANDMARK TRACKING

COLLINS The operation of P22 was easy. The procedures that I had condensed into a checklist on the LEB panel were more than adequate. I always went to P22 early, got AUTO optics, and pointed at the landmark far in excess of 50 degrees trunnion. I sat there with a PROGRAM ALARM until such time as the trunnion angle came down below 50 degrees. At this time, I punched off the PROGRAM

COLLINS (CONT'D)

ALARM, and the optics then began to track. I found this was an easy way to operate the system. I had the center couch underneath the left-hand couch for EVA. It was easy to move from the LEB up to the MDC. I found that window 2 or preferably window 3 could be used to give you an idea of where you were relative to the landing site. I could look out either of those windows and see all the landmarks approaching. When I got fairly close, all I had to do was leisurely wander down to the LEB, look through the optics, and be ready to mark. The problem was I didn't know where the LM was, and the ground didn't either. There is too much real estate down there within the intended landing zone to scan on one, two, three, or four passes. On each pass, I could do a decent job of scanning one or two grid squares on the expanded map. That map is the 1:100 000 map called LAM 2. The ground was giving me coordinates in the grid square coordinate system that were as much as 10 squares apart. This told me they didn't really have much of a handle at all on where the LM had landed. As I say, it was just too large an area for me to visually scan. I used AUTO optics each time I looked at the area they suggested. I never did see the LM. I don't have any suggestions for future flights. You have to know with considerable accuracy

COLLINS (CONT'D) where the LM is before you can mark on it. If you knew where it was that accurately you wouldn't really need P22 to refine your estimate. Perhaps a different Sun angle would yield the possibility of a flash of specular light off the LM skin giving you a clue. I looked for flashes and never saw any.

11.4 MSFN

COLLINS MSFN worked fine. I was using AUTO on the high-gain antenna. It worked well. The ground was conscientious in updating AOS and LOS times. I don't think that's really necessary. If you're in a near nominal trajectory, as we were, it's an easy thing to do if you have good COMM. If the COMM is intermittent, you can waste 4 or 5 minutes trying to read back and forth AOS and LOS times which really are not required. When the LM is on the surface, the command module should act like a good child and be seen and not heard. The communications with it should take on a negative reporting method.

11.5 PLANE CHANGE

COLLINS Plane change was not required. The plane change procedure of uplinking a new REFSMMAT and gyrotorquing the platform around to that new REFSMMAT is a tedious procedure. I'm not sure that the gyrotorquing is the way

COLLINS (CONT'D) to go. A few days before the flight, we abandoned that gyrotorquing method in favor of coarse aligning to the new REFSMMAT. The gyrotorquing took an excessive period of time and had no protection against gimbal lock. We could not even predict in which direction the platform would gyrotorque. That was the story we were given. Some thought should be given to a better procedure for doing that.

11.7 SLEEP ATTITUDE

COLLINS The procedure was worked out fairly well. I don't recall any mention about deadbands. The ground, in all cases, wanted a 10-degree deadband. This was something they asked for in real time. I think it would have saved some chatter over the radio had all this been worked out and put into the flight plan. I needed the control mode and the four or five DSKY operations that are necessary to achieve a 10-degree deadband. Had they been printed in the flight plan, I think that would have helped.

11.8 PHOTOGRAPHY

COLLINS I thought photography worked out well when I was in there by myself. The amount of time I devoted to photography was somewhat limited by the fact that I was doing P22 each and every pass. P22 was not compatible with good

COLLINS (CONT'D)

photography. I probably would have spent more time taking pictures had it not been for the question of the LM landing location and the need for the additional P22's. I did use the intervalometer. I'll have to wait and see how those pictures came out. I feel the command module should carry plenty of film, and I think the key to getting some good pictures from the command module is having the luxury of being able to expose lots of film without worring about running out of film.

11.10 MONITORING LUNAR ACTIVITY

COLLINS

There was some difficulty with the ground S-band relay. The preflight agreement was that all my transmissions would be relayed to the LM, and all LM transmissions would be relayed to me unless that mode of operation, because of systems failures or other problems, became too cluttered. At this time, the ground was free to amputate that relay mode. In flight, it did not work out that way. The relay was rarely enabled. I gather that this was because there was a ground switching problem. I would have preferred to be receiving continuous S-band relay from the LM, and I felt somewhat cut out of the loop, although it was not a safety problem. I felt out of the loop during the extended periods of time when the relay was not in effect.

11.11 VISUAL MONITORING (MONOCULAR OR SEXTANT)

COLLINS I did not use the monocular because I did not have the monocular. It went to the surface with the LM. I don't believe it would have been of any use in looking for the LM. The sextant is a more powerful and steadier instrument. It was not possible for me to find the LM on the surface with the sextant.

11.12 CO_2 CANISTER CHANGING

COLLINS CO_2 canister changing was the same as when three people are in the spacecraft.

11.13 MANEUVERING TO SUPPORT LIFT-OFF

COLLINS Maneuvering to support lift-off was worked out well preflight, and I followed it that way. I couldn't see the LM, but I did nonetheless go through the motions of maintaining the proper attitudes so that my radar transponder would be available in case the LM wanted to lock on. The CSM solo operations were fine. I was at ease about going to sleep and leaving the command module unattended. That didn't bother me at all. I would have guessed preflight that it might have, and it might have if I had had some failures prior to this time.

12.0 LIFT-OFF, RENDEZVOUS, AND DOCKING

ARMSTRONG Feed water measurement was performed and the numbers were passed to the ground. I don't remember what they were. First, we zeroed the scale and then with the empty bag on, we took the bag off and reported the RCU weight, with the RCU and not the bag on. Then, we put the water in the bag and reported that weight. That's about a full bag of water.

ALDRIN Throughout all of this, I didn't have a real high confidence level of the accuracy of what we were doing.

ARMSTRONG One full bag of feed water is a lot.

ALDRIN I would think that a volume measurement might be just as accurate.

ARMSTRONG A volume measurement was the initial plan. That was discarded based on its accuracy.

ALDRIN The ground had concluded that the water level was lower in my PLSS. It would have seemed to me that that would have been the one to measure, but that wasn't the idea from the beginning. Since they had some indications that consumption was higher on mine, it would have been better to verify that one. We'll see what we get on that.

ALDRIN (CONT'D)

We were given an update on consumables, and we have already talked about the sleep period. They were looking at your BIOMED during the rest periods. As far as I know, we got up just about on schedule and started our activities. It might have been a good bit ahead of schedule, maybe a half an hour or something like that. To try and identify just what our position was, the ground wanted us to go through a P22 radar track of the command module. We had done this once, maybe twice, in the simulator, and on the surface, it looked like a fairly involved task. Once having run through it in the simulator, it's fairly straightforward. It turned out to be quite a simple operation. Before doing this, we configured circuit breakers and went through a DSKY computer check. I'm not sure why it was felt we needed to do this. These were notes as to how we were to handle a P22, option 1, no update. If we got a 503 alarm, we were to key in a proceed and leave the tape meter in altitude/altitude rate so it wouldn't drive into the stops — if it were on range and range rate. It would have been much easier to do a VERB 95 before starting it, because that's evidently what they meant. We went through an LGC self-test and brought the AGS back on line and then proceeded into the P57. I might point out a few things on the previous day's P57. The yaw left tended to move the one

ALDRIN (CONT'D) star I wanted to use, Capella, out of the right rear detent. The Sun was in the rear detent and generally obscured it, even though it was not visible in the detent. Its light level was sufficiently high so that no stars could be seen in the rear detent. The Earth was in the forward detent, and due to the yaw left, it was also in the right detent.

12.1 APS LIFT-OFF

ALDRIN We had another update from the ground instructing us not to go to AGS in the event that the LM engine didn't ignite and not to make a manual start. We agreed that we would wait a REV. Everything worked according to the checklist. We just emphasized that we did use the lunar align mode in the AGS and did not align the AGS to the PGNS, so it lifted off with its own reference system. It did have a PGNS state vector instead of the manual one that we could have given it in the LM slot.

Lift-off, or at ignition, we waited until the last 2 or 3 seconds, or almost simultaneously, Neil depressed the abort stage and threw the engine arm switch to ascent and I proceeded on the computer.

It might have been a second after the T-zero that any motion was detected. There was, as I recall, an appreciable

ALDRIN (CONT'D)

bang of the PYRO's and a fair amount of debris that was tossed out at the same time that we did detect first motion. It was a fairly smooth onset of lifting force. There wasn't any jolt to it. Yaw started gradually; it was not abrupt either in starting or ending. As a matter of fact, I really didn't notice it. I was looking more at some of the gages and the altitude rate, both in the PGNS and the AGS. It seemed to take quite a while before we accumulated 40 or 50 feet per second.

