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GEMINI VII

TECHNICAL DEBRIEFING

December 23, 1965

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PREFACE

This preliminary transcript was made from voice tape recordings of the Gemini 7 flight crew debriefing conducted December 19 through December 21, 1965 at the Crew Quarters, Cape Kennedy, Florida.

Although all the material contained in this transcript has been rough edited, the urgent need for the preliminary transcript by mission analysis personnel precluded a final edit prior to its publication.

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1.0 COUNTDOWN

1.1 Crew Insertion

Borman I have no comment. I thought it went very well.

Lovell Likewise, no comment on crew insertion. I think we got quite a bit done. It was very orderly.

Borman Timing was good and it was done properly.

1.2 Communications

Borman Communications were good. I had no trouble at all.

Lovell I had no trouble with communications in the cockpit or the spacecraft, but the communications in the van from the suiting area to the other area are rather poor. Maybe we should try to get that improved sometime.

1.3 Crew Participation in Countdown

Borman Again, I think they have been used on 4 or 5 launches, and I thought they were fine.

Lovell Right. Countdown procedure and crew participation is just what you expect now.

1.4 Comfort

Borman Comfort was fine. No problems?

Lovell No problems for comfort, but I was surprised when I got in the cockpit, because there was a lot more there than there was when I got in it for the stowage review. But, it all turned out for the best. No problems.

1.5 ECS

Borman ECS worked fine. We had no trouble with ECS at all during prelaunch or launch.

Lovell That is true. The purge was a lot slower and it was just perfect for the final countdown. It was too fast for the SIM Flight, which we went through, and I got an ear blockage. For the countdown, it was just right. Very slow.

1.6 Sounds

Borman We had been well briefed on all the sounds: the gimbaling, pre-valve, and erector. As a matter of fact, when the erector started down there was no sound. We had been told that probably there might be a clanking or something. I heard nothing.

Lovell All I saw was the sky.

1.7 Vibrations

Borman Vibrations. No comment. I had no problems.

Lovell Is this liftoff vibrations?

Borman No, this is countdown. Vibrations of the spacecraft during countdown.

Lovell No, nothing we had not heard before.

1.8 Visual

Lovell The windows were perfect. We had no fogging.

Borman No fogging.

Lovell The windows were heated previously as a result of 5's problems, and our windows, I thought, were perfectly clean. Didn't you?

Borman Right.

1.9 Crew Station Controls and Displays

Lovell No comment. Exactly how we had planned it for months.

Borman Exactly the way that we had seen it, and no problems.

2.0 POWERED FLIGHT

2.1 Liftoff Cues

Borman Stoney came in loud and clear, counting the countdown.

Lovell Came in loud and clear.

Borman We knew exactly when it was, and I for one had absolutely no question in my mind when we lifted off. It felt like I had been tied back, and someone cut the string and there was a slow but definite acceleration at lift-off.

Lovell I thought you could just about put CAP COMM, Vibration, and noise together, because the motion, vibration, and noise all contributed to a definite knowledge that you were going someplace.

Borman In other words, what you are saying is that you had no problems determining lift-off.

Lovell No, it went.

Borman Okay vibration was nominal during lift-off. Again, perhaps

it is because we were so well briefed on the simulations we have run, but I had no problems.

Lovell There was a little more noise than I expected, but a little less vibration.

Borman Jim said there was a little more noise than he expected. Even so, it was not oppressive, or a problem at all. Visual. I did not have any visual cues. I was watching the instruments. What about you, Jim. Did you pick up any?

Lovell I had the clouds, and there was a visual cue. Just normal cloud cues.

Borman Cockpit displays were good. The fuel pressure and oxidizer pressure were nominal the whole flight. Just perfect.

2.2 Roll Program

Borman The roll program, was so short it was almost like a spike. We hardly even noticed the roll program. Did you Jim?

Lovell I did not notice it at all. I heard you call it out, but I did not notice it.

Borman I called it out, but we only rolled, I think, about 2 or 3°.

2.3 Pitch Program

Borman The pitch program started just as in the simulator, which is very accurate on this. It looked exactly the same on the ball, and there was no problem.

Lovell The pitch program for the RGS followed exactly what the IGS

was giving for the entire launch. The needles were just matched perfectly--nulled. I did not see any unusual attitudes that some of the other people commented on.

2.4 Aerodynamic

Borman Again, we had had this described to us many times, and it seemed to follow right along. In the maximum q region we got some vibration and noise, but after we got through maximum q it was just like going supersonic in a fighter. You just slip through, and from then on it was just like riding on a train.

Lovell I don't think it was bad either.

2.5 ECS

Lovell Pressure went up to 5.5 in the initial stoppage, and it slowly leaked down to 5.1, and stayed there.

Borman I was cool during lift-off.

Lovell I was too. Comfortable.

Borman Comfortable. I mean cool in the sense that it means comfortable. Of course we can not very well comment on the cabin atmosphere because we were sealed.

2.6 Maximum q

Borman We have already discussed this. There was some noise build up and some vibration, but nothing to worry at all about or even discuss.

2.7 Wind shear

Borman Wind shear. I did not notice any.

Lovell I did not notice any wind shear either.

Borman You could not see any on you attitude gauges either, could you?

Lovell No, that is what I mean.

Borman The attitude gauges stayed pegged. Right?

Lovell They stayed nulled throughout the entire flight. I was amazed at the accuracy with which the RGS was following the IGS program.

2.8 DCS Updates

Lovell Came through on schedule.

Borman No problem?

Lovell No trouble.

Borman Have any trouble punching the light?

Lovell After the second update, about 2:23, the g's are too high to let you punch off the light. So, you have to wait for staging, and then punch the light.

2.9 Engine 1 Operation

Borman Engine 1 operation, I thought, was normal. But I did notice a slight hint of a POGO around about, I would estimate, two minutes. The slightest, faintest hint. I do not think Jim even noticed it.

Lovell I did not notice any POGO.

2.10 Engine 2 Status

Borman It seemed to me that from about 3 minutes and 30 seconds to around 4 minutes, the noise and the feel was a little bit different than it was after that, as if it was vibrating a little bit more. But this was sort of, again, a sensing type thing. The instruments were all nominal, and it may have just been me. I certainly can not complain about the operation.

2.11 Acceleration g's

Borman Any problems, Jim?

Lovell No problems. They were pretty nominal, weren't they? I could not see the g meter.

Borman They were right on the money. And, of course, the g's we have are all experienced in the centrifuge, and so on. One thing, when the g's dropped at staging and at SECO I had no sensation of tumbling and no sensation of disorientation. Nothing at all.

2.12 POGO

Borman I've mentioned that I detected a slight hint of one that was so small we cannot even really discuss it.

2.13 Guidance Initiation

Lovell We had a guidance initiation. It was in the form of booster

yaw deflecting downward, more so than booster pitch deflecting. Booster pitch deflected slightly to the right, indicating, at guidance initiation, a booster-high trajectory. But, they both came right back to null just after guidance initiation, and that was it.

Borman We did not have the feeling that we were lofted, and then a sudden pitch down.

Lovell No, there was no change of booster performance at all. It was just that the needles deflected at guidance initiation to say that we had guidance initiation, and after that they nulled and stayed that way from there on.

2.14 BECO

Borman At BECO, the whole spacecraft was engulfed in a red flame. I noticed that out of the corner of my eyes. Jim, you probably had a better view than I did.

Lovell Yes. Flames came up the side there to the window.

Borman There was a definite, very brief instant of it, probably in the order of milliseconds, but it did envelope the spacecraft and I, in my own mind, wonder if this is not the place where we are picking up some of the smudge on the window.

2.15 Staging

Lovell Well, I did not notice any smudge at the time of staging.

Slayton You did not notice any?

Lovell I did not notice any. Of course, things were going pretty fast. I did notice it after we got into orbit, but not at

that particular time.

2.16 Engine 2 Ignition

Borman Again, it is so well simulated that--

Lovell It is very smooth.

Borman It is very smooth, and away you go.

2.17 RGS Initiate

Borman Well, we have talked about that.

Lovell Yes, that is what I was talking about back previously.

2.18 GO/NO GO

Borman GO/NO GO. Houston, on the ground, came through great. We got a GO/NO GO before the 30 seconds we were waiting for spacecraft separate. So, we knew we were in good shape before we ever had the possibility we would have to burn. Of course, we also had the IVI's onboard and they are very good also.

2.19 Systems Status

Borman The systems were all great. No problem, during powered flight. We got two delta P lights.

Lovell Oh, yes, that is right.

Borman We are talking about spacecraft systems. We got delta P light on BECO in the first stage that went off at staging, then came back on during second stage flight, and then the

Section 2 delta P light did not go out and it was...

Lovell No, Section 1 went on and out again during the flight. It went out at, I think it went out at SECO.

Borman That is right.

Lovell But Section 2 came on and we saw that one for the next 14 days.

2.20 Acceleration

Borman Acceleration during stage 2 was right on the money, right on the program. I read off, I think it was about six and a half g's maximum. We read this off after SECO.

2.21 Fairing Jettison

Borman Fairing Jettison, I did not even hear it. I was concentrating on the horizon, trying to get set for turning around. Jim jettisoned the fairing and punched the Spacecraft SEP. I did not see anything or hear anything.

Lovell I saw debris and heard it and had a definite knowledge that a squib had gone off. There had been an explosion.

3.0 INSERTION

3.1 Post SECO

Borman Maneuver controller was easy to reach. I had it out, and there was no problem. It came out and was ready to go. Attitudes and rates, there were none. The thing was as solid as a rock as far as I could determine. I was watching

the horizon, and the attitude remained constant and the rates were so minimal you could not even pick them up. I noticed no transients, we experienced no ..... as far as I know that was discernible.

Lovell Did you try to damp out the..

Borman There was nothing to damp out.

Lovell Okay.

Borman In fact, I did not use the thrusters at all for that. It just sat there.

3.2 SECO plus 30 seconds

Lovell I have the IVI readings on a card. Do you have those cards that we took off?

Borman Yes.

Lovell I am sorry. We did not get forward-aft, left-right, up or down because they were so quick, and I was trying to get the camera. But it was 17 in the fore and aft window, 13 in the left-right, and up and down was 20.

Borman What do you mean you did not get them? They are there.

Lovell No, I did not know aft or forward, or left or right, or up or down.

Borman Oh, I see.

Lovell I just saw that they were so small that I just wrote down the numbers as a ...

Borman 17, 30, and 20. There might have been a 13, 17, and 20...

Lovell About what the numbers came up with.

Borman Spacecraft separation. We separated with minimum delay between thrusting and Spacecraft SEP. Jim actuated the spacecraft separation. I did not hear the thrusters firing. I could not hear them; and I did not even hear spacecraft separation, but --

Lovell I heard Spacecraft SEP, but I could not hear the thrusters firing. But you told me you were firing the thrusters--

Borman I said thrusting and SEP Spacecraft and we did it and away we went. I thrusted for about 2 seconds. Almost immediately, as soon as we had finished thrusting, I started a yaw right 180°, and the rates were right around, I think around --Of course, you should be able to pick this up off telemetry, but I would estimate they were 3° to 4° per second turning around. As soon as I had the booster in sight, I thrusted back 5 seconds. This is the way we tried in simulations. The simulations in St. Louis were excellent.

Lovell Turned out that was the best technique to use, 2 seconds for the 2 seconds forward and a 5 second return.

Borman We turned around and there it was, bigger than the devil!

Lovell At that distance there was no problem staying in there.