The pitch maneuver, as seen from inside the cockpit, was not in any way violent or very rapid as we were expecting. We seemed to have a good altitude margin looking down on the surface. It wasn't something that you'd describe as a particularly scary maneuver. I felt that we had adequate altitude rate at the time for that type of a maneuver. Right after the pitchover, I could still look out to the side and see the horizon. We could verify out the window what our pitch angle was.

12.4 VELOCITY AND ALTITUDE

ARMSTRONG

Velocity, altitude, altitude rate, and attitudes were consistent with the ascent table that we were monitoring. AGS and PGNS were consistent in attitude as frequent crosschecks on the attitude indicators showed and also in altitude rate,

ARMSTRONG (CONT'D) which was being read off the DEDA and compared with the PGNS value of H-dot.

ALDRIN A couple of years ago, we had a simulation rigged up that tended to give us the sensations in the cockpit that you were liable to experience during LM ascent. We did this in the DCPS and they rotated us back and forth. Based upon this and many ascent simulations in the simulator, watching the rate needles pop back and forth, and the arrow needles wipe back and forth, I expected quite a roller coaster ride of whipping back and forth. Nothing could have been further from the way it actually turned out. It was a very smooth wallowing type of an ascent with far less excursions. Maybe the total rates were approximately the same, but the physical effort of them was not at all objectionable.

ARMSTRONG The rates and attitude errors and attitude changes were consistent with the simulations. The physiological effect of these was much more akin to the description presented by the Apollo 10 crew of their ascent engine burn. It was very pleasant. It had a Dutch roll mode and relatively low frequency. It was not at all distracting toward your ability to monitor the ascent quantities that were significant. It was a very pleasant and unusual trajectory.

ALDRIN It was quite easy to look out the window and pick up craters as we approached them. We were keyed to look for the Cat's Paw or anything in the close vicinity to the landing site. I did see several craters, none of which I could positively identify as being the Cat's Paw or in that immediate vicinity. The track looked good as we came up and went by Ritter and approached the crater Schmidt.

Communications were excellent throughout the lift-off. We had backup S-band angles at 3 minutes. We didn't need to change any of those. We did accomplish everything in the checklist. The balance couple came off; we were called on the START button at a minute or so after lift-off.

Changed the film frame rate to at about 3 minutes from 12 frames a second to 6 frames a second. Throughout the remainder of the trajectory, I monitored the targeting quantities in NOUN 76, looked at the countdown time in NOUN 77, then picked up the DELTA-V to go in NOUN 85, and crosschecked it back with V_I to compare it with the trajectory. The numbers agreed very closely in H-dot and V_I. The altitude looked like it was coming right in on the targeted values, and the AGS agreed quite closely. The V to go, in address 50, did differ a good bit from what I was reading in NOUN 85. However, the AGS gave slightly

ALDRIN (CONT'D) different targeting. Its targeting is done on a different computation cycle, and I attributed the differences to that. The RCS quantity looked good, and the ascent feed seemed to be operating quite well. To avoid any rush approaching insertion, I elected to open the shutoff valves at about 700 to 600 ft/sec to go. I opened them one at a time, turned off the ascent feed, and closed the cross feed. As we approached 50 ft/sec to go, we still had good pressure in both ascent tanks. Of course, that was one thing we were looking at right up to lift-off to make sure we were feeding on both tanks. I think we inserted with 700 or 800 psi in both helium tanks. Approaching 50 ft/sec to go, we disarmed the engine and it was an AUTO cutoff.

ARMSTRONG I think the overburn was about 2 ft/sec, and we nulled those.

ALDRIN There was a certain amount of bounce to them, but since we didn't have anything over 1 or 2 in Z-component, we were able to get the X-component down to near zero, I think 0.1 or 0.2. The out-of-plane residual was small, in the order of 1, but not over 2. The AGS showed about 8 ft/sec out of plane, and it was, as I mentioned, operating on an independent alignment. VERB 82, as I recall,

ALDRIN (CONT'D) showed something like a 47-mile apogee. We didn't have the radar to confirm the insertion, but MSFN was quick then to give us a good orbit. The AGS agreed very closely with the PGNS.

We got our range rate from the CSM.

ARMSTRONG It was a satisfactory range rate.

12.5 ATTITUDE

ALDRIN We got the attitude hold and balance couple on. I don't think we reset abort stage and engine stop immediately. We held off on those, disabled the TTCA's, and designated the radar down out of the field of view in preparation for the alignment. We configured the switches, stopped the camera, and progressed on with aligning the platform.

12.6 PGNS AND AGS

ARMSTRONG The initial platform alignment planned use of Acrux and Antares as the stars, knowing that Acrux, based on our simulations, would be close to the horizon. I had an alternate in case it was too bright down there. When I AUTO maneuvered to Acrux, it was below the horizon and I couldn't see it, so I chose the first alternate, Atria and Altair. I AUTO'ed, so I went out of the program. I re-entered P52, going to star 34, Atria, AUTO maneuvered to

ARMSTRONG (CONT'D) the point, and it wasn't in the field of view either. Both of those stars had been in the field of view in all simulations. We terminated the program and reentered at Antares, I think. Is that right?

ALDRIN 37 and 34 are what I have.

ARMSTRONG We reentered at Nunki, which we knew would be in the field of view. While I was getting marks on Nunki, I had Buzz look up something that might fit with Nunki to be a good second star, and I guess you came up with Atria.

ALDRIN Yes. It was up in the field of view at that time.

ARMSTRONG By this time, of course, the stars were rising at a rapid clip, and we could go back to Atria and be quite sure it was in the field of view.

SPEAKER Which one did you try first?

ALDRIN Acrux. That wasn't in, and neither was Antares.

ARMSTRONG Neither was Atria.

No. We came back at Atria and got it, and the horizon was in the field of view during the mark. But we had satisfactory marks. We got all zeros on our star angle

ARMSTRONG (CONT'D) difference and very small torquing angle, indicating that our graph, our prelaunch alignment, was quite good.

ALDRIN I think the largest one was in roll; and, of course, that doesn't affect the insertion as much. The most critical one is the pitch and that had 00064. The one that intrigued me was yaw (which will affect the out-of-plane insertion), and that had 406. The yaw that we had before that was based solely upon the star alignment that we used before lift-off. It went with the gravity, so it indicated that we had a very good azimuth alignment on the surface. The gravity was certainly adequate to do the job.

12.7 RENDEZVOUS NAVIGATION

ARMSTRONG It was our intent to pick stars here that would be in the field of view and require a minimum amount of maneuvering and time to get through the alignment and would end up back in plane so that we would be in a place where we could turn the radar on, designate the acquisition, and start getting marks so that we would have a good solution for CSI. Somehow or other, all this planning didn't work out on those stars. Why our simulations did not correctly place those stars relative to the horizon, I don't know. They didn't, so we wasted a little time and a little fuel.

ALDRIN Even with these problems, we did quite well because we finished about 28 - 27 minutes before CSI and were able to proceed with getting the radar to lock on. That was accomplished without any difficulty. We got one VERB 1 NOUN 49 that we accepted. Before entering the program, we had VERB 95 then loaded to W-matrix. The enable updates - only one of them (the first) failed to pass the test, but it was significantly small, so we proceeded on it. While Neil was doing the alignment, I queried the AGS to see what it thought of the insertion and what it thought the CSI maneuver would be. It came up, just based on the insertion vector, with 15.5 DELTA-H and 51.3 ft/sec.

12.10 ASCENT CAMERA

ALDRIN The camera was set up with settings as in the checklist, and inserted (pasted) into the checklist at TIG minus 2 was a notation of camera on. At that point, since we were starting at 12 frames per second, it was too early to bring the camera on. I would estimate something on the order of 30 to 40 seconds into the ascent before the camera was turned on.

In looking down at the time of the pitchover, I could see radiating out many, many particles of Kapton and pieces of thermal coating from the descent stage. It seemed almost

ALDRIN (CONT'D) to be going out with a slow-motion type view. It didn't seem to be dropping much in the near vicinity of the LM. I'm sure many of them were. They seemed to be going enormous distances from the initial PYRO firing and the ascent engine impinging upon the top of the descent stage.

ARMSTRONG At the completion of the pitchover, you could easily detect visually that a strong positive outward radial rate had been established. There was no concern about attitude or falling back toward the Moon. I observed one sizable piece of the spacecraft flying along below us for a very long period of time after lift-off. I saw it hit the ground below us somewhere between 1 and 2 minutes into the trajectory.

ALDRIN It's very difficult to conceive of such lightweight particles like that just taking off without any resistance at all. It's easy to think back and say that they would do that. But it just seems so unnatural for such flimsy particles to keep moving at this constant velocity radially outward in every direction that I could see out the front window. I don't recall seeing any impact with the ground, but there were sizable pieces.

12.13 UPDATES FOR CSI

ALDRIN The ground gave us an update of 51.5 ft/sec for CSI with a 1 ft/sec out of plane. I have the values logged down here for what the PGNS came up with, and it eventually settled down on 51.5, also. Mike's solution agreed with the AGS at 51.3, and we elected to burn our solution without any out-of-plane component.

ARMSTRONG I was just amazed that we had four solutions within 0.2 ft/sec for CSI. That never happened before.

12.15 RCS/CSI BURN

ALDRIN I might point out two reasons why we didn't get a backup chart solution. One of them was the alignment. It took a little more time. I think we could have gotten a range rate at 28 and still gotten a good solution; however, the range rate that we were reading at that point was about 51 ft/sec. This was less than the values that were acceptable for the chart. In other words, it exceeded the limits for the rendezvous charts, and since we did end up with a 15-mile DELTA-H and had a good nominal insertion, the only thing I can attribute it to is the command module not being in a circular orbit having enough eccentricity to perturb the R-dot from what it should have been. I think this is another indication of where a late trajectory change was

ALDRIN (CONT'D) not completely analyzed to see what effects it had. Certainly, we had nominal conditions, but the trajectory change did result in range rate values that exceeded the ability of the chart to cope with them.

SPEAKER How about the handling?

ALDRIN The nulling of residuals with the thrusters, even with two-jet operations, produced a pronounced difference in translating with just the ascent stage. Each time you hit the thrust controller, the vehicle behaved as if somebody hit it with a sledge hammer, and you just moved. There is no doubt about the fact that the thrusters were firing.

ARMSTRONG It's a very light, dancing vehicle, and this is true in attitude also. It's very unusual, and the fact that we got five zeros on that alignment, I think, is just a matter of being consistent with all the other good luck we had that day. It certainly was more difficult to do than the unstaged alignment where the vehicle was a lot steadier, and we didn't get results that were that good.

ALDRIN It was sporty; there's no doubt about it. It appeared that with the automatic tracking and the wide deadband of the radar that it was not bouncing all over the sky. I guess I anticipated that it might have been even sportier

ALDRIN (CONT'D) than it turned out to be, even though it was a difficult job doing precise aligning with it. I think the 10 mission indicated that. They thought that they had a lightweight vehicle, but, of course, they had much more fuel on board than we did.

ARMSTRONG We did not find as severe a reaction to operating in PGNS AUTO as had been earlier reported. I can't confirm just what their configuration was in terms of the DAP and vehicle inertias, but our combinations made the vehicle fly quite comfortably in PGNS AUTO. We used that mode more or less intermittently with PGNS pulse. We almost did all the manual flying in PGNS pulse, and the remainder of the time, we were in PGNS AUTO. Burns in PGNS attitude holds were generally done with VERB 77.

ALDRIN That lightweight a vehicle did appear as though it was not an easy task to make either X- or Z-axis burns. Of course, all burns were Z-axis burns. To make them, and at the same time avoid having residuals of a fairly sizable number (at least less than 1 ft/sec) is quite difficult. We did end up with minus 0.2, plus 0.7, minus 0.1. The AGS agreed fairly close again, showing the greatest difference in Z, which I think is attributable to the rotation of the burn

ALDRIN (CONT'D)

when loaded into the AGS. The radar stayed locked on throughout the maneuver.

We started updating right on schedule, changing the W-matrix to the flight plan values. We checked the numbers just before we changed it. I think we could recall them, if somebody wanted them. 1900, maybe something like 15.3 milliradians. Then we started to work on the plane change. What I did was make use of VERB 90 and ask it what out-of-plane condition it had right now. This saves a little bit of time in not having to load in numbers. We were coming up with things on the order of 1 mile out of plane and 2 or 3 ft/sec. The actual solutions that both vehicles came up with were: our first one was minus 3.2, Mike had minus 2.3; our final one was minus 2.9. As small as they were, we cancelled the plane change maneuver to get more tracking data.

12.18 RCS/CDH BURN

ALDRIN

At CDH, we took out time as computed by the CSI program for the CDH maneuver and voiced in the maneuver to Mike to put in his P76. When you're really getting precise, the question arises what to do with residuals on the order of a couple of tenths. Do you take advantage of them or ignore them? We chose to ignore these small amounts and

ALDRIN (CONT'D) not thrust. The exception was the out-of-plane condition, and we were handling that as a separate item anyway. DELTA-H varied between CSI and CDH solutions anywhere from 15.3 to 15.7. In general, the CDH maneuver decreased in magnitude. Even on the ones we had in the CSI program, it came up with 19.3 ft/sec and settled down to 18, which I think is indicative of the noncircularity of Mike's orbit. We had no concrete evidence of that really. Our procedures had not called for finding what his orbit was. The ground never did tell us what his orbit was and what we ought to expect for CDH. I think we were kind of left on our own coming up for CDH as to what was an acceptable burn. The data card gives a nominal H-dot of 4 ft/sec. We had 18.

COLLINS Four is for circular CSM orbit.

ALDRIN Yes, and that's what you're supposed to have.

COLLINS I didn't.

12.20 TARGETING PGNS AND AGS

ALDRIN I had components here for the AGS maneuver: CDH 9.1, 2.4, and 14.6. As per the procedures loaded in the PGNS maneuver, the AGS was updated with the PGNS for CDH.

12.21 UPDATING AGS WITH RR DATA

ALDRIN After CDH, things seemed to be working so smoothly, and DELTA-H seemed to be so constant that I elected to start putting radar data into the AGS. This seemed to be accomplished without an undue time burden. I've got the data here that indicates what the AGS solution was for TPI with only AGS update going into it. I think this will be fairly interesting to some people. In other words, it solved for a TPI.

12.23 RCS/TPI

ALDRIN We burned the PGNS at TPI and then I left the AGS residuals, which are a measure of the difference that it would have solved, and they were on the order of 2-1/2 to 3 ft/sec. Everybody zeroed in on about the same maneuver for the TPI. I guess in the LM you want to delay committing yourself, since you're picking the angle option, to saying exactly what time TPI is going to be until as late as possible. Unfortunately, this presents a burden on the CMP, because he's got the time option. He wants to know what time we're executing it. We gave him a time, and it changed by maybe 30 seconds.

12.27 MIDCOURSE CORRECTIONS

ALDRIN The first midcourse correction was less than 1 ft/sec. I think we gave the values to the CMP, and he put them in external targeting. The second midcourse correction was about 1-1/2 ft/sec. We burned them in components. I guess it's up to you on angular rates. We picked up range rates from that point on.

In a moment of confusion about this time, I observed a significant nonzero lateral deflection in my cross pointer, which I interpreted as being a lateral line-of-sight rate indicating some out-of-plane velocity. This was just a misinterpretation, however. I had to switch in landing radar computer rather than radar line-of-sight rate. So we were actually reading in either AGS or PGNS a version of out-of-plane velocity at that point. I can't explain why that was indicated to be a large number. There wasn't a real number. The line-of-sight rates were, in fact, very low. And as I remember, it was indicating something like 7 ft/sec.

ARMSTRONG The whole thing from once we finished alignment was just a very leisurely running through of what we had done many times before. Where we were familiar with it was a relatively simple operation. Rendezvous with the PGNS is a

ARMSTRONG (CONT'D) piece of cake as long as everything's working. When you start getting PROGRAM ALARM's and radar won't go in, it gets pretty hairy. This happened during several SIM's. You start chasing yourself around the cockpit. But with things working fine, it's simple. It does require close coordination with the other vehicle to keep the flow of information going back and forth. The ground didn't bother us at all. They were watching what was going on, and they called up confirmation of our CDH solution.

12.31 BRAKING GATES

ARMSTRONG Braking was pretty much on the braking schedule; no problems there. The line-of-sight rates were small and easily controlled. The line-of-sight rate indicator gave us proper indications of line-of-sight rates. The line-of-sight rate indicator does not work like the simulator in several areas. The most significant is when the radar antenna goes from a Sun line-of-site rating back to zero; it does not do it instantaneously as in the simulator. It takes about 5 seconds for the antenna to slow down for a stop for the needle to come to the peg back to zero. Both the sizes of the needle deflections and the rates that they deflect are not correctly simulated in the simulator.