Borman Now, I did have some problem because the booster was bending

so rapidly. It was tremendous. It looked like one of the autogenous lines had been cut. I guess it was cut with a pyro, and it was really bending and this was causing it to translate as well as rotate. And in order to stay with it, I was having to use quite a bit of fuel; although it was certainly a nominal task. I also went through several control modes switchings. I started out in PULSE and I could not get around fast enough, so I went to DIRECT and then slowed it up in RATE COMMAND. Slowed up the direct rate I was using with RATE COMMAND, and left it in RATE COMMAND without using the hand controller for a while. Finally went to PLATFORM. When I went to PLATFORM, we had been off to one side of the booster. When I went to PLATFORM, it yawed me back around, and I lost sight of the booster. So we went out of PLATFORM and flew the rest of it in PULSE Mode using the reticle on the horizon for stabilization and using the maneuver controller for thrust. This is all on onboard tape, incidentally. The air to ground communications, throughout the flight were superior.

Lovell I was really amazed at the communications, especially the primary station. The UHF was outstanding.

Borman We have already discussed GO/NO GO. They came through loud and clear before we ever SEP spacecraft. We had no need for

a velocity correction.

Lovell As a matter of fact, right now would be a good time to mention that address 72 read --

Borman Nominal was 25 804 and address 72 read 25 804.

Lovell Can you imagine that? Right to the foot! 25 804. I could not believe it when I punched it up.

Borman The orbit quantities were given to us, I think, by Bermuda. Of course, at this time we really were not interested in them, although they were sort of nice information. We had a GO/NO GO.

Lovell It was 87-178 -- the initial forward quantity that was called up to us.

Borman The MDU readouts: Jim read 72 and when he saw it was 25,804, we had a GO/NO GO from the ground. I do not believe you even read the rest of them out, did you?

Lovell No, I did not bother reading out the rest of the addresses 94, 97, 52, or 73, because I saw the 72 nominal. I saw the IVI's were right in there so we did not bother reading out anything else.

Borman Debris. I did not notice any debris.

Lovell I noticed debris. I was looking out at Spacecraft SEP and Jet Fairing, and noticed debris. I also noticed debris between the spacecraft and booster when we first turned around.

Borman Could you identify any type of the debris?

Lovell No, pieces. That is all I could tell.

3.3 Insertion activities

Lovell We followed the regular procedure.

Borman We did not have any problem with safing our switches. No problem. I did not even stow my D-ring at insertion. I was too busy trying to stay on the booster, and I did not get it stowed for the first orbit, I guess, or half an orbit.

Lovell What we planned on doing was getting pictures of the D-ring. I got the bracket up at staging, and I actually had a minute after guidance initiate to reach back there and get the bracket and stick it up. It worked out very nicely before the g's started building up again on second stage. The bracket was up and in place and no problem at all. Then at SECO, I went around to pick up the camera, because we had the camera stowed where the Agena control box is located. I managed to get the camera up, and it was already plugged into the electrical wire. All I had to do was turn the auxiliary switch on, put it on the bracket, and push the button, and it started taking pictures. Just about that time, Frank mentioned he was going to start thrusting pretty soon so I had to go back and punch off the spacecraft. Then I read up address 72. So, I hope the pictures come out.

Borman We were looking right into the sun; I hope they do too. The drogue pins were no problem. Jim got them, but again, not until well into the first orbit. As a matter of fact, I pulled my own yesterday morning there. The problem is solved; I think they are easy to get to.

Lovell Yes. They are easy to pull out.

Borman I think that we have covered station keeping with stage II booster,partially. I will mention that the booster, being without attitude control, translating also with this impulse it was picking up from the venting, is definitely an order of magnitude more difficult than station keeping with a stable vehicle like Spacecraft 6.

Lovell First of all, you do not have anyone controlling the thing; you do not exactly know where it is going to go, and it might translate because it is venting and has a slight thrust.

Borman I know a couple of times we got in a little too close and I backed out, because you just do not dare get as close as you do the way this thing is spewing. We got a real good picture, a good look at the nozzle. I thought that it looked like the nozzle was bent in on two places on the booster engine. It looked like the nozzle, the ablative skirt had been bent in. But then, it may have been just a

shadow, because the next time I looked at it, it looked just like a new engine. The booster itself had no apparent damage. The only thing we could see was this big spewing where the venting was coming from. I did not see any venting from the roll nozzle at all. Did you?

Lovell No, the venting came from some line right along the bottom edge, near the engine section of the booster.

Borman That is right.

Lovell It was a line of some sort that was open, and fuel was spewing out of it.

Borman I hope they got the data they wanted on the D-4 and D-7 Experiments. It was, again, a very uncomplicated maneuver, one that we practiced many times, and it worked just like it does in simulation. Had no difficulty at all. The lights on the booster worked fine.

3.4 Post station-keeping

Borman We did not do anything with stowage on the first orbit at all. D-ring, pins I have already mentioned, we did not get those in at all.

Lovell Arm restraints went down at 55 seconds. Belts. We did not even loosen them until after we had done D-4, D-7. The life vests we left right on the harness for the entire flight, but the harness did not stay on us for the entire flight.

The sequence light test. This was done after the first orbit. We really had this insertion checklist in two phases, one at insertion and then one after D-4, D-7.

4.0 ORBITAL FLIGHT

Borman We have already discussed the station-keeping. That is no problem. I think the situation that we used, going off with about 2 seconds--2 to 3 seconds--and thrusting back with 5 seconds while you are still on your side getting back to the booster as quickly as possible, solves the problem and takes a lot of the orbital mechanics out of the situation. I hope the film comes out. The one thing that did make it a little difficult on this one is when we looked back, we were looking back into the sun, and the booster was right in line with the sun. It was just like flying formation when the leader makes a turn, and you are down-sun. It is difficult to see, and I tried to move off to one side and swing around and look a little bit more to the north. I think it was north. I guess I was trying to look to the south where I could get the sun out of my line of sight. I also had a cut-off on the booster at station-keeping at 88% fuel, so that at 88% fuel we were already in darkness, although we had not reached the time for the D-4, D-7 separation which was to occur at 00:25. I think it was about 00:23 or

00:21. So when we reached this limit and we were in darkness, I went ahead and separated, thrusting down.

Lovell We actually separated earlier than 00:25. We actually separated at 00:21.

Borman That is right. So we separated because we were in darkness and because we had reached the limit on fuel. We had been in darkness for awhile. One thing I did notice was that the docking light was not particularly helpful on that stage of the business. I guess it is because we were not close enough to the booster.

Lovell We tried but the docking light just did not work.

Borman I suppose because, again, we were looking at a lighted horizon with the docking light, and it did not work as well as it did later on with Spacecraft 6. The booster measurements went off. We got indications on the needle, on the measurement needle..

Lovell The recorder did not get on until 27 minutes. That is a guess. I am not too sure, but as I understand it, they had live transmissions up until that time, to Bermuda, and Antigua, wherever it is, so we were okay there.

Borman The booster measurements were normal. Again, the simulator was perfect for that. The lights. Jim McDivitt had made some comment about not being able to judge distance because

they only had two lights on there. We had four lights on and I will be darned if I will try to judge distance by four lights or fifty lights. You have got to have illumination or you have to have a stable vehicle.

Lovell You have to have something that illuminates the vehicle, not a light that flashes because you cannot tell from a flashing light.

Borman Especially on vehicles rotating. I do not think that it is possible to control them. You have to have a controlled vehicle before you can judge distance from it, as far as I am concerned. The GO/NO GO, 17-1 T_R were no problem. We ran through the platform-off post station-keeping checklist just the way it is listed.

Lovell Yes, that is where we caught most of the things.

Borman That is where we caught most of the things like putting the D-ring away and the drogue pins and so on. Only one time in flight did we require attitude control fuel to change attitude for critical delay time playback. There was no problem. Communications, as always, were superior. The D-4/D-7 Void Measurement was again no problem; just lined up on the black and ran for two minutes. Purging of the fuel cells. This is the first of a long--

Lovell Yes, but we did not do it then, did we? Did not we wait until we powered down and then waited two hours?

Borman That is right. This is one of the things that they had in the flight plan that we asked them to change because --

Lovell Yes, we did not purge the fuel cells then.

Borman Originally, this came right after power down and all of the fuel cell people recommended that you purge before power down, or wait until two hours after power down. So we did not do it at this time in the flight. This was changed. D-4, D-7 star measurements. There was no problem. The stars were well selected, and we were right on them. Right Jim? Jim copied down, on the procedures book, a check where we got the maximum return on the needle.

Lovell D-4, D-7 was a well organized experiment as far as Brentnall keeping us hopping about what to do. I will have to admit that.

Borman He did a very good job. We knew just what to do. We had all the equipment with us and everything went very smoothly. MSC-2 and-3 turned out to be not much of a problem because at about the seventh day we turned it on and left it on for the rest of the flight. The Berigee Adjust Maneuver. Jim made the Perigee Adjust Manuever. We did it on stars without a platform. I was timing for Jim and I think I fouled up. We planned to use a perigee to 102 miles, and I think we wound up with about 15 feet per second too much. It seemed like about 117 miles. One of the reasons that was causing this was we had come back into the vicinity of the booster, and just about midway through the burn the booster venting that was still occurring suddenly lit up, became lit up. It looked like we were flying through a lot of foreign objects or debris. I was afraid that we were going to hit something. At the same time this trailing wire came forward and slapped the spacecraft.

Lovell That is where I stopped.

Borman Yes. After we had stopped and it hit us, I looked down and got confused and said,"No, we haven't burned enough". So we burned for about five seconds more. We had a trailing primer cord that would flop around and we didn't know what it was at the time, but it came forward when Jim stopped burning and flopped on the spacecraft. It made a

noise and I thought we had hit some of the stuff that was spewing out of the booster. I wasn't sure that it was just fuel.

Lovell I think the ground people thought that this wire came forward because it had gotten in the way of the thruster fire. It definitely came forward after I stopped burning, because I stopped burning and this wire came slapping forward. It still had the momentum, you know. It slapped right in front of the window. I think the people got the impression that the thing had hit a thruster. It hit in front of us, then we stopped burning. But we ~~stopped and then~~ that thing hit and we added some more because we were still at apogee.

Borman The first of many powerdowns was no problem. We went right by the check list. Some of these switch functions in the space craft, particularly toward the latter part of the flight, toward the 12th or 13th day--we were getting, I won't say lax in making them, but it seemed more of a chore to make these things right to the minute. Things like the BIOMED recorder and so on--we lost interest in having them turned off on the second. We knew what they needed to be turned on and off for. We didn't do as good a job from about the 10th day on as we did the first part as far as making those right to the minute.

Lovell As a matter of fact, why don't we get out the flight plan. I think we might have a lot of comments on it.

Borman Let's start from the beginning.

Lovell The recorder was on at 27 minutes. D-4/D-7 measurements. The GET of measurement that the COLD IR was outside the two degree field of view of the booster was at 30:13.

Borman At 40:58 we had 84 % fuel left. We were right on the flight plan there.

Lovell There was another GET of measurement where the spacecraft was lined outside the field of view of the booster at 38:00.

Borman We saw the booster for 2 or 3 revolutions after that. The lights were still working. We called it out and the ground got readings on this.

Lovell The moon and booster were in view at 43:00. The booster and moon were in view and we might get an erroneous reading because we were almost on the moon.

Borman Here we have a note that at 2:32 the fuel cell Delta P light blinked off at 2 hours and 30 minutes and then came back on. That is the section 2 delta P light.

Lovell Okay, then as far as stowage goes, the M-1 cuff was turned on at 3:03.

Borman We put the bypass hoses on at this time also-- the ECS bypass hoses. Incidentally, they turned out to be not too much of a problem. They were very handy for the type of

work we did without suits on.