12.36 DOCKING

ARMSTRONG We stopped braking phase at 50 to 100 feet, insured that both vehicles were in a docking configuration, and at this point, we ran into a problem that we wouldn't have anticipated preflight. Our procedure was for the LM to get into stationkeeping position 40 feet out in front of the command module plus X-axis, pitch over 90 degrees so that the X-axes are colinear, then yaw left 60 degrees so that we are in the docking attitude with the command module. It was obvious when we got to this point, if we pitched the LM over 90 degrees, we would be looking directly into the Sun. We knew that would be an unsatisfactory lighting condition for docking. So the alternative would be to roll the LM 60 degrees, pitch down, and then you'd be in the same attitude and would have prevented the Sun coming into the window. After arriving at that attitude, a discussion between the LM and the command module indicated that we weren't quite far enough, so I rolled a little farther, pitched over, and waited looking through the top window. We were asked to rotate a little farther by the command module to line up the docking aids and get the proper alignments. We complied and promptly maneuvered the vehicle directly in the gimbal lock. I wasn't aware of it because I was looking out the top window. No doubt,

ARMSTRONG (CONT'D) we were firmly ensconced in gimbal lock. We had all the lights on, the DAP was not operating anymore, we had no control outputs, clearly no CDU outputs were being processed, so we just put it in AGS and completed the docking in AGS.

ALDRIN And I don't think the AGS is a good system to dock in, or PGNS either.

ARMSTRONG This was just a goof on our part. We never should have arrived at the conclusion from any series of maneuvers. However, that's how it happened. It wasn't significant in this case, but it certainly is never a desirable thing to do. There's nothing catastrophic about it here, but I'm sorry that somehow or other we hadn't studied the docking maneuver a little bit more carefully and recognized that there might be some attitude constraints in the maneuver that we hadn't considered.

ALDRIN The few times that we'd done that previously we ended up approaching docking with the Sun more along the line of sight to the two vehicles. This was more our concern, arriving at the docking point a little bit late. If you arrive there a little late and the line-of-sight motion happens to be such, the Sun is going to be pretty close

ALDRIN (CONT'D)

to where the command module was. In this particular case, it was about 90 degrees away. After getting in that attitude (or getting docked), to have a PGNS operating, I aligned it to zero and went through the quick alignment procedure. I got the PGNS back in operation again and figured it was not a known REFSMMAT. There were no postdocking maneuvers planned by the LM, so to get both systems the same, I then aligned the AGS to the PGNS. Both of them lost their reference, but both of them were 00 and as far away from any future gimbal lock as they could be. That might have been a better way to operate anyway.

COLLINS

The rendezvous procedures from the command module viewpoint were about as well worked out, I thought, as they could be with the existing command module computer structure and with the degree of participation necessary by the CMP. I have always felt, and I still feel, that the system is designed in such a fashion that the CMP is too busy during the rendezvous procedure. Although I was able to keep up with the timeline quite well, I felt that I was devoting too large a percentage of my time to the job and that I really was poorly placed to

COLLINS (CONT'D)

cope with any systems problems or any other difficulties or abnormalities that might have come up. I don't propose any sweeping changes from mainline Apollo. It would be fruitless to do so, but I really think that for future vehicles the rendezvous should be something that is relatively straightforward, something which does not require literally hundreds of simulator hours to master the procedural aspects of. I think, as we get into these lunar-exploration flights, the crew is going to be forced to devote more and more of their attention to what they're going to do once they've arrived, not just to working out the procedures for how to arrive. I really think that. From the command module viewpoint, with one man inside the command module, I think the procedure should be simplified, and if that requires a greater degree of automation, then I think we ought to have more automation. I had a solo book which combined features of various other publications, the idea being I wouldn't have to chase around the cockpit; I would have everything under one cover. This concept worked well. I recommend it highly. The only funny I had during the rendezvous was the VHF ranging kept breaking lock. I had a good lockon during ascent just as I had during the simulations.

COLLINS (CONT'D)

I was surprised when, after insertion, VHF ranging broke lock. I did reacquire, but from then on, the thing broke lock 25 times during the course of the rendezvous. Sometimes, I could immediately reacquire with the reset switch on panel 9. Other times, it was not possible to reacquire. I would have to go VERB 88 ENTER to lock the VHF ranging data out of the computer, and then at some later interval, I would get a good reacquisition and do VERB 87 ENTER to allow that data to come back into the computer. It was possible for me to tell, after a little practice, whether I was going to get a good lock or not by listening to the tone during the lockup procedure. There are three tones, two of which are in the audible range. If it was going to be a good solid lock, the tones would be very clear and sharp just as they are in the simulator. If it was not going to be a good lock, if the lock was going to be unsuccessful, the tone sounded very scratchy and had a lot of static. After the third tone had completed its cycle, the numbers would appear very briefly on the EMS and then they would almost immediately go to zero, indicating the thing had broken lock. I used a technique of setting the mission timer in the lower equipment bay to the nominal LM

COLLINS (CONT'D)

lift-off time of 124 hours, 23 minutes and 25 seconds. At the instant the LM lifted off, I started that clock running. I kept two times; the LEB time was flight plan time. If I followed it, I could with a high degree of accuracy tell you where I should be in my procedures book. I left the MDC clock undisturbed, so that all the updates and communications with the ground could be done in true and correct time. It worked well for me. I practiced it in the SIM's. I was influenced by the fact that the digital event timers had a poor history of reliability and that the digital event timers in spacecraft 107 had been replaced once and further had little funnies in them during tests. If you trust the

COLLINS (CONT'D)

digital event timers to count down to burns, then probably my procedure is an unduly complicated one. On the other hand, it is workable. I found it an aid in running through this, despite the fact that we were a couple of minutes off nominal. I have some numbers on breaking lock. I first got lockon during the latter part of the ascent burn. It broke lock at 124 hours and 31 minutes, re-acquired immediately, and broke the second time at 124:34. It broke twice thereafter in rapid succession. I relayed my out-of-plane solutions to the LM. They

COLLINS (CONT'D) were, after insertion, on the order of 1 ft/sec, and the LM Y-dot minus 1.0. I had my own Y-dot plus 1.4. CSI solutions compared fairly close with the LM and the ground solutions. I think Buzz has reported those numbers previously. I was in an orbit of 63.2 by 56.8, which could explain some of the up-down component in the CDH solution, as well as some R-dot peculiarity the LM experienced.

I had some eccentricity in your orbit after CSI. I had you 49.5 by 46.1. I think the combination of those two screwy orbits could explain lots of R-dot dispersions and up-down components.

ALDRIN I asked the computer what time we were going to get to apogee, and it was only a couple of minutes off to CSI time.

ARMSTRONG Yes, but you didn't know where his apolune was.

ALDRIN That's right. Ninety degrees away.

COLLINS I don't think it's worth our spending a lot of time here trying to hash out these numbers. I just mentioned them for the record. A plane change was not required during the burn. I still think that it's possible under some

COLLINS (CONT'D)

disperse circumstances to have a large plane change required following an ascent from the lunar surface. This plane change might have to be done by the command module using the SPS. This is something that had never had procedures worked out for it. I did invent a procedure. I don't think FOD liked it although they didn't have any better procedure. I would suggest that the FCOD come up with a procedure that MIT and FOD and the Center agree might be used to allow the command module to whip around and make an out-of-plane SPS burn. Now, the one that I invented was sort of sneaky. It took P52, the platform align program, and told P52 to align the platform to a landing site which arbitrarily was said to be 35 degrees north latitude. Of course, this is completely phony, but it cocked the platform off 35 degrees in roll, so that when you yaw out of plane either left or right, you'll go above the cherry or below the cherry, because the platform has been rolled out of the way. It worked well in the simulator. I don't know what the objection to it is. I had a little procedure drawn up, and it was included in the rendezvous book. If this is not a good procedure, then it should have been substituted

COLLINS (CONT'D) for something better. You need to have in your hip pocket some quick way of whipping that command module around 90 degrees and burning SPS.

ALDRIN You didn't want to do it by just taking it 45 and asking for a good preferred alignment?

COLLINS But you have to get a new REFSMMAT from the ground and everything else.

ALDRIN Another way, you load the burn in P30.

COLLINS I see what you're saying.

ALDRIN Then go into P40, find out what it is, set the REFSMMAT flag, and then go into it.

COLLINS Yes. That's another way of doing it. You can do it that way as well. This P52 way was just quick and simple and dirty.