Lovell Right. We took the S/C out of the horizon at 2:08 to get some measurements, as requested from DOD, after we measured the stars. This is after we powered down the equipment. We connected the bypass hoses at 2:32. This was 2 hours plus 32 minutes.

Lovell Crew status reports. We had 3 or 4 a day.

Borman 5:20, we started unpacking the meals. This is one thing that we had trouble with. Both left and right food boxes were jam packed. Fortunately, we changed the lanyards. We changed this during our stowage review, although it was difficult we got them out. Several of the meals had lost vacuum.

Lovell Which made them more difficult to get out.

Borman Really you can't complain about this. The people did the best they could. We had an awful lot of food to store and we were able to get them out.

Lovell We had several blinkings of the Delta P light during this period. It went out at 6 hours, a littleless than 6 hours, then came back on again at 6:27.

Borman One thing that I wanted to find out about, and I still don't understand, is why we turned on the crossfeed valve right after launch. The FC O_2 pressure was just on the minimum

of 150 psi at launch. I called up Houston and said I would like to leave the gauge in the FCO_2 position rather than the ECS O_2 position. Chris said, "No, unless we really felt strongly about it, they would rather have it in the ECS O_2 position". So we left it there and after we were inserted and we were still with the booster, they came in with a recommendation that we open the cross feed. When we did, this immediately raised the pressure to 250 psi. The thing that was bad was that we had over 100% oxygen and we were down to about 100 lbs. on the FCO_2. We agreed that we would fly at least 50 lbs. above the dome. So, I really didn't see the need for opening that valve although it didn't cause any problems.

Lovell They wanted to pump up and make sure.

Borman It worked fine and we got right back up to 250 lbs.

Lovell That is one system that did work fine.

Borman The first 7 hours was pretty nominal. All throughout the flight plan we have notes that the Delta P light went out and came back on and so on.

Borman At 16:40 we sighted a satellite much lower and on a slightly higher inclination path than we were. It passed underneath us. It was so far away it looked like a sighting from the earth. It was just a reflection. We were very religious about the exercise periods. We got

those three times a day with the exception of the last day and one other day when we got only two. I think this is a very good idea. It is difficult and requires discipline because the last thing in your mind is the desire to exercise. You get lazy very easily. We did a very extensive operation with the bungee and also isometrics three times a day.

Borman They were programmed 10 minutes. I think a more realistic one would be about five minutes, three times a day. I did 60 pulls on the bungee cord with both hands, 20 with each leg, and then ended up with 10 with each arm on the bungee cord in addition to the few for the crew status reports.

Lovell I did 60 pulls on the arms and 60 on each leg and it didn't make any difference. I could have done 20 on each leg and would have probably been better off.

Borman At 45 hours Jim started taking off his suit. During that first 45 hours our noses were clogged and stuffy, our eyes were irritated, the cabin was hot; it was miserable. As soon as Jim started taking off his suit, the cabin even though he was out of the suit and I was in, got better than it was with both of us in our suits.

Lovell I didn't realize it was that long. We were almost up there two full days before I started taking the suit off.

Borman At 49:53 we got a picture of Houston with the 250 mm lens. I hope it comes out. Okay at 69:40 we did a Perigee Adjust Maneuver, Delta V 12.4, 16.5 seconds, and came right on the money, using the stars, no platform. I don't think that there is any problem at all with the proper stars in making a gross adjustment.

Lovell I think it was an excellent idea to do it without a platform, it takes two people. One person times and the other person burns on the star from attitude. Both people check the attitudes by looking at the star charts and getting the updates. Then making sure that the S/C is alined right and the reticle is up to get the accuracy pretty good. After that, once you get it set in your mind what you are aiming at, one guy is in the cockpit with the watch or event timer and clocks it. The other guy has to look out the window because you can't go back and forth. If you look in the cockpit at the watch, you can't adjust to look out for the stars. So it takes two people for that. I think you can do a good job without a platform.

Borman I do too.

Borman There is one thing that was a pain in the neck, and I hope they get some good out of them, were UHF and the HF tests. That was an hour and a half transmitting every five minutes

and having the HF/DF on. I'm not sure what kind of data they got but I hope they got something. The first one we had to do on the HORIZAN SCAN; it took some fuel and I wonder really if it was worth it.

Borman At about 166:40 we noted our drift rate picking up and we finally determined this was from the water boiler venting. It resulted in a left yaw rate and this continued periodically throughout the mission. It certainly would not be objectional if we had fuel to counteract it. During a night period, in which we didn't do any attitude control at all, I timed the rates during the 13th day, and when we woke up they were about 7 degrees per second. I timed them around the horizon and came up with 7 degrees per second. About the only thing you can say about it is that it requires fuel to stop it.

It occurs primarily in left yaw and left roll.

Lovell There are two things in the S/C that causes the yaw left for some reason. Gus first noticed it and I think it is characteristic of the S/C. One is the water boiler and the other is,every time you turn off the power it fires two thrusters that give it a left yaw. The same two all the time.

Borman We tried to beat that ever way we could. Every time we

shut down, we put it in a different control mode and it still fired the same two thrusters.

Every time you turn off ACME bias power it would go "boop," "boop," just like that. Every time we were without attitude control for extended periods we ended up with a left yaw and a left roll.

Finally at 191,48 we got both crewmen suitless. That was the best decision in the whole flight. The performance of the Cryo bottles was fantastic.

Lovell That was one thing we were worried about. The hydrogen bottle I thought was never going to last. Forty per cent of the hydrogen bottle was still left at the end of 14 days. One thing I wanted to try was to blow the squib. Remember they said "Did you blow the squib?" I forgot about it. Just prior to retro, I wanted to go over there and blow that squib that opened up into a vacuum.

Borman It would have taken several hours for it to do any good.

Lovell Yes, I know, I just thought maybe we could hear it or something.

Borman One thing that cropped up more and more as the mission progressed, it seemed to get worse as it went along was the fact that things were cancelled because of weather. We picked up large areas of clouds over the U. S. and over S.

America. About the only area that stayed clear was Northwest Africa. A lot of the experiments and a lot of the Apollo landmarks were shot because of clouds.

Borman On the 6 launch, the second time, we were able to track it. We were not able to pick up lift-off because of clouds again, but when it got to the con level, above the clouds, we were able to pick it up and we tracked it using IR until we couldn't see anymore. Even above the con level I think we were tracking the exhaust from the stage two engines using PULSE mode. I hope we got some good data on that.

Borman At 266:16 we really got cold; the suit inlet temperature dropped below 40 degrees and we started squirting water out of the suit inlet hoses. We informed Houston about this and they determined that the water boiler had frozen up and they recommended a procedure to clear it. We did this with Gemini 6 watching; essentially it involved putting the radiator to BYPASS and changing some switches.

Lovell Evaporator heat on.

Borman Put the evaporator heat on and setting up to 10 degree per second roll rate.

Lovell That's the picture you saw in the movies.

Borman It actually threw a lot of fuel out and a lot of water out. It left a glob of ice on the side of the S/C, about 10

inches in diameter at the exit from the water boiler vent.

Lovell There were only two problems that we really had. There were the Fuel Cells and the two thrusters. We also had a cold Spacecraft.

Borman Yes, that is when we had that water boiler problem.

Lovell Before that; the first time we woke up, it was 20 degrees colder inside.

Borman Oh yes, I'm sure what had happened during the night was that we vented the water boiler, used the water boiler. This is the day when we woke up and had such high rates on the S/C. We have all that in the cabin temperature survey. The wall temperature was 20 degrees lower.

Lovell It was just freezing in there.

5.0 RETROFIRE

5.1 TR-2:00 Power Up and Alignment Checklist

Borman We had a slightly different procedure as far as retrofire goes. Powering up for it took two hours. The power up and alignment checklist was called up from the ground since we had open circuited two stacks. We turned our main batteries on and the squib batteries back on at TR minus two hours.

Lovell During the flight they had powered us down on the squib batteries and put in the bus ties about the last week of the

flight.

Borman We were flying with bus ties and fuel cells and no squib batteries.

Lovell To conserve the squib batteries for the retrofire period.

Borman Right.

Lovell Because of that configuration, and because of the fact that we lost two stacks, we had to modify our power up procedure.

Borman Right. Incidentally because of the fact that we had two degraded thrusters, 3 and 4, we didn't use the PLATFORM mode at all for this alignment. We aligned it all manually. The thrusters were degraded, but there was still enough in them to allow you to get fine maneuvers, fine control. I used less control by turning off the circuit breaker for thruster No. 12 and used 11, giving back thrust and this would give you right yaw.

5.2 TR-26 events

Borman At T-26 the event timer was set, we didn't read anybody because of our orbit, and we weren't able to start our event timer counting down until T-20.

Lovell T-20

Borman Read out from Carnarvon.

5.3 TR-5 GMT Stop Clock

Borman At TR-5 Jim got the bug on the eight minutes, no problem.

Lovell Yes, I got that okay.

5.4 TR-256

Borman TR-256 Sequence light came on exactly on schedule.

Lovell The digital clock never lost a second during the entire flight.

Borman We didn't touch it.

Lovell We didn't touch that digital clock one time during the entire flight. That is the best instrument in the whole S/C, especially for this type of flight when you have a lot of updates and everything.

Borman Electrical was no problem. Control system, the RCS worked perfectly. It just worked beautifully.

5.5 TR-1

Borman Retro attitude minus 20 degrees pitch. The ball had been aligned for two revolutions and it was perfect. If we had not had the ball, I would have been happier if we had retro fired in the daylight. SEP OAMS, as advertised. You hear it.

Lovell Yes!

Borman You feel it slightly.

Lovell That is right, and you even feel SEP ELECT.

Borman Yes, and you really feel SEP ADAPT. It felt like I had put in forward thrust at that time.

Lovell Yes.

Borman It was really a good thud when we separated the adapter. Retrorocket squibs were armed at TR-30. Arm AUTO-RETRO was actually done at about TR-10.

Lovell We did that a little bit early.

Borman The event timer was perfect. MDU, Jim got all the readouts and they were exactly what had been called up.

Lovell Yes. There was one or two that the last digit was one number off, but that is nominal. We didn't bother that.

5.6 TR-0

Borman From the time we got the countdown at Carnarvon we really didn't talk to anybody at all until we heard Houston at TR-10 seconds come in with a count through Canton.

Lovell We didn't think that they were going to come in, as a matter of fact.

Borman No, we were wondering...

Lovell That is a very poor place to retrofire. Canton had poor communications compared with the rest of it.

Borman But they came through that time.

Lovell Yes, they came through.

Borman We really didn't need them because we had every indication

that our timing was good on-board. They did come through but not until TR-10 seconds. At TR equals zero the S/C attitude was 20 degrees down. S/C rates were easy to control, but I thought that the thrust from those retro-rockets was high. I really had a sensation of being accelerated. Didn't you Jim?

Lovell Well, it was different from what I had expected because we were so used to zero g flight.

Borman The only thing I could do was fly instruments, the needles and the ball. Trying to hold it right on the ball.

Borman I was very glad that I was in RATE COMMAND. I had to control it in RATE COMMAND a little bit, particularly on the fourth retro rocket. The first three went bing, bing, bing. Then there was a pause of about ½ a second and the fourth one went. The fourth one seemed like it was a little misaligned, I think it was left yaw. I had to bring it back. I would like to emphasize this. I thought those retros were really powerful, and that you were holding on to something that if you really didn't have good control it could get away from you pretty easily.

Lovell But, I was sure happy to hear them go.

Borman Control mode was Rate Command, and the IVI readouts there- did you write those down?

Lovell I have them here.

Borman We called them off and we have them.

Lovell This is what I've been using. It was 298, and 112.

Borman And 3 left.