Another little funny I noticed (maybe it's something that I overlooked in my training) was after CSI when I went to P20. P20 would not track the LM; in fiddling around, I found that if I recycle the optics zero switch it would track the LM. Now, as a matter of practice, I had always left the LEB in optics manual and optics zero to

COLLINS (CONT'D) zero. The reason you leave it that way is because of failure modes in the CDU's, which are shared with the thrust vector control if you're going to burn the SPS. In the simulator, when you get back down into the LEB, all you have to do is take that optics zero switch and throw it off, and P20 will immediately start tracking the LM.

ALDRIN Did you have it in CMC?

COLLINS Yes, CMC. But on two occasions it wouldn't do it. I found if I cycled the optics zero switch, it would track the LM. I don't understand this. It's as if there is a funny in that switch in regard to the optics power. When you first turn optics power on for P52, you have to cycle that switch back to zero for the program to be aware that it has been zero. Otherwise, you get into CDU difficulties. It's something similar to that. Anyhow, after CSI when I went to P20, the sextant would not track the LM until I had recycled the optics zero switch. How I knew to do that, I don't know. It was just trial and error.

VHF ranging broke lock again along about plane-change time. It broke lock again at 126 hours. We've already discussed the CDH solutions.

COLLINS (CONT'D)

I had hoped to get some sextant marks immediately after CDH, but prior to going into P34 this was questionable because of the position of the Sun. I thought that I could probably get three or four marks before Sun shafting prevented it. I was wrong. I couldn't get any marks at all. After CDH, I was able to get VHF marks only for a little while.

In the meantime, I went into P34 and I had a very slow COMP cycle the first time through on P34. Up until this time, the AUTO optics had been doing a smooth job of tracking the LM. I noticed that this smoothness disappeared a few minutes prior to the TPI. It became quite jerky. I made a little note here - the LM tracking jerky in sextant, and DAP excessive pitch thruster firings. It seemed like there was a little flurry of pitch thrusters firings along about this point as well, which I don't have any explanation for.

Everything progressed normally through TPI. It was along about midcourse time when I first saw the LM coming up from below. It looked like the doggone LM was riding on rails. There was absolutely no line-of-sight rate that I could see. It really looked great to see the LM coming up from the surface. For the first time, I had

COLLINS CONT'D)

the feeling that that son of a gun was really going to get there in one piece.

Midcourses were very small. Braking was done entirely by the LM. I was completely passive, and that's all I have to say about the rendezvous.

Docking we did in CMC, AUTO, narrow deadband under DAP control. Neil made the crude alignments to get the correct side of the LM pointed toward the COAS. Then I made the final adjustments. I estimated that I contacted the LM just about exactly dead center and at a slow-but-adequate closing velocity. I would guess slightly in excess of 0.1 ft/sec. Despite this fact, I couldn't tell the instant of contact. The empty ascent stage is light enough relative to the command module that when the two vehicles touch, it's just sort of like pushing into a piece of paper. The LM recoiled enough that they could feel it in the LM, but I couldn't really feel it in the command module. I thought I was getting there, and I thought I was getting there, and I finally was fairly sure I had contact. I looked up for the third or fourth time, and I did have two barberpoles indicating that the capture latches had made. At this time, I looked out the window, and the situation appeared static. I threw the

COLLINS (CONT'D)

switch from AUTO to FREE, so that I was in CMC, FREE. I looked out the window again — this was all going pretty fast now — I would say this was 3 seconds after contact. The situation looked like it had previously; that is, the two vehicles were statically joined together with no motion. At that time, I fired the bottle. No sooner did the bottle fire than a yaw gyration started between the two vehicles. I'm not sure whether it was a result of the retract cycle beginning or whether it was a result of the LM firing thrusters toward me. At that time, this static situation became very dynamic, and a fairly large yaw excursion took place. I would say that relative to the LM I rapidly went to about a 15-degree yaw right angle. I put the CMC, FREE switch back to CMC, AUTO. This enabled the hand controller in rate command and minimum deadband. I made manual inputs to yaw back over towards the centerline, and there were a couple of other oscillations enroute. I can remember thinking, "I don't think we're going to get a successful hard dock this time. I'm probably going to have to let the LM go and try again." About that time, the docking latches fired, and we were hard docked. I would guess that the time interval from firing the bottle to hard dock was about 6 to 8 seconds. This is probably

COLLINS (CONT'D) a pretty normal retract time. Things were happening fairly rapidly, and the oscillations had built up almost exactly at the time I fired the bottle which was primary 2.

ARMSTRONG I can add a few comments here from the other side. At the time we felt the contact — which really was difficult to feel — it was a very low bump sound, or touch in the tunnel; we fired plus X RCS in the LM as per the preflight plan. Shortly thereafter, we also observed significant attitude oscillation. I guess it would be primarily right roll as observed in the LM. We were in AGS RATE COMMAND minimum deadband and, in addition, plus X. As soon as the attitude deviation started, I left the plus X off and called for Buzz to give me MAX deadband in the thrusters so we wouldn't be firing a lot of attitude thrusters. Then I took control and manually maneuvered the vehicle back toward colinear status. About that time, it snapped us in there and locked the latches.

COLLINS I didn't like the idea of these two vehicles being joined together just by these two little capture latches. I was in the habit of firing the bottle the first time it appeared; the two vehicles had been joined together and the situation was static. I never gave these oscillations

COLLINS (CONT'D) a fair chance to develop. Maybe a better thing to do is delay firing the bottle until you are sure the oscillations are not going to develop. Although it was sort of alarming there for a second or two, this way did work and it was within the envelope. I'm not sure if I had it to do over again that I would do differently. It depends on what caused the oscillations to get started. It could be the thruster firing of the LM or it could be some other cause. If it's the thruster firing of the LM, then you ought to delete the thruster firing on the LM. I'm not really sure you need that thruster firing on the LM.

ALDRIN I'm not either ...

COLLINS If it's some other cause, then the thruster firing of the LM is probably not a bad thing.

ALDRIN It should tend to give some stablizing effect to the LM. You'd like to have some control system that's holding the LM fairly close to where you want it to be. I think automatic is probably able to catch sooner than manual. Because you're looking up this way, it's pretty darn hard to maintain a close position. That argument says that you ought to be in some kind of automatic rate command system.

ARMSTRONG I think we have to admit that this was one area, in retrospect, that we gave less thought to than it probably deserves. During simulations, none of our simulators is able to duplicate this kind of dynamics. We saw some film that had been taken of a McDonald study. We saw these and observed what their recommendations were. That's what was incorporated in our docking plan.

That really was devised to get the capture latches in. I really suspect that everything we experienced happened after the capture latches were engaged. The results of that study really weren't pertinent to this particular phenomenon. We hadn't experienced any trouble at all on your previous docking. That was just as smooth as glass.

ALDRIN It seems to me that it's not too good a mode to be working in. You're tempted, if the thing starts to move on you, to touch the stick. As soon as you do that, you have now reset a new attitude that may not be what the combined systems are going to be happy with; and if it's not, it's going to fire.

ARMSTRONG That's right. I'm not sure that a lot of thought on our part in this area would have made the situation any better.

COLLINS No. That's right.

ALDRIN I don't think we got a tremendous amount of guidance out of the AOH or anybody. It seemed to be, however you want to do it. You can do it this way or that way. They are both acceptable means in the AOH. It seemed to me there were two ways to be acceptable, and this was with primary guidance control. We didn't have primary guidance control because of the gimbal lock problem. It seemed to me that the book treated that subject a little lightly. Wasn't it written for LM active?

ARMSTRONG Yes.

COLLINS We gave the subject very little training time, but had we given it a lot of training time, I'm not sure we could have come to any different conclusions.

ARMSTRONG It did bite us a little bit.

ALDRIN It's worthy of concern because if you do prang something the consequences are time consuming and nasty to have to go through.

ARMSTRONG This one got to us and, for one reason or another, we didn't understand it well enough. I suggest that the next crew spend a little more time than we did in this area and try to improve on the procedures.

ALDRIN All other dockings were done in PGNS.

COLLINS This was the same procedure from the command module. The only difference was that the LM ascent stage was considerably lighter.

ARMSTRONG The LM control configuration was different.

COLLINS Yes, I meant from the dynamics of the command module viewpoint. I had the feeling that going to FREE under these circumstances was a mistake.

ALDRIN You don't have a good choice of deadbands. Half a degree seems to me to be too tight for this operation, and 5 degrees is much too loose.

COLLINS Flag it as a problem. I don't have a solution.