Lovell Yes, and 3 left.

Borman What were the nominals? Let's just make a note of what the nominals were.

Lovell This is usually about....

Borman They called up the nominals.

Shepard They were 113 and 296.

Lovell Yes. That was 2 off from nominal, I recall that....298 actual, and 112 actual, 298 aft and 112 down as the actuals.

Borman And 3 right.

Lovell And 3 right.

Borman So we got in close to the nominal, and when you figure this out on our onboard charts you come up with a bank angle of 50 degrees.

Lovell That's why I couldn't understand the 35--well, maybe I'm wrong but let's take a look at this thing again. Let's go through it.

Borman All right.

Lovell That's a minus 1 error here, right? And a plus 2 error there, right?

Borman Right.

Lovell Okay, so I went in here and got to a plus 2 error here, right?

Borman Right.

Lovell Went up here to a minus, here's the zero mark right here, to a minus one error; where this thing crossed this thing right up to here, plus 2, and by gosh, it came right out to 50 degrees or 53 degrees.

Borman They gave us 55 degrees roll left, which is what the nominal level was...

Lovell I've got it right here. Fifty degrees and 60 degrees is what they gave us. Bank left 50 degrees and bank right 60 degrees.

Borman Yes.

Lovell And so I looked up the chart and it said 50 degrees as the back up angles--everything was working just like a charm and then I went back here to the bank contour line to get out our down range deflection, and it was 1 or 2 miles, I think it was, no, 5 miles overshoot; which was just about as close as you can hack it. And I thought oh boy, this is really, talk about nominal reentry, this is the one

that's going to be it, and then they came up with 35 degrees, 45 degrees, and I misinterpreted it; I was arguing with Frank after retrofire and he says no, that's 30 degrees--50 degrees.

Borman 50 degrees.

Lovell 53 degrees is what he's saying. He just wants to get it down to a little finer line. And then Frank called back again and said, "No, it was 35 degrees," so I don't know what the story was there.

Borman The EDI as far as the retrofire goes, it was no problem. It worked out fine, and I just like to have it, I think. If you really were forced into it you could do it on rate needles, but you'd have to have a lot of confidence in your ability to hold it. I wouldn't want to do it without Rate Command; and again, I did it in Rate Command. I'm not even sure how much the thrusters were firing during retrofire. Did you notice? I was watching the ball, and I didn't notice.

FCSD Rep Did it light up the horizon pretty badly?

Lovell It was really not too bad. But actually; yes, it did, it lit it up quite a bit.

FCSD Rep Okay.

Lovell There was a point in the flight plan that they wanted the

Pilot to evaluate the horizon for a night, no platform, retro. And the thing is this: you can turn out all the lights, you can get lined up for BEF retrofire, without a platform if you get the stars and everything. But once you start firing, you are going to have to use the rate needles, if they are working, to hold position, because you can't see the horizon any longer, because the thrusters do blank out any sight outside. And also, if you've got the lights turned up in the cockpit, so that you can see things; that means that you can't see outside. So, you have to go either outside to get cues, or you have to turn the lights out in the cockpit. And if you're going to use stuff inside, then you have the lights on. I would be hesitant to make a night retrofire without platform too. I think I would probably wait for a day one.

5.7 Retro Pack Jettison

Borman The retro pack jettison - Jim fired...the one thing here on manual fire, Jim fired the manual retros the way we always have. We fired in the way we always have, one second after TR equals zero, but we got an auto retrofire.

Lovell Yeah, because the first one fired before I pushed the button.

Borman That was right on the money. The retro pack jettison was accomplished 45 seconds after, when the amber light came on, and you could feel and hear this one going; of course, it was pitch black so we couldn't see a thing. This was one of the things that we didn't see, the RETRO ADAPTER, the ADAPTER, or the RETROPACK.

Lovell No, I didn't see any of that stuff go at all.

Borman Total darkness.

Lovell Besides that, the thrusters blank out anything you could possibly see.

5.8 Communications and 5.9 updating

Borman Communications were rather sketchy there. I was very glad though, that we were able to get through to Houston. I think it was over Guaymas when they came up and told us to change in retro angle, and bank angle; I don't know who did that but that was good work on the ground following up that computing, and getting us real time updates, I guess they must have done it after tracking.

Lovell Yes, That's probably what it was.

Borman That's probably how they did it. And that was darn good.

Lovell Yes.

Borman Because the 35 degrees, I was flying right between 35 degrees and 0 degrees most of the time, and if we'd have followed the 50 degrees, we'd have ended up way short.

So that was very good work on the ground's part.

Lovell It looks like the initial computation of retrofire time was off, and they already had a good orbit on us.

Borman I don't know what it was, but they corrected it when we came in.

5.10 Post Retro Jettison Checklist

Borman The post retro jettison checklist was accomplished with no problem. Oh, I'm thinking; we did have some discussion about as far as the retro goes. With the--we'll cover this more fully under suits. The question was whether to leave those hoods on or off for retrofire. We found that the noise and the--I don't know why we didn't notice this at launch, but we did during reentry, the noise from the air blowing in the G5C suits was an impediment to crew discussion.

Lovell It would go on the mikes and make a lot of noise on the mikes. The mikes picked up a lot of whistle.

Borman Plus the fact that the vision out of that thing certainly needs to be imporved. So, we didn't know what to do--we finally decided to leave them on for retrofire.

6.0 REENTRY

6.1 Reentry Parameters Update

Borman Reentry. 400,000 feet, we had that time updated; and at 400,000 feet I rolled left 55 degrees, because this...or fifty degrees, the value of the backup angles at that time.

6.2 400K

Borman Spacecraft attitude at 400,000 feet was difficult to determine. We didn't have a horizon until we were below 350,000 feet, and I was having a lot of trouble trying to find it. Jim, you got the horizon first on your side.

Lovell Yes, the horizon came up first on my side. Well, we did not have it right at 350,000 feet, but we could look out between RCS firings and see the air glow, if you'd stuck your face right up there and look out. But when you're doing the reentry on the instruments you have the lights up so, one guy can't do it, you have to have two guys; one to look out and find out where the horizon is and--

Borman That was a heck of a thing. I'd like to be able to cross check between the balls and the horizon once in a while to make sure that I knew exactly where we were. As it turned out this was a completely instrument reentry. We finally found the horizon and Jim would tell me yes, it's about in the right place. But I just watched the ball. And I think that it would be very difficult to back up a reentry by watching out the window. One person could provide backup guidance for you, and tell

you where you are and what the bank angle looks like with the horizon. But, I don't think that a person that is flying the reentry can cross check between the ball and the horizon. I think you have to make your choice and live with it. Okay, roll commands were just like the simulator; time correlation was good. The guidance initiate came right on the money, and the needles jumped indicating an undershoot, a slight undershoot. From then on we just flew it the way we'd flown them a hundred times in St. Louis and in the simulator. I think we were very well prepared for this. I tried to fly it so that we took it downrange, and we got a slight overshoot indication on downrange of about 1 needle width, 1 dot. Then as we got down to around 2 g's or 2½ g's, I tried to start zeroing it out, so then when 3 g's came; the downrange was pegged right on the money. And we were indicating zero on the cross range. And at 3 g's I switched to flying the roll bug, and just zeroing the roll bug; and as we came on down further and further the downrange stayed zero, but the cross range started going off full scale. Well, this really doesn't mean anything because all the cross range is indicating is

your per cent of miss verses per cent of capability. And down on that range what it was really doing was, we were coming in a little bit short, and it was sacrificing the cross range in order to get the down range cleared up, because the cross range was very small anyway.

Lovell There was a bias in the down range needles between his ball and my ball, and I think, that fortunately, my ball was the one that was out. Because when he was right on.

Borman You said we were overshooting all the time.

Lovell Yes. He was right on - I said you were overshooting, it was about a needle and a half width bias.

Borman Okay. The initial indication of g's, I remember Jim called over and said, "how many g's are we on now." I said less than one" and you said "get serious." I think you couldn't believe it. The first onset you feel like you have about a ton on you, but then as it builds up it never seems to get much worse. It's almost as if it were a step function. As soon as you get the g you really notice it, and then you don't notice it much more. And the maximum g's that we pulled during the reentry were 3.9.

Lovell Yes, that amazed me. I actually thought we did pull more g's.

Borman 3.9 g's. So, it was a long extended time.

Lovell Yes.

Borman During the later part of it I started out in PULSE Mode and rolled over the 55 degrees in PULSE Mode, and then when we got Guidance Initiate I went to DIRECT. I was finding that in order to keep the cross range zeroed, and we had been told that Wally had trouble with his cross range, I was banking back and forth quite frequently maneuvering the spacecraft around the full lift point, from one side to the other and I was overshooting a little bit in DIRECT. I was also starting to pick up some pitch and yaw oscillations, so then I went to single ring RATE COMMAND. And boy, this was really a great control mode, it was steady as a rock. You could put it right where you wanted and it stayed there. But pretty soon we got down around, I guess it was when the g's were coming off, after 3.9 g's. I started losing it in single ring RATE COMMAND so I threw two rings on and it held it like a rock. But they were sure firing.

Lovell Oh, yes.

Borman Boh, those thrusters were really firing. And we started getting ablation off the heat shield. It was coming back in and hitting the nose of the spacecraft, and that was pretty

sensational. Jim was giving vivid descriptions on what was happening, and I was watching the ball.

Lovell That's one thing that no one had ever told us before. I was amazed. Maybe it was peculiar to the spacecraft.

Borman No, Tom and Wally had mentioned it.

Lovell Oh, is that right? That ablative material went back and hit the forward end near the recovery section, rather the RCS section; and I thought well, I never heard of this before, and I was a little worried that maybe we were too far off, and the stuff was going to start getting into recovery sections. But it turned out to be okay.

Borman Another thing was that the windows really got scrounged up on that reentry; that's something else. I could hardly see out of my window. Stuff was coming over from the heat shield and hitting it. It was really gunky.

6.3 Acceleration Profile

Borman Okay. The acceleration profile was very small. It was a very high lift reentry, and of course, this results in a low g and long duration build up. No problem at all.

6.4 Spacecraft Control

Borman Spacecraft control was excellent until we got down to 100,000 feet or even below 100,000 feet. We turned on

the LANDING SQUIB at 100,000 feet and sat there and watched it.

6.5 100K Feet

Borman I started losing it; I think we may have run out of RCS fuel between 100,000 feet and 50,000 feet; at least I thought we had.

6.6 50K Feet

Lovell Well, didn't you turn off the RCS?

Borman I didn't turn that off until after we got on the drogue. We were starting to build up the yaw and pitch rates. Then at 50,000 feet, I was anxiously awaiting the drogue, because these rates were building up a little. They weren't very bad yet, though. I pushed the drogue expecting it to decrease, and all it did was amplify them. And we got a real ride on the drogue for a while, sounded like the one Jim and Ed discussed. It was really going pretty bad.

Lovell Our angles were what? About 70 degrees. We pitched up?

Borman Oh no, I estimate we were oscillating back and forth maybe 20 degrees.

Lovell From the drogue here pitching up we were rolling back and forth more than 20 degrees on that initial part.

Borman We'll have to see. We don't have readings on that.

Lovell Okay, because I'm sure we did more than 20 degrees.

Borman Then I threw the motor valves back open again on the thrusters, and that seemed to stop it. So I left them open a while and finally turned them on again and it stopped, and it settled out, and it was pretty smooth on the drogue. As a matter of fact, when we got down to main chute, it was steady as a rock on the drogue.

Lovell Yes.

6.7 35K Checklist

Borman I turned off the RCS motor valves and blipped the thrusters to clear the lines between 30,000 feet to 26,000 feet. And Jim then opened--The 40K barostat worked fine.