12.38 POST DOCKING CHECKS AND PRESSURIZATION

COLLINS When I went into the tunnel this time, I had that same strong odor of burnt material. Again, I checked everything very closely and couldn't find anything wrong. All the decals and checklists were well worked out for the probe and drogue. I was glad to see it work. I never had much confidence that our tunnel was going to work as advertised, but it sure did. I was very happy to see the

COLLINS (CONT'D) tunnel, the probe, the drogue, and all that stuff part company and go along with the LM.

12.39 TUNNEL OPERATIONS

COLLINS We went through an extra operation, and this is something that we never practiced jointly. It was my intent to take the probe out, the drogue out, and put those two items inside the command module. I guess it was your intent to take them out from your side and put them inside the LM. I just happened to beat you to it. It really wasn't very efficient the way I did it.

ALDRIN I thought you were going to do it.

ARMSTRONG I had it in my mind that I was going to do it.

COLLINS The flight plan didn't mention it. It sort of implied that you guys were going to do it, because it said to remove and stow tunnel hatch, and then it said to notify LM crew they could open their hatch. It didn't mention the probe and drogue. When I came to that, I thought they just left that out of the flight plan. I said, "Stand by one." Then I got the probe and drogue out and stowed them onboard in the command module. This was an

COLLINS (CONT'D) extra operation because subsequently they had to be transferred to the LM. This is another area where we couldn't say that we had smooth coordination. I knew how to do my end, and the LM knew how to do their end; but we hadn't sat down and discussed who was going to do precisely what.

12.40 TRANSFER OF LM EQUIPMENT AND FILM

ARMSTRONG The equipment transfer and cleaning back contamination procedures were done essentially in the manner that was planned. We had a couple of small differences. We decided we wanted to bring the LEVA bags, and the LEVA's, and the EVA gloves back with us for postflight examination. We brought the whole ISA, interim stowage assembly, with all its transfer gear into the commmand module. The intent was to unload that, restow it in the command module, and then take the ISA back into the LM. We didn't do that. We brought the ISA back in the command module with us. That's a 1-pound item or something. We were able to get through that procedure about on the planned timeline.

ALDRIN As a matter of fact, they were thinking about moving up TEI.

ARMSTRONG Well, as it turned out, our LM jettison time could not have been moved forward a REV.

ALDRIN Because of attitude.

ARMSTRONG We couldn't have made it really.

ALDRIN Because of the attitude?

ARMSTRONG No, we just couldn't have gotten through in time.

COLLINS We were an hour, maybe an hour and a half, ahead of time.

12.41 VACUUMING EQUIPMENT

ARMSTRONG I was concerned that it might take us a lot of time to clean the LM, and I was also concerned that we would have a lot of free-floating lunar dust in the cockpit going back to insertion. We really wondered at engine cut-off whether we wouldn't be completely engulfed in soot and be unable to take our helmets off for the alignments. However, there wasn't much dust, and we couldn't figure that out because - -

ALDRIN The stuff seemed to stick to things and stay there.

ARMSTRONG I thought we'd tramped a lot of it with us, but it didn't bother us.

ALDRIN I wiped it up with my suit on the floor.

ARMSTRONG We did clean with the vacuum cleaner as best we could. That vacuum cleaner has a very low suction, and more time was required than we planned to do the cleaning job. We were afraid it wouldn't be done to the degree of completeness that we had hoped for.

We were able to clean the suits satisfactorily with a scrubbing motion. However, there wasn't a large amount of free contaminate in the LM. We wore the suits back into the command module and restowed them in the L-shaped bag after a drying-out period. The LCG's were also stowed with the suits in the L-shaped bag. The suits were relatively clean, but they had a lot of residual smudges on them.

ALDRIN There was no hope of getting that off.

12.43 STOWAGE OF SRC's

ALDRIN The bags for the rock box, I think, could have some better labeling on them. You want the box to be mounted correctly in the command module so that one g or the g forces of entry will push the material down towards the bottom of the box instead of the top. But nothing really tells you how you put the box inside the bag. You can

ALDRIN (CONT'D) put it either way. We learned by the way the lettering was, you had to put the bag on the box upside down to the way you normally think. It would help if the zipper went around the bottom instead of around the top; so I think that some more labeling would be in order just to make sure that no one puts the box in the bag upside down. I don't know how critical that is, but it's worth noting.

ARMSTRONG Stowage was planned, plus we had a large temporary stowage bag completely filled with command module trash, food wrappers, and so on, which was transferred to the LM to clean up the command module volume.

13.0 LUNAR MODULE JETTISON THROUGH TEI

13.1 LM JETTISON

ARMSTRONG LM jettison went as planned.

ALDRIN Was there ever any intentions to track the LM after jettison.

COLLINS No. That was never even discussed.

ALDRIN I don't understand why we left it in VHF ranging mode and left the track light on.

COLLINS I have no idea. We never had a DTO on it, or to my knowledge, it was never even discussed.

ARMSTRONG The separation was slow and majestic; we were able to follow it visually for a long time.

COLLINS The LM held its attitude extremely well. I don't know what mode you left it in, but I thought when the explosive charge fired, it would sort of start going ass over tea kettle. It must have been in some good attitude hold mode, wasn't it?

ARMSTRONG We could watch the jets fire to hold attitude as it went away.

ALDRIN It was in MAX deadband, AGS ATT hold. It seemed to me that, right at the time of separation, as the LM moved away, I could see some cracks that had developed in the outer thin skin of the top part of the LM in the gray material that forms an area around the docking cone. However, according to the ground it held pressure. I couldn't see any other damage that had been caused by blowing the tunnel.

COLLINS The only comment that I had is that the separation burn was something that MPAD had changed their minds about a time or two. Originally, it was going to be 1 ft/sec horizontal retrograde. Then for some reason, they wanted it 45 degrees up from horizontal, and they wanted 1 ft/sec retrograde component or a total burn of 1.4 ft/sec. I don't have any preference one way or the other. It just seems like that's a fairly simple thing, and they ought to get their desire worked out early in the game and not have that be a late, last minute change, because it just makes for last minute conversations on unimportant things.

13.2 DOFFING AND BAGGING HELMETS AND GLOVES

ALDRIN We didn't put the helmets in the LEVA's did we?

ARMSTRONG No.

ALDRIN Looking back on it, I think it would have eased the stowage problem in the command module.

ARMSTRONG Yes, but there was a reason for that, and that's that the LEVA's and the EVA gloves were both awfully smudgy. The choice there was to leave them sealed up in the LEVA bags rather than to get that soot out into the command module.

13.4 ORBITAL NAVIGATION

COLLINS The activities prior to TEI were leisurely. The updates were passed up in good time, we passed our sextant star check. In general, the usual sequence of P30 and P40 is one that has been well worked out and TEI had no surprises up until TIG time.

13.9 TARGET-OF-OPPORTUNITY PHOTOGRAPHY

COLLINS Well, we took a few photographs prior to TEI, but essentially we spent the time preparing for the burn. We didn't do any television prior to TEI.

13.12 TEI OVERBURN CRITERIA

COLLINS Those criteria were ones that had been hammered out for a long time. We didn't have any argument with them. Essentially it was a 2-second overburn, if confirmed by EMS reading of minus 40 ft/sec. We came close to shutting

COLLINS (CONT'D) the burn down manually — I'll get into that a little bit later.

13.15 PREPARATION FOR TEI

COLLINS At TIG, this was the first burn with CSM only. I had my rate needles on 5/1 and I did that because I think it's a good mode to be in if you're worried about any sort of abnormal dynamics. They're much more readily apparent on the sensitive scale.

13.16 SPS/TEI BURN AND ECO

COLLINS AT TIG, I noticed more rate-needle activity that I had seen in previous burns. I had a start transient of probably 0.4-ft/sec activity on the rate needles in both pitch and yaw; there was very little attitude deviation. It was just a fairly rapid oscillation of both the gimbal position indicators and the rate needles and it damped itself down I'd say within the first 10 or 15 seconds of the burn. In roll, the vehicle was deadbanding. Instead of plus or minus 5 degrees, it appeared on my attitude indicator to be more like plus or minus 8-degree roll deadband and it was banging against the roll stops fairly crisply. It would cruise over, hit deadband and jets would fire, and it would go back the other way.