6.8 Communications

Borman And we gave the reentry status report. I'm not sure that Houston heard it, but we told them the drogue was all right and okay.

6.9 26K Checklist

Borman Jim, at 26,000 feet you opened the vent air snorkel

and we got a cabin full of I don't know what it was.

Lovell You had your hood off. Why?

Borman I took my hood off to try to find the horizon, so I made the reentry with the hood off.

Lovell Okay, I had my hood on, and I think when we opened up the snorkle; the way that works, the snorkle draws air through the suit compressor, and then into the suit circuit. I had my hood on; and the flow comes out of an opening back here in the hood, and flows down. I got an eye full of something that was an acid.

Borman Acid, eh?

Lovell Yes. Really burned my eyes. My eyes were watering when I finally got the hood off.

Borman Well, we accomplished all the checklists, and we had no problems; as a matter of fact, it went pretty smooth in the time between the drogue deploy and the 10.6 barostat.

6.10 10.6 K Barostat

Borman It was just like the simulator. One thing I did notice, initially, when we were on the drogue, the altimeter was completely inaccurate. You couldn't even read it. We were oscillating so badly that it was jumping in thousands of feet per second , oh maybe not thousands, but the needles were going all over the place; and I remember thinking boy,

if this oscillation doesn't stop, I'll have to punch the main chute on the amber light, rather than the altimeter. But the oscillations did stop.

6.11 Main Chute Deployment

Borman I punched the main chute at 10,600 feet as indicated on the altimeter, and just a millisecond after that, the yellow light came on the 10.6 barostat light. The thing deployed immediately into a reefed condition, and we examined it in the reefed condition and it looked very good.

Lovell Frank thought it was in the reefed condition for 3 months.

Borman It seemed like it stayed reefed for a long time, then it unreefed, and I couldn't find one gore or one panel that was ripped or frayed or anything.

Lovell It was a good chute.

Borman Perfect chute.

6.12 Post Main Checklist

Borman We accomplished the post main checklist, and then we braced ourselves very well and went to the single point of attitude.

6.13 Single Point Release

Borman When we went to the single point attitude it was exactly the same as we had had it at St. Louis--where they'd rigged--they had a test after John and Gus's flight. They put a test capsule suspension at St. Louis, and this was

exactly the same. You get a good whack and then you sit there and vibrate back and forth for a little bit.

6.14 2K Checklist

Borman 2,000 foot checklist we accomplished with no problem. About this time, at 2,000 feet, I heard Air Boss calling and we started communicating with Air Boss. I saw him flying around while we were still on the chute. Houston came through about this time and wanted to know if we had a main chute. I'd called all these things off, but I guess that the communications—maybe the Auto Cats weren't working or something.

Lovell Air Boss should have called back and said...

Borman But I called back and confirmed main chute.

6.15 Landing

Borman We hit the water with a pretty good thud, and your window went under water, didn't it? Jim's window went under water. We hit in a drift. We were drifting to the right rear, and there was a 14 knot wind, and when we hit the spacecraft rolled to the right, and your window went under the water, and mine stayed up. Nothing serious though.

Lovell Nothing serious.

6.16 Postlanding Checklist

Borman We extended the HF antenna to get a test for them and went on HF-DF; I hope that somebody heard it. But they had

swimmers there in about 4 minutes, and so I put the HF antenna back down to keep it from getting damaged. And we conducted the electrical check. I must say that I'm glad that the electrical check was simple, because it was hot in there, and we were tired. I was worried about this before and I would never have been able to sit there and go through this complicated, long check.

Lovell We had both planned, that what we were going to do was take off our suits in the spacecraft, and wear our orbital flight suits. And I think that we probably would never have gotten out of the suits, because we were just too hot and too beat.

Borman It was even hot in the spacecraft, so Jim came through with the idea of opening the repress valve, and this was great. We had all that oxygen and you weren't going to use it. It blew all that cool oxygen out and we had O_2 HI RATE and the snorkel on. So we stayed pretty cool when you get right down to it. So it was a good idea. I don't know if you got the blood pressure measurements or not, did you?

6.17 Blood pressure measurement

Lovell I took them, I don't know whether they came out or not. I put the reprogrammer on in the water and started taking blood

pressure measurements and--but that's hard to do. I ought to comment on that. Because to take a blood pressure measurement you had to pump up the thing and leave your hands still, and leave your arms still until it bleeds down; well it takes a little while for it to bleed down. Meanwhile, Frank's got the checklist out and the guys out there are putting on the collar, and we're trying to throw switches and take this and that; I just thought I might as well start doing it with my other hand.

Borman Same way with the blood pressure they requested over Guaymas during reentry, I make a complete testimonial here; I think once the reentry starts that everything else gets left aside, and you don't mess around with blood pressures, or experiments or anything else. From then on it's sort of a case of surviving the darn thing. I didn't want him messing around looking for a blood pressure; so we didn't do it. About that time we couldn't find the horizon anyway.

Lovell We got called up from the MCC.

Borman But, anyway, we didn't do it. So it didn't bother us.

Lovell That's the first I'd heard of it when they call up.

7.0 LANDING AND RECOVERY

7.1 Impact

Borman We were drifting backwards, blunt end forward, rather, as

we hit the water, Although it was a good jolt, I wouldn't say it was anything outstanding. We hit, and Jim, your window went under water, right?

Lovell The spacecraft rolled to the right, I believe.

Borman Yes. We hit, rolled to the right, and you went under water and bobbed right up.

Lovell Right

Borman I released the parachute and it floated in front of us for several minutes.

Lovell I saw part of it on the left hand side there, or rather on the right hand side as it floated by my window.

Borman It stayed there for several minutes. It's just the way it's been described before.

Lovell There was an awful lot of fog on the window, though. I noticed that the humidity was such that you could hardly see out. Very foggy.

Borman I'm not sure that was humidity or that was from reentry.

Lovell Might have been from reentry, I don't know.

Borman I did see the S2F on the chute. We saw it while we were still on the chute coming down.

7.2 Checklists

Lovell The only thing I had about the checklists; during the recovery phase, I had a hard time doing the checklist, in fact, I had to give it to you, because I couldn't move my

arm doing the blood pressure work. And that complicates the recovery phase of it quite a bit.

Borman Yes.

Lovell I think it also compromised the blood pressures that way too.

Borman We didn't feel like running foot races when we finally hit the water. We had planned to get out of our pressure suits into that orbital flight suit, but the effort was just too great. So, we just opened the repress valve to get some more cooling in there and sat.

Lovell That's right. We opened up the repress valve; did we have the cabin fan on?

Borman No, we didn't have the cabin fan on. We had the snorkle valve with the suit fans and the O_2 HI RATE and the repress valve open.

Borman The checklists were all right then as far as you're concerned?

Lovell Yes. I thought the recovery phase was very good. I think I missed one or two. I know I didn't turn all the stack switches off, but the power and control switches were off during the reentry phase; so, there was no problem there.

7.3 Communications

Borman UHF. We had communications with Air Boss while we were still on the chute, and we had very good communications

with them in the water. The communications with Houston via UHF were poor. Once we were on the drogue they kept calling us asking us to confirm main chute. I'm not sure they ever heard us confirm main chute.

Lovell I've often wondered about that. Watching the other spacecraft come in, why they don't call; and I found out that they do call but they can't get through. Must be the relay planes trouble or something.

Borman Communications with recovery forces on UHF was excellent. HF: we extended the HF antenna, put out HF-DF tone for awhile. Again I am not sure if anyone picked it up or not. We retracted it after it had been up only 8 minutes, because of the fact that we did not want to get the HF antenna broken off during the recovery operation.

Lovell There was no need for HF communications since we were so close to the recovery group.

Borman The chopper was over us about 5 or 6 minutes after landing. We had much better UHF communications, so, we did not use HF.

On point of impact, onboard data. Within the limits of the readability of that scale, it was excellent. Down range and cross range needles were fine. We actually ended up about 8 or 9 miles from the carrier. You just can't get much finer information out of the down range and

cross range.

Lovell Did you have any kind of a malfunction in the accelerometer?

Borman No, but Spacecraft 6 did. I don't remember that being a condition of the bet.

Lovell I didn't either.

Borman Ground information. The ground gave us excellent information, as far as everything we needed to know, including recomputing the guidance angles after retro. The ground did an excellent job. Tracking data, I don't remember receiving that. When Spacecraft 6 was entering, they kept telling them that they were fine, and they were going right down the slot and everything. I do not remember ever hearing from the ground on anything like that on ours, do you? Perhaps we did and we were so engrossed in flying it, that we did not notice it.

Lovell Well, we had good communications prior to blackout over Guaymas. After we started guiding, going into the atmosphere, communications went to pot.

Borman Status of recovery. I do not think recovery could have been any better.

Lovell Very smooth.

7.4 Systems Configuration

Borman The ECS, as we said before, we had O_2 HI RATE with both

suit fans, snorkel valve open, and the vent valve open. We also opened the repress valve. Electrical: We performed a simple electrical check. We turned off 3 and 4, left 1 and 2 on, and watched for the variation in voltage on the main buses. The bus that is fed by 1 and 2 batteries varied with wave action.

Lovell That is right. But 3 and 4 did not move from zero.

Borman And then you turned off squib batteries 1 and 2 also didn't you?

Lovell I left squib battery 3 on.

Borman Squib battery 3 was the only one that was on.

Lovell Control: We turned off the platform, the computer, the circuit breakers to the thrusters, and the RCS thrusters.

Borman We left the computer in PRELAUNCH for 48 seconds or more, before we turned it off. Aeromedical, no comment. Except blood pressure being a nuisance, and perhaps even a hindrance when we were trying to go around the cockpit with the switches and you had to hold one arm still.

7.5 Spacecraft Status

Borman RCS fumes: When you open the snorkel at around 26,000 feet you get a good load of them.

Lovell I am not sure what kind of fumes they were. They were not familiar to me. I have smelled the results of fuel in the

RCS system, and I know what that smells like it. It did not smell that way. I got a burning sensation in my eyes, which was different. Now, I might have got a more concentrated one. I still had my helmet on, and zipped up. You had your helmet off. I believe, that with the snorkel open, the compressor pulled the ambient air through the snorkel through the compressors and into the suit circuit. That is why I got a concentrated dose of whatever was on the outside, which caused my eyes to water and to burn. Whether it was the ablative material, the shingles, or the RCS fumes, I do not know.

Borman The main chute was perfect.

Lovell Looked beautiful.

Borman I could not see a rip or a tear or any fraying or anything; it was just perfect. The windows were foggy in flight. I thought they fogged over and the visibility out of them during the hot part of the reentry, was very poor also.

Lovell They started to burn a little bit. Started to peel off on the outside. I do not know what it was.

Borman When we got on the water they were fogged over with humidity and salt spray. I guess you have to expect that. Leaks: There were none, that I know of. Couldn't see

any or hear any.

Lovell I did not see any leaks.

Borman Electrical Power: We mentioned we had 1 and 2 main batteries on, and when we evacuated the spacecraft, we turned all four of them on per the checklist. Turned off everything but the rescue beacon. Electrical power was ample, very good. We were running both suit fans.

Lovell Oxygen: Went to repress valve open.

Borman We went through that swiftly, as a matter of fact, to keep cool.

Lovell We noticed before we got out that both the bottle pressures were down to zero.

Borman Hatches: After one of the swimmers said we were clear to open the hatches, I unlocked mine. It operated very freely and easily. I could budge it about 2 inches, but I could not lift it. I probably could have if I had exerted a lot of effort, and gotten my legs up under me. However, the swimmer was right outside, and I asked him to help. He helped and it came right open, worked very well. We had the suit on and left them on.

Lovell We were warm, undoubtedly. Getting out of the spacecraft as quickly as we did helped us.

Borman That was the smart thing to do.

Lovell I wouldn't want to sit in there with our suits on.

Borman Plus, I thought the visibility of that suit during re-entry left a lot to be desired. That is why I had to pull my hood back to find out where we were and what position we were in. I think the suit is an excellent one, but it is going to have to be improved. We better grab it and start working, modifying it; to make it acceptable for Apollo. The sea condition was very good; 2 to 4 foot waves. We bobbed around, although I got a little queasy, I did not get nauseated, Jim didn't either.

Lovell The sea condition was outstanding for landing.

7.6 Postlanding Activity

Borman Postlanding activity was well organized. We were a little busy. We did not get thru until about 10 o'clock that night. Is that right?

Lovell Yes, that is right.

Borman We had a little misunderstanding about riding a bicycle. We understood we were not supposed to ride until 18 hours after impact. They wanted us to ride it that night after we had been through a full day of medical exams, and finally had a good supper. So, we told them they would have to hold off until 18 hours after impact.

FCSD Rep You are still in the spacecraft for this part.

Borman Okay. On postlanding we just sat there.

Lovell Well, we went through the check-off list. That took all the time. I saw the swimmers, checked the electrical system, that they wanted us to do for postlanding. By that time the swimmer had the collar up. I could see the collar going up, and then he got the jacket on.

Borman We had good communication with the swimmer through that jack.

Lovell Excellent communications with the swimmer.

7.7 Comfort

Borman It gets pretty warm in that spacecraft. I would hate to spend any great deal of time in there without any ECS.

Lovell I can speak as an authority on that.

7.8 Recovery Force Personnel

Borman We covered communications, it was excellent. Flotation collar was fine, worked good.

7.9 Egress

Borman Egress was normal, just as we practiced in Galveston Bay several times. These helicopters did a fine job. I think someone said it was about 23 minutes after we landed that we were on our way back.

7.10 Survival Gear

Borman Even the underarm life preservers inflated this time. Wonder of wonders. No problem.

7.11 Crew Pick Up

Borman The crew pick up was nominal.

Lovell Nothing else. Everything was fine.

8.0 SYSTEMS OPERATION

8.1 Platform

Borman We aligned the platform 3 times. Each time it worked just as advertised. Daytime alignment, of course, was no problem. We got very ample yaw reference out the window.

Lovell Caging, for fast heat dropout took approximately 23 minutes.

Borman Night time, the initial alignment is a little difficult if you do not have a full moon. With a full moon it is almost as easy at night as it is in the daytime. It really lit the terrain up.

Lovell To get your initial spacecraft attitude, the full moon is very nice.

Borman Right, without a full moon, I think it would take you a little while to align to get your Spacecraft BEF, so that you would not have to torque the platform too far for alignment.

Lovell You get to know the stars.

Borman Yes, you have to use the stars. It would be difficult to pick up the ground and track it. Platform Modes: CAGE. Jim said that took 23 minutes for a fast heat drop out.

SEF worked perfectly. BEF worked perfectly. ORB RATE seemed to be fine. We used it preparing for the rendezvous with Spacecraft 6. After running ORB RATE for approximately an hour, and then going back to align SEF, we did not notice a great amount of misalignment. The only time it was on FREE was during reentry. I guess the FREE worked fine.

Lovell No problem about displays, were there?

Borman No, not at all.

Lovell Been using them for a couple of years now.

Borman No problem about controls. The PLATFORM mode worked well. During our last alignment, we had degraded operation in thrusters 3 and 4; so we aligned it manually for 2 orbits. It was very easy to do, and it worked fine.

We had all the confidence in the world as far as attitude reference is concerned.

8.2 OAMS

Borman OAMS operational check, Pad: I think we went around the horn about 3 times before they were satisfied.

Lovell It took three circuits to get them.

Borman Right. Inflight OAMS: The only operational check we had is when we lost the complete authority in yaw right, thrusters 3 and 4. We noticed this first in PULSE mode;

we switched to DIRECT and in DIRECT we did not get any ignition at all as far as I could tell. In the OAMS PULSE yaw right, we were getting slight little pops. It seemed we had about ½ control authority that we had before we experienced the problem. We went to DIRECT, to see what effect DIRECT had on it and we got some thrust, but it was a whishing. We weren't getting any sound of the thrusters. It was a whishing sound. I think we were only getting an impulse either from the oxidizer or the fuel escaping.

Lovell We could hear a clicking of the solenoids or the operation of the valves, whatever they were back there. They were working all right, but we were not getting any resultant thrust.

Borman Right. Systems Monitoring: Source pressure was fine. Went right down the predicted schedule.

Lovell As a matter of fact, the source pressure dropped, just as predicted, when we ran out of initial OAMS fuel before we went to the reserve tank. It came back in again when we actuated the squib.

Borman No, that wasn't the source pressure, that was the regulated pressure.

Lovell I mean the regulated pressure, I'm sorry.

Borman The source temperature worked fine throughout the flight.

The regulated pressure stayed at 300, right on the money, throughout the entire flight until the auxiliary tank was actuated. We operated the auxiliary tank when the pressure dropped about 30 psi.

Lovell Yes. It went down to about 260 or 270.

Borman Right. It came right back up, and the system worked just exactly as advertised. The propellant quantity gauge worked fine. For most of the flight it was right in agreement with the ground computations.

Lovell What was the final propellant quantity reading?

Borman About 2 percent to 3 percent.

Lovell And we still had 300 psi regulated pressure.

Borman Source pressure remained about 1,000 psi. Monitoring of OAMS propellant remaining: On board information I thought was good. The OAMS propellant quantity gauge, worked fine.

Lovell At least it was on the side favoring us.

Borman Yes. The ground information was excellent. At the end of every day they gave us ground rundown of how much OAMS fuel we had remaining. It worked out fine. We were short on OAMS fuel. Any time we didn't have a specific assignment, we were in drifting flight. That's one thing we want mentioned. Every time we powered down we'd turn off the ACME bias power and the ACME inverter, and invariably this would

end up in two pulses of "bump," "bump", that would tend to yaw left and roll left. And the natural tendency of the spacecraft to yaw left due to water boiler venting, I guess, and perhaps ECS venting, was aggravated by this added impulse of two blips when we shut down the ACME. How about the selector controls and switches in the cockpit?

Lovell No comments there.

Borman I don't have any either. The attitude controller, I thought, was fine. No problems. Maneuver controllers were fine.

Lovell The right hand maneuver controller was a very nice operating controller and it was very handy. Very easy to operate.

Borman As far as inflight malfunctions or irregularities, we lost authority on thrusters 3 and 4. We got some of our yaw right capability back by turning off the circuit breaker for Thruster 12 and then thrusting backwards with the maneuver controller in order to give us yaw right. This worked very well and enabled us to check yaw right drift rates and enabled us to make yaw right maneuvers. The only thing—you couldn't get very small control inputs with this mode.

Lovell And you used a lot of gas.

Borman And you used a lot of gas. I was very happy when we finally

aligned the platform for reentry that we were able to get enough control out of 3 and 4 to align the platform. When we did this, of course, in order to get yaw control we went to roll jets - pitch, and that worked fine. I don't have anything to add to that malfunction. We heard the solenoids working. When we went to DIRECT we could feel we did get an impulse, but we did not seem to get ignition. It sounded more like a swishing noise. The ground analyzed it and seemed to think it was a problem with the valve seats. I'm not certain what it was. I do know that we also tried secondary drivers and that didn't help. I could tell that wasn't the problem when we first heard it.

Lovell We tried different modes--PULSE, DIRECT, and RATE COMMAND, but that didn't help. I think it was mechanical problem.

Borman RATE COMMAND is a very tight control mode. I'm very glad it was there. I think it is very important to have that for retrofire. We also used it for reentry. I think it is a very good mode. Of course, it is expensive in fuel. We used it also for all our thrusting when we were making orbit adjust maneuvers.

Lovell Let me ask a question. When did you go to RATE COMMAND during the reentry?

Borman I went to RATE COMMAND during reentry after guidance initi-

ate and after I started flying the needles.

Lovell Because you were overshooting with DIRECT?

Borman Right. I was not able to get the fine control I wanted. It would not stay in there. It seemed like the spacecraft was picking up a torque in roll also, and I was having to watch it too close.

Lovell And this was different than what we had in the simulation.

Borman Yes. REENTRY RATE COMMAND we never used. DIRECT we used once for tracking the Reentry Minuteman in order to catch it. It was moving so swiftly. We also used it in the initial phases of reentry, and it worked fine. The PULSE mode, of course, was the one we lived with most throughout the 14 days. I thought it was an excellent mode.

Lovell It is a gas saver and even when you do have a platform the PULSE mode is adequate for most of the work you can do-- for any attitude control, ground terrain observations—except for rapid rotations where you need a faster authority.

Borman Right. All ground tracking, PULSE was adequate. We did not have any problem at all. We were able to track the Polaris using PULSE. Everything except the reentry ~~one~~ we could use PULSE mode. The HORIZON SCAN mode was fine. The only thing I noticed there was at sunrise and sunset sometimes, we were driven to a 30 or 40° nosedown pitch attitude

by the thrusters. The scanners worked great except at sunrise and sunset.

Lovell They would lose lock...

Borman Sometimes they wouldn't lose lock but, remember, they drove the spacecraft nose down. About 40° pitch down.

Lovell The one big thing, which was the question in all our minds, actually happened. Another spacecraft nearby will interrupt the HORIZON SCAN mode.

Borman Right.

Lovell It does effect the scanner operation, so it is something you have to take in consideration.

Borman That's right. When 6 got between us and the sun, the scanners were inoperative and lost lock. PLATFORM mode worked excellently when we had it, and we used it to align the first two times we had the platform. I think that you can do a finer job, and you can align the platform more closely manually. This is because the deadband on the PLATFORM mode is larger than you can control manually. But it certainly is a worthwhile mode and for station keeping it is a superior type of operation. Translation maneuvers at spacecraft separation at SECO + 30--I did not hear the thrusters. I just thrusted. Jim hit the SEP spacecraft. Did you hear the thrusters?

Lovell No. I did not hear the thrusters. One reason why we didn't hear the thrusters in that particular case, whereas we did later on, was the fact that we had our hoods on and the air was blowing in and making a lot of noise. It was strictly by feel and by sight. No sound.

Borman Right. Perigee Adjust Translation. Accelerometer bias was what they thought it was prelaunch, and it remained that way throughout the flight. This was a no platform Perigee Adjust, so, really that doesn't have any meaning there. The timing on the first Perigee Adjust Maneuver was off, thanks to me. Jim made the maneuver. We did it without a platform on a star. And, as I mentioned earlier, about this time we were in close proximity to the booster, and we started flying through some particles, but I was not sure exactly what it was, so I told him to stop thrusting as we approached this. Then, when we got in there, when we stopped thrusting, this wire came forward, hit the hatch, and I lost the timing again. We thrusted, I guess, a little too long. I am not sure exactly how long it was. I think we were aiming for a perigee of about 102, and ended up with about 120. Maybe they changed their minds and went for a perigee of 120. I don't know.

Lovell Well, that time which they gave us was not consistent with

the flight plan. They gave us one minute and 16 or 17 seconds, and the flight plan called for 46, I think.

Borman Well, we may get that cleared up when we talk to the ground. But, it was greater than I thought we had planned to do. Updating throughout the flight was excellent. Checklist was fine and, of course, we did not use the computer.