COLLINS (CONT'D)

This roll deadbanding was quite obvious during this burn as opposed to the other burns. I think all these indications are normal. They were just somewhat exaggerated during the first 20 seconds of the burn compared to the more damped case of having the LM attached. The EMS counter moves out pretty swiftly and it was difficult for me to estimate exactly when I might have minus 40 on the counter. The I_{sp} of the engine must have decreased or something; at any rate, the burn duration was longer than predicted and when burn time plus 2 seconds had elapsed, I had thought that I would have minus 40 on the EMS counter by the time I could get the thing shut down. There was some doubt in my mind as to whether it was shutting itself down automatically or not; so, at burn time plus 2 seconds and some small fraction, I turned both EMS DELTA-V — or both DELTA-V — normal switches off. I think just a fraction of a second prior to this we got a good automatic shutdown. At any rate, our residuals were very small; so either we got a good automatic shutdown followed immediately by my turning the switches off or else I shut the thing down manually and was just extremely lucky in that it coincided with the PGNS residuals. For some reason, that burn duration was a little bit longer than I would have expected. LOI, you remember,

COLLINS (CONT'D) was shorter than we had predicted and this was the next burn to follow LOI, so I was sort of surprised that it did take longer than normal.

ALDRIN The PUGS was a little bit unpredictable based upon performance during LOI. The fact that I couldn't catch up with the increase and it got ahead by about 0.4 or 0.5, something like that, plus the preflight briefing that that would be the case was why I left the switch in INCREASE. We lit off and got through the initial guidance and I looked at the meter and it was showing down in DECREASE, which struck me as not being what it should do. I expected it to be in INCREASE, but I thought "Well, maybe this is a characteristic such that early in the burn it does this sort of thing." So I left the switch where it was to try to catch up. I guess in the meantime that the two numbers — where one had been bigger that the other — had changed positions, in addition to the fact that when it says INCREASE, you throw it in the INCREASE direction. It's not at all obvious during a burn if one is a little bigger than the other. You're not sure whether the needle is believable or not, so I left it in INCREASE and it seemed as though it was getting farther apart and the needle was staying down; so contrary to what we had been led to believe, I put the thing down to DECREASE just to

ALDRIN (CONT'D) see what was going to happen. Sure enough, it stopped the divergence of the two numbers. We didn't have a long enough burn for it to get right to zero, but it was within 0.2. Anyway, it was a little different than what we had expected. I guess, if you really want to play that game, you might need to write some cues or something on there so you don't misinterpret anything. It worked out well. But it was unusual and that might have something to do with burn time.

ARMSTRONG We tried something different on this flight. The ground computed a postburn state vector, a predicted postburn state vector and put it in the LM slot. After the end of the burn, we could call up VERB 83 and get an R and R-dot from our state vector over to the predicted state vector. It came out real close — 0.7 mile and 0.8 ft/sec — indicating (it's kind of another double check) that we really did get the burn that we thought we were going to get. That's not really any kind of requirement if everything works. It is a nice kind of thing if you have an SPS problem or if you take over with the SCS in the middle of the burn when your computer is working okay, but the guidance isn't working. You can use that vector in your hip pocket to find out how good of a switchover you did and how close your SCS burn came out.

14.0 TRANSLUNAR COAST

14.1 SYSTEMS VERIFICATION FOR COAST

COLLINS All the systems were GO; there wasn't anything to do.

14.2 NAVIGATION, NAVIGATIONAL SIGHTINGS, AND OPTICS

COLLINS We didn't do any onboard navigation. Our flight plan called for doing it only in the event of COMM failures. The optics worked normally on the way home.

14.3 EVAPORATORS: ACTIVATION AND DEACTIVATION

COLLINS We did not activate either the primary or the secondary evaporators until just prior to entry; so, during transearth coast, those were not in the system.

14.4 PASSIVE THERMAL CONTROL

COLLINS Passive thermal control three modes — we didn't have three modes, we just had the one mode. We always rolled G&N control at 0.3 deg/sec; that procedure we've already talked about. There were no differences in transearth, although the geometry of the vehicles was a lot different and I thought that the command module by itself would go unstable more quickly. Neil thought it would not, and he was right. It was very stable on the way back, just as it was on the way out.

ALDRIN The LMP would have preferred pointing north. However, there was an added advantage in that we got to look at the Magellanic clouds by PTC-ing at 270.

ARMSTRONG To look at the earth, to look north, you had to get upside down.

COLLINS Yes, we went out in 090 pitch angle and came back 270 pitch angle. It's "macht nichts" to me; I don't care one way or the other.

14.5 EXCESSIVE MOISTURE ON TUNNEL HATCH AREA

COLLINS There was a little tiny bit of moisture up in there at various times. On the way home, there was less than there had been earlier. The last time I checked was at 180 hours or thereabouts.

ALDRIN You thought it was less? I don't remember much moisture at all.

ARMSTRONG I thought it was more on the way home.

ALDRIN I did too. We made use of the ECS hoses.

COLLINS Yes, I put the hoses up there and there's one comment in here. Here it is - "180 hours, dry as a bone."

ALDRIN That was after we put the hoses up there.

COLLINS Prior to that, there was a little bit of moisture up there and I did wipe it off with a towel sometime after TEI.

ARMSTRONG I could go into the tunnel usually and wipe my finger around the hatch up there and come back with a wet finger.

COLLINS Well, you could see little beads of moisture like on a beer bottle or something like that.

COLLINS There weren't great globs of moisture and, as I say, at 180 hours, it was dry as a bone. When we came to entry, we wiped excessive moisture from the tunnel hatch area. That leads me to believe that it has something to do with the routing of those hoses. If you really cram a set of hoses up in that tunnel as far as it will go and sort of wedge the hoses up around the side of the hatch as far as you can, it might help keep the circulation pattern up. That would keep it fairly dry.

ALDRIN We shot up a batch of film right after TEI. We pitched down and picked up a good attitude to photograph the moon out the hatch window.

COLLINS Yes, we took a whole lot of what I think should be real good pictures.

ARMSTRONG We made a lot of color-comparison checks.

ALDRIN Well, we haven't mentioned anything yet about the color as viewed particularly and I guess it is one thing people are going to be listening or looking for before they debrief us. I think that it makes some difference which window you're looking out because the windows do seem to have a little bit of a coating on them. I got the distinct impression that it depended on how you looked out of a particular window, what angle you looked out of it, to tell you just what color you were going to see on the surface. It didn't look the same out of each window. That could answer a lot of questions about the differences that people see and I'm sure that not every spacecraft has the same coatings on the windows. I don't know how significant it is though.

14.6 FUEL CELL PURGING

COLLINS Fuel cell purging was normal on the way back.

14.7 CONSUMABLES

COLLINS We finally - we almost caught the RCS budget. Last hack on that, we were 1 percent down and on the hydrogen and on the oxygen we were very close to nominal. Whoever figured those out did a good job.

14.8 SPS MIDCOURSE CORRECTION

COLLINS None was required on the way back. We did have one midcourse of 4.8 ft/sec which we did with the RCS.

14.9 MIDCOURSE LUNAR LANDMARKS

COLLINS That's not applicable.

14.10 STAR/EARTH HORIZONS

COLLINS That's not applicable.

14.11 ECS REDUNDANCY

COLLINS We did not investigate any of the redundant systems of the ECS.

14.12 DAP LOADS

COLLINS DAP loads were as called out in the flight plan; I don't have any comments on those. We widened up the DAP deadband PTC to 30 degrees, which is really sort of a waste of time in that DAP PTC procedure, because as soon as you widen the deadband, you turn all 12 or 16 of your RCS thrust switches off. It really doesn't matter whether the deadband is wide or narrow, the thing is incapable of firing any thrusters anyhow. The DAP loads as written in the flight plan were satisfactory.

14.13 IMU REALIGNMENT

COLLINS IMU realign was all right. Throughout the flight, I was able to get satisfactory IMU alignments during the PTC at 0.3 deg/sec. This is a fairly fast rate, and it feels uncomfortable. You have to go to RESOLVE MEDIUM, and you have the feeling that you are lucky to click the stars that pass through the center of the reticle pattern. It's not really possible to track smoothly and hold the star in the center and make a very precise mark. However, the star-angle differences came out usually 00001, so I guess that the accuracy is well within the limits that you would call satisfactory.

14.14 COMMUNICATIONS

COLLINS Again, the ground was changing between OMNI B and D in PTC. When we were stopping PTC, we were getting little snatches of the high gain. Difficulties with that system were traced mostly to ground-switching problems, although you would have to say it is a fairly cumbersome system using the four OMNI's and the high gain. I don't have any suggestions for improving the operating procedures.

ALDRIN It would be nice if the ground had control of that OMNI switch to select any of the four.

COLLINS Yes, that's true. Right now, the ground can either switch between high gain and D Dog or between D Dog and whatever is selected on the switch to its left, which is normally B Baker.

14.15 BATTERY VENTING

COLLINS Battery venting and waste dumps were all normal, just as they were on the way out.

14.16 POWERING UP AND DOWN OF SPACECRAFT

COLLINS We only powered a few items down each night. We really maintained power for the entire flight, and that was a mode of operation I enjoyed, not having to power down.