Lovell We might mention here that both Frank and I think making adjust maneuvers without a platform is very feasible. You can use the reticle for alignment and use the stars as a reference. Since you are usually using the aft thrusters, you do not have thruster light to worry about. You can turn down the lights. It takes two people though; one person to burn, hold attitude on the star, and watch the star reference and the other person to time. It required two people, but it is a very feasible method of doing it. I think you get some very good accuracies with it, because we found out from the second burn.

8.3 RCS

Borman RCS operational checks were nominal. We had no problems at all with the RCS. System monitoring was perfect and it did not drop one bit during the 14 days. After we actuated it, it went from 3,000 to about 2,600 to 2,500 psi on the source pressure. No problems. Control modes, RATE COMMAND. As I

have said, it is a very tight and fine mode. We used it during most of the reentry. REENTRY RATE COMMAND we did not use. DIRECT I used for the first part of the reentry, and it seemed that we were picking up rolling torques, and I was also starting to pick up pitch and yaw oscillations as the gs were coming on. They were slight ones but I really wanted to get the spacecraft steady, and I was really trying to lock it in on the attitude indicator, so we went to RATE COMMAND. I didn't see any reason to bring back a lot of RCS fuel anyway. REENTRY RATE COMMAND we did not use. The PULSE mode was used in the reentry prior to guidance initiate, and it worked fine. Retrofire attitude control was excellent and I'm glad we had RATE COMMAND there because we had no outside reference at all. Retrofire was done on the ball with the rate needles, and I thought the rockets were outstanding. Yeah, outstanding, I thought they were a little more powerful than I had anticipated.

Lovell Quite all right.

Borman Reentry attitude control deadbands and rate damping was fine. The only thing, I guess, that was wrong with RATE COMMAND was the fact that it uses an awful lot of fuel. But, it certainly holds that spacecraft steady as a rock. The heater lights - we solved that problem very easily. We

turned on the RCS Heaters on the second day and left them on through the entire flight. They sequenced and went on and off, I am sure, but we did not know about it. We never saw the light, and we did not have to worry about it.

Lovell The temperatures kept right around 80° all the time.

Borman No comments on thruster firing, worked fine. We shut the RCS system down initially around 35,000 feet, shut off the motor valves and then the oscillation on the drogue built up even greater than it was. So we turned them back on again, and I'm not sure if it is my imagination or not but it seemed like this had some effect on damping the oscillations. It may have been just the position in the reentry, though. I had the feeling that perhaps we had run out of RCS fuel prior to drogue deploy. I am not certain, but if we didn't then the RCS didn't have the authority, because we were oscillating before drogue deploy. I didn't notice any RCS fumes after impact. Did you, Jim?

Lovell After impact? No. I think that our system of turning the Repress on and getting the...

8.4 ECS

Borman Why don't you comment on suit mobility?

Lovell This was a flight that actually did some evaluation on the suit. We had the new light weight suit. Mobility is better

than the 4-C suit, but mobility in the Gemini cockpit with the 5-C suit still restricts the person such that it degrades his performance for long duration missions. It is still quite immobile in the 5-C suit. We still have a lot of trouble with it. The suits checked out all right prior to the flight. We did not do any integrity checks with the light weight suits during the flight. The air flow through the suit was adequate where the flow got to the body. However, there were many pockets where the air became stagnant, especially in the crotch area. It would heat up in local areas of the body and would not provide adequate cooling. Humidity goes right along with temperature. The areas where the air flow did not go across the body, was very humid. We also noticed that it gave you sort of a wet clammy feeling when the cool air went in there. It gave you sort of a cold, clammy feeling where the flow went through. Places where the air did not reach were hot and clammy.

Borman Also, the humidity in the cabin was very, very low when we were in the suits. The cabin was dry and hot. Very, very poor.

Lovell The humidity dew point was between 52 and 58 most of the time. We have some accurate figures on that. I don't recall any instance of even seeing the CO_2 gauge move other than

during tape dumps. We had no evidence of CO_2. Comfort in any pressure suit is compromised. It restricts mobility and the Gemini cockpit is just not that big for long duration flights where you can live with the suit. Suit controls were very adequate, no problems there. We had absolutely no problems with the O_2 demand regulator. The electrical umbilical is ungainly and heavy. The connection right angle sticks out in the cockpit. It could be better designed. We did not have fingertip lights. Our mode of operation, with the suit on, was primarily with the hood off, the cover visor on, and the gloves off. Many times we also unzipped the big zipper through the crotch and up the back, and left that zipper open. We found that the big opening in the neck, with the crotch zipper closed, most of the air would go out through the neck and would not adequately vent the lower stomach area. We had planned in our flight plan to try going suitless. As per plan, about the second day, I got out of my suit and found after settling down to the environment that the skin became drier. There were no wet spots or dampness in the underwear area. I put my suit inlet hose along side of me on the center stowage area with the opening facing aft blowing air down alongside the seat blowing aft. The exhaust hose was put back into its stowage

position, with the screen on, along the lower right hand footwell area. This provided adequate ventilation during most of the time. When we exercised we found out we built up quite a bit of extra heat. I would then move the inlet hose to a position along side of me, along my left leg, and tie it down along the side pedestal with the opening facing upward. This would provide more cooling into the basic cockpit area and would actually keep me a lot cooler than I had been before. We found out that without suits on, the cockpit actually became bigger. There was more opportunity to move around. You could move the body, there was less hesitancy to exercise, less resistance to exercise, you could get to things easier. You actually had more control and more comfort without the suit on. We stowed the suit on the seat, putting the visor along the outer part of the top of the seat rest and doubling the legs back against the back of the seat. We stowed the harness in the juncture of the back and the seat of the ejection seat. During zero g we were floating up and we never touched the back part of the seat.

Borman I have some flight notes that I will just read out for the record. Ventilation without suits: The bypass hoses on the Gemini provide excellent return ducts for the suit compres-

sors. They were mounted with the inlet on the outside wall near the individual crewmans outboard knee. The suit inlet hose was then positioned to secure different flow patterns. Because no provision had been made for special inlet hoses, only two positions were tried. The one most often used was the suit inlet hose located near the inboard shoulder pointing forward. This produced a flow pattern from right to left down across the body. The body was never really in the flow but a very comfortable circulation pattern was set up. The other primary pattern consisted of leaving the suit outlet hose in the same place, but putting the inlet hose near the outboard knee, pointing 90° from the direction of the outlet hose. This pattern also produced a comfortable flow pattern. In truth, I believe the cabin is so small in volume compared to the amount of air introduced by the suit circuit that almost any arrangement would provide enough air to provide efficient cooling. We also have some sketches of how this went.

Lovell We also believe, after spending several days without suits on that the theory that at zero g there would be no convection cooling...

Borman I am sure that there isn't any, due to change in the heating condition.

Lovell The mass of the air being pushed out by the compressors is enough to give adequate flow throughout the entire Gemini cockpit. We had no problems with air flow.

Borman It would have been a very, very difficult task to stay in those suits for 14 days, if not impossible. We certainly would have been in much worse shape when we got down.

Lovell I believe so. We were requested from Houston to try the hose position evaluation where by the inlet and outlet hoses were together.

Borman Yes.

Lovell We tried it and to be perfectly honest, with the small cockpit and the amount of flow out of the inlet hose, we did not find much difference, it was adequate, but it was awkward to use it that way. We did find out that if my exhaust hose was put on Frank's side that we would get stagnant spots on my side of the cockpit where although I wasn't uncomfortable...

Borman ...that is with your inlet hose being turned off. So all these flows were introduced on my side and both the return hoses were on my side.

Lovell That is right, they were on your side. I found stagnant areas, I wasn't uncomfortable, but I did find stagnant areas where there was no flow going on on my side. You have to

have adequate positioning of the exhaust and inlet hoses.

Borman I think really to solve the whole problem, if you want to design efficient cooling for suits off operation in spacecraft, design it the same as you would on the ground.

Lovell Right, I think you are right.

Borman You would have no problem. For instance, in most of the airplanes now that are pressure cooled the flow is so great across them that you have a continuous flow pattern in there, coming out usually from one inlet located up around your right shoulder and a couple in around your feet. I don't think you have to worry about the bugaboo of no convection in zero g because it is overshadowed by the large kinetic energy input through the large amount of air.

Lovell Cabin pressure was 5.5 on lift-off, came down to 5.1 and stayed there exactly 5.1 for 14 days. It did not move when we jettisoned the adapter and went on the bottles, it stayed exactly 5.1. The only time I saw it move was on the water when we used all the oxygen up and it went to zero.

Borman Well, it was below 5.1 when we opened the Inlet Snorkle.

Lovell Inlet Snorkle.. yes, that is right.

Borman You were talking about the inlet bottle pressure.

Lovell Yes, that's right, the bottle pressure.

Borman The temperature varied with the suits on and the suits off operation. I have gone through my notes here, and I note that it says when we both had suits on and we were just barely cool enough with both suits on and the B pumps running. On the other hand, when we were both out of the suits, the B pumps only running, we were very comfortable. When we were up working and operating, we noticed that the temperature level in the cockpit was just right. We were running most of the time with the suits full cold, the heat exchanger full cold, and maximum air flow on both controls. Then for several days when we went to bed, we left the controls that way, and we would wake up very cool.

Lovell Well, there are several factors. I think the size of the Gemini cockpit and the fact of a completely closed loop system is very dependent on 2 factors. One was the heat output of the people and two was the amount of heat you get in through the windows due to the sun. At night our heat output decreased, we put up shields on the windows, including some aluminized foil to reflect the sun, and I think the combination of both these things with the systems we had during the day time really dropped the heat in the cockpit. Then, during the day when we were active and had the windows open again, the temperature increased inside the cockpit so

it was very comfortable.

Borman That is right but the last couple of days we turned down the suit flow at night and it helped out.

Lovell To compensate for this thing we turned down the suit flow.

Borman There's a lot of inertia in the cooling system and it takes a long time from the time you make a move on the controls before you can feel it.

Lovell Just to regress here one minute. When I was out of the suit and Frank was in it, we put my suit flow to full decrease and his to full increase to give him maximum cooling in the suit. I was not uncomfortable with the full decrease flow in the cockpit.

Borman The humidity in the cabin was higher with the suits off. It was a much more comfortable cabin. Your skin didn't get dry, and the nose problems we had the first 3 or 4 days went away. I am not sure that we can contribute this solely to being out of the suits or whether it was the fact we were becoming more acclimated to the 100 per cent oxygen.

Lovell We have some accurate figures. I believe though, that with suits on the humidity-temperature range was about 20 degrees difference. With the suits off they went around 10 degrees, I suspect.

Borman We have them all there. The only time the CO_2 jumped at all

was during tape dumps, it would go up and then come back down but we knew this before flight though. Comfort day and night, with and without suits .. There is just no comparison.. I have the notes that I wrote down while we were still up there. There is no comparison between suit on and suit off operation. The suit off is 1,000 per cent better. I think I may have been conservative. It was maybe a lot better than that. Comfort without the suits was by and large very good. We used the cabin fan only once in the entire mission during one of the checks with the suit off. This was when we had Jim's suit inlet hose blocked off and my inlet hose operating in my side and the two suit outlet hoses in my side of the spacecraft. As we already mentioned here, Jim noticed some stagnant areas in the spacecraft, and we turned on the cabin fan to see if this aleviated the problem, and it did help. There was a definite circulation with the cabin fan on. The only problem is the cabin fan draws a considerable electrical load, and we did not have the power to run it continually. The cabin pressure regulator worked perfectly, it never worked at all.

Lovell That is right, never heard it, thank goodness.

Borman That's the pressure relief valve. Right, never heard it. It never actuated. The cabin pressure regulator was as

steady as a rock. As Jim has already mentioned it stayed 5.1 the whole flight, and I never saw it budge at all, until you opened the snorkel.