14.17 TELEVISION

COLLINS We made a goof on our last television show. We left the circuit breaker out, which allows the monitor to be operable without transmitting. Consequently, we lost a lot of the entry data. It's the one on 225 called S-band, FM transmitter, data stowage equipment flight bus. Of course, the entry checklist didn't mention checking that circuit breaker, because the people who wrote the entry checklist had no idea that it would be out because of a television program hours prior. I guess the TV checklist doesn't mention it either as best I can recall.

ALDRIN I was sort of disappointed in the ground not catching that. It seemed to me that they might want to make some checkout of the tape because they had control of it before entry, or because we called out to them that the talkback barber-pole didn't go gray.

COLLINS We did lose control of the tape because the circuit breaker was out. I believe that we and the ground both got tricked into thinking it was because we hadn't gone to COMMAND RESET. But didn't you tell them once that you had gone to COMMAND RESET and you still didn't have tape control?

ALDRIN Yes.

COLLINS To make a long story short, we did inadvertently leave that TV circuit breaker out, and therefore, the taped entry data were lost. They'll still have a lot of information through the downlink.

14.18 COAST PARAMETERS - ANOMALIES

COLLINS The machine held together beautifully on the way home. I don't know of any anomalies.

14.19 HIGH GAIN ANTENNA TRACKING

COLLINS High gain antenna tracking was as it always was.

14.20 S-BAND PERFORMANCE

COLLINS S-band performance was good.

14.21 NECESSITY OF ADDITIONAL IMU REALIGNMENTS

COLLINS The IMU, by this time, had had its compensation terms updated once or twice, and it was in good shape. I don't recall the longest period of time we went without an IMU alignment, but it was on the order of 12 hours. At the end of this period of time, the stars were still well within the sextant field of view.

14.22 MCC UPDATE

COLLINS Midcourse correction update was well handled. We only had an RCS burn.

14.23 W-MATRIX

COLLINS We didn't fool with it; we left it alone.

14.25 PRESLEEP AND POSTSLEEP CHECKLISTS

ALDRIN We talked once about looking into some modifications of the COMM so that you didn't have the two options available, plus referring to another checklist with exceptions. I think there's some way to simplify that.

14.26 PHOTOGRAPHY

COLLINS We took lots of pictures on the way home, using up the remainder of the film. We took photos of the exterior of

COLLINS (CONT'D) the Earth and the Moon at various settings. We'll just have to wait and see how they came out.

14.27 PASTIME ACTIVITIES

COLLINS What did we do with our free time? We mostly just waited. We had plenty of time to eat, had plenty of time to get rested up. We used simultaneous sleep periods on the way home. Our inclination during preflight was to use staggered sleep periods on the way home. I'm not sure in retrospect which is the best way to go.

ALDRIN I didn't see anything wrong with the way we did it.

COLLINS I didn't see anything wrong with what we did, because nothing broke. Had we had things start breaking, I'm not sure we wouldn't have been better with the staggered sleep periods.

14.30 TIMELINES AND FLIGHT PLAN UPDATES

COLLINS There was none that I recall.

14.31 MANEUVERING TO ENTRY ATTITUDE

COLLINS Maneuvering to entry attitude was done easily and early.

14.32 BORESIGHT AND SEXTANT STAR CHECKS

COLLINS We did not have a boresight star, but the sextant star check passed as it always did.

14.33 ELS LOGIC AND STAR CHECKS

COLLINS The ELS logic check was done early with the ground looking over our shoulder, and it gave us a GO for PYRO ARM.

14.34 EMS

COLLINS We checked the EMS out insofar as we could the day prior to entry. I think this is a good idea because if there are any funnies in it, then the ground has a good 24 hours or more to have meetings and decide whether or not all or portions of the EMS are GO or NO GO for entry. The DELTA-V counter worked normally in EMS. Accelerometer bias - I don't really recall that we checked that preentry. We just ran through all the self-test patterns, and one of those checks accelerometers when it counts down to zero plus or minus something.

14.35 ENTRY CORRIDOR CHECK

COLLINS The ground kept reporting our gamma, which was indicating a little steep, 65 something. Then we got closer and closer to nominal as we got closer in, and I don't recall what our actual gamma was. I think it was 652.

ARMSTRONG No. 648 was the last we hit.

COLLINS 648 is as close to nominal as you can get.

14.36 FINAL STOWAGE

COLLINS We had a couple of items, mostly helmets, that did not go according to the entry-stowage plan. The helmets were supposed to go in the foodboxes. Only one helmet fit in the food box and that left us with two helmet bags plus two LEVA bags. These four little packages we bundled up and put inside the right-hand sleep restraint and latched down with tiedown cord. That system worked fine. Our first inclination was to put all those bags inside the hatch bag underneath the left-hand couch. However, the ground objected to that because they thought that the bag wasn't stressed sufficiently for that weight during entry, but I think you could have put 10 helmet bags inside the hatch bag and it would have been perfectly safe. That hatch bag is very strong and it's a very convenient place to stow things even of helmet weight during entry.

ALDRIN We ought to find out what limits North American places on that for entry.

COLLINS You could grab that hatch bag and pull on it with all your might and you weren't about to pull that thing loose.

14.37 SYSTEMS VERIFICATION

COLLINS The systems worked fine.

14.38 FINAL ENTRY PREPARATIONS

COLLINS Final entry preparations were done early with a good checklist.

14.39 CM RCS PREHEAT

COLLINS CM RCS preheat was not required.

14.40 MANEUVERING TO ENTRY ATTITUDE

COLLINS We used the system of manually tracking the horizon and cross-checking gimbal angles and horizon positions in the window versus time out from 400 000 feet. The ground had given us several check points at EI minus 30 minutes and EI minus 17 minutes. In addition, we had a little graph that showed for any instant in time what the pitch gimbal angle should be to keep the horizon on the 31.7-degree line on the window. All these checks reinforced our belief that we did have a good platform and that we had a good trajectory.

14.42 CM/SM SEPARATION

COLLINS CM/SM SEP went normally. The water boiler was in operation during this period of time, which gave the spacecraft a left yaw. I was in MINIMUM IMPULSE a good percentage of this time, and thus it was quite noticeable. I yawed out 45 degrees left, jettisoned the service module, and yawed back in plane by yawing right. When I got a yaw

COLLINS (CONT'D)

rate started, the water boiler would fight me, the rate would reduce to near zero, and I would then have to make another input.

Having gotten back to zero yaw after jettisoning the service module, I noticed there appeared to be something wrong with the yaw-left thruster at this time. It had worked normally for a little while, but after several minutes of operation, it did not. That was command module RCS thruster 16, yaw left. It appeared to be functioning improperly using the automatic coils. When you yawed left, it made some noise, but it did not give the proper response. It would work properly if you'd move the hand controller all the way over to the hard stops and use the direct coil. At this late stage of the game, I didn't want to devote any time to troubleshooting or talking about it. I probably should have brought the number 2 system on the line in that axis, but I didn't; and everything else seemed to be working normally. I'm just flagging that as a possible systems problem; somebody should look at that thruster and its associated wiring after the flight and see if there's anything wrong with it.

FCOD REP

Did you see the service module?

COLLINS Yes. It flew by us.

ALDRIN It flew by to the right and a little above us, straight ahead. It was spinning up. It was first visible in window number 4, then later in window number 2, really spinning.

14.44 0.05g EMS AND CORRIDOR CHECK

ALDRIN What was the comparison of when the final g light came on?

COLLINS Twenty-eight seconds, I think.

ARMSTRONG When the DSKY indication of the accelerometer acceleration read 5, the 0.05g light came on. At that point, the clock read 28 seconds.

COLLINS The spacecraft was briefly out of the sunlight at 400 K, and all of a sudden the thing lit up and I thought we were starting to get ionization, but it really wasn't that; it was a brief period of sunshine.

ARMSTRONG I wasn't looking out, but there was a weird illumination. I also thought it was just ionization at the time.

COLLINS We got the 0.05g light, and I got the 0.05g switch and the EMS roll switch on. We were cross-checking the clock, and this was 28 seconds after 400 000 feet. I did not

COLLINS (CONT'D)

notice the corridor verification light, either the upper one or the lower one. Both of them could have been on. I was busy at this time checking other things, such as were we holding the right bank angles with the lift vector up and did the g on the EMS agree with the g meter. I was also listening to what Neil was saying about the computer. Of course, our intent was to hold the lift vector up unless we had some considerably off-nominal entry with no communications; so we started to do that regardless of what the corridor verification light said.