Lovell Right.

FCSD rep Cabin vent valve.

Lovell We had a double vent valve with the tip bent up to protect the stop. We never used that until we got down to the checklist during the reentry portion of the flight.

Borman The Cabin Repress Valve was on the entire flight because we had the M-1 Experiment hooked to it. Then, of course, we actuated it again when we got on the water just to get some cooling oxygen into the spacecraft. I have no comments on it, we had no problem with it, the friction had been increased on it so that it worked quite well. It stayed in the open position for the entire flight. The Cabin Air Inlet Valve, we used...

Lovell Just during the reentry phase..

Borman Right. Just during the reentry phase.

Lovell ...with the snorkel valve, that is when I think I got a whiff of that stuff through there.

Borman All the time with the suits off, we were running with the Cabin Air Recirculation Valve closed. The rest of the time when there was one person in the suit and one person out of

the suit we ran with it in a 45 degree position. When both people were in the suits, we ran it in the 45 degree position.

Lovell I'd like to make one comment on the Cabin Inlet Valve, I think a future procedure would be to either open the visor or unzip the hood prior to using the snorkel valve, so you do not get this concentrated ambient flow into the suit in a small concentrated area. Okay. Primary O_2 System Monitoring.

Borman Primary O_2 System Monitoring was no problem. The cryogenics bottle for ECS O_2 oxygen did vent... I think it was about the 8th day it started venting. Performance of the cryogenics bottles have been outstanding. The first one, ECS O_2, started venting today. And we were still adding heat to the other two bottles. Let's see, this was Sunday morning so that would have been the 8th day that it started venting. The quantity measuring system worked fine. The flow rates were adequate. I just cannot emphasize enough the desirability of going without suits. The pressure and temperature remained just nominal. We had dome plots aboard the spacecraft, and we checked them out. We had to use the auto heater on the ECS O_2 bottle perhaps, the first two days or so and then we were able to turn the heater off complete-

ly. That bottle had a big enough heat leak so that it maintained pressure itself. As I said, it started venting on the 8th day. We never used the manual heater on the ECS O_2 bottle.

Lovell As a matter of fact, the primary O_2 helped, rather we utilized the primary O_2 to pump up the pressure on the FC O_2 sometime in the early part of the portion of the flight.

Borman Yes, we used the crossover valve. When you hit the squib or when you hit the switch to open the solenoids, even though we had been led to believe that it takes some time for that pressure to build up, it looked to me that it went to about 250 in the FC O_2 bottle almost immediately. It went from 100 to 250 almost immediately. I imagine it will come down when we talk about the FC O_2 problem.

Borman Secondary O_2 System Monitoring was nothing, we checked it... all the time, but GO/NO GO decision once a day. It stayed exactly the same throughout the entire flight--5400 and 5300.

Lovell It did not budge at all.

Borman Quantity measuring..we do not measure except for pressure, and as we said that stayed constant. Flow rates, pressures, and controls were nominal in the secondary O_2. You could not tell when we had gone off the primary onto the secondary

O_2. We have already talked about the CO_2 partial pressure. It was below zero the entire flight except during tape dumps when it jumped up due to a glitch that the tape dump puts in the TM system. Radiator operation and configuration...We ran radiator on all the time except for two checks that were made. Actually when we opened circuited the fuel cells before we brought them back on the line, we went to RADIATOR BYPASS twice. Then we went to RADIATOR BYPASS once when we wanted to get the water out of the ECS System. One time during the flight we were picking up water. This might be a good place to cover that. We were picking up water coming out of our suit inlet hose, in quite large quantities. We called the ground, and they suggested that perhaps the water boiler was not venting. They called up the procedure that included putting on evaporator heat, turning off the radiator and going to bypass on the radiators and rotating the spacecraft at 10 degrees per second. This threw out large amount of water and things got back to normal. Later on in the flight we noticed the same thing, but we were busy aligning the platform and other things and we did not want to setup roll-rates. All we did was put the suit coolant to warm and put both suit fans on and blew the water out of the system, and that worked also. We did notice that during

the flight, down in the vicinity of my right foot in the center pedestal lower area there, around the cabin heat exchanger, we got a lot of condensation. It was very wet on the walls and the blotter paper was sopping wet, a radius of about 12 inches on the lower right pedestal, on my side. I do not know how it was on your side.

Lovell It started getting wet on my side, the inboard.

Borman Yes, inboard side. That is the only place in the spacecraft that I noticed any condensation. As far as I know the evaporator only operated during launch and the first orbit. We also had one other day when we woke up and were tumbling quite badly and the wall temperatures were 16 degrees to 20 degrees lower than we ever recorded them before. I suspect that the evaporator might have worked that night. We mentioned this to the ground and...let's see, I have some notes on that.

Lovell It probably got filled up from the moisture going into the system.

Borman This was noted in the data for the cabin temperature surveys also. I don't remember exactly what day it was, where we noticed this big change in temperature.

Lovell It was about 5 or 6 days after the mission started, wasn't it?

Borman Yes..here it is here...it was 158 hours and 27 minutes when we got up, and we had a wall temperature of 64 degrees and a pilot hatch temperature of 66 degrees. Comparing this with 144 hours and 53 minutes, the hatch temperature had been 84 degrees, so there was a 20 degrees drop during this one evening. I attributed this, plus the fact that we noticed large drift rates when we woke up, to the fact that the water boiler must have been operating during the night. It was the only time during the flight that we noticed these large drops in temperature...the very cold wall temperatures. We were on double loop, B pumps most of the time. Finally, went to A pump twice in the flight when people were in the suits in order to stay cool. We went to double A pumps, of course, when we were powered up.

Lovell We had one time when we had one A pump on.

Borman Twice we had it on.

Lovell Twice, but just one primary pump. We did not go to two A pumps.

Borman No. A pump in the primary loop was on twice to keep cool.

Lovell Right. The secondary loop A pump was not on.

Borman Never on except during periods when the platform was running.

Lovell Right.

Borman Now, as I mentioned before, when we were running both B

pumps with the suits off, it was comfortable. When we got the suits on, and both B pumps going, it was not enough to handle the load.

Lovell It was marginal.

Borman That is right. Normal mode was all we used on water management.

Lovell Never touched the---

Borman Never touch the condensator.

Lovell The drink gun worked as advertised.

Borman One thing I would mention is the fact that this logging every ounce you drink was an operational nightmare.

Lovell I think the gun is adequate for flights if all you want to do is to know the total quantity of water that is going out for ballast purposes or CG purposes. I do not think there is a requirement to know just how much each crewman is drinking as long as it is adequate. There is no need to log, all you have to do is report counter readings once a day for the guidance people and fuel cell people to know just how much water is being consumed.

Borman Right. It says flush mode. We never used the Flush mode or Evaporator Fill mode.

8.5 Communications

Lovell The interphone Operation and Quality was okay, without the

hood on. The G5C suit made communications poor, because of the flow of the air to the hood. Other than that I thought the interphone was pretty good.

Borman Yes, we should mention the fact that the G5C suit with the hood zipped did introduce a lot of noise.

Lovell Yes, a feed back into those two mikes and there was a lot of noise.

Borman The quality of the interphone was excellent. With the suits off we didn't use them most of the time, just like talking in a room, so we didn't need it. My UHF was a little fuzzy during countdown.

Lovell Mine was good.

Borman Yes, yours was good and mine was a little fuzzy. I could hear people all right but they claimed that I was a little weak. In orbit, I just can't say enough nice things about the UHF.

Lovell UHF was excellent in orbit for the entire 14 days. Very little static. High quality reproduction.

Borman With the squelch on zero.

Lovell Right, the squelch on zero.

Borman The UHF performance during recovery was excellent. No peo-
blems with that at all.

Lovell We did have trouble getting back to Houston.

Borman I was very pleased with the entire Voice procedure operation around the world. I thought they did an excellent job. We didn't have any problems at all. They were quiet when they were requested to be during our sleep period.

Lovell They were outstanding.

Borman They were outstanding, yes.

Lovell The voice tape recorder operation was fine. There were no hitches as far as operating the voice recorder. It was easy to, well, that's three feet of change. We used mostly the CONTINUOUS mode rather than the MOMENTARY. I used MOMENTARY when we just wanted to make a comment. As a matter of fact, I think the MOMENTARY position does save a lot of voice tape, because you don't have it on and forget it. However, we had a procedure with the voice tape that was going to record the quantity of urine that was dumped. And this led us to leave the voice tape on quite a long time when we weren't doing anything or saying anything--and using quite a bit of tape. I think that it would be helpful if we had some sort of a little light of some sort to let you know that the tapes on. When we have a flow meter which was being evaluated for future flights and might be a standard piece of equipment then it would certainly be nice to have

some indication if the tape is on. On long flights you can't have the tape on all the time like the short flights--you have to conserve tape. Cartridge change was no problem. The controls were adequate. Data Recording? We tried to record as much data as we could.

Borman We didn't indulge in a luxury many times of recording both in the log book and on the tape. We only had 20 tapes for a 14 day mission. If we got a good representation of it in the log book--we didn't put it on the tape. Now, we find out we probably brought back some unused tapes, too.

Lovell We did. It was hard for a 14 day mission to adequately budget the tape. We would try to budget it so that we could get the information on there without leaving long periods of inactivity on the tape. However, we didn't budget it well enough, and we left about 1 or 2 tapes without any recordings.

Borman Digital Command System updates were good, no problem--everything worked fine. Real-time transmitter, and delay-time transmitter were no problem. As a matter of fact, that whole system I thought was excellent. The only problem we had in the area of Digital Command System or the telemetry was that we lost the tape recorder and...goofed up the delayed time. The procedure that we worked up for operating

with Spacecraft 6 in the air, I thought went very well. It posed no problems. Communications Controls and Switches-Voice Control Center, Audio modes, Keying and Antenna Selection, were all nominal. We might mention in Sleep Configuration--we never used the Sleep switches because we had the situation where we pretended it was night and went to sleep every evening and the ground never called us. I don't think they ever violated that for the 14 days. They never called us during the sleep period.

Lovell So that worked very well.

Borman Beacon Control was no problem. We didn't use the Reentry C-band Beacon until reentry. The TM controls, transmitter, and antenna again were no problem. It was operated just as advertised due to all instructions from the ground.

8.6 Electrical

Borman Now we have some interesting things to talk about.

Lovell Well, we monitored the electrical system pretty closely.

Borman Yeah, I guess we did.

Lovell The only thing we can say here is reiterate what we have probably said before. On lift-off we had delta P lights come on for fuel cells--both sections. 1 blinked on and off several times and went off. 2 blinked on and off several times and stayed on through insertion and stayed on

most of the time during the 14 days. We have recorded in the flight book of the flight plan--those times that it went off and on to the best of our knowledge. I'm sure we missed several of them.

Borman When we were sleeping particularly.

Lovell When we were sleeping we missed them, but it appears to me that there are two things now that these fuel cells have a lot more latitude than we really first realized: 1) We can operate with the fuel cells with delta P lights on more than we thought we could. As a matter of fact, we were doing normal purges with the fuel cell delta P lights on which the systems book said flatly not to do. But we had some excellent guidance and assistance from the ground in keeping the sections running.

Borman I think so, too.

Lovell I think that's what kept Stacks 2C and 2A going as long as they did go. The gauge is a little inaccurate to monitor the system. If we are going to have troubles with fuel cells as we did on this flight, and if the ground is going to keep requesting accurate stack amp readouts. The gauging system is poor because it is hard to read accurately the amps when they are down in the low 1 and 2 amps. Each indicator is canted a different way—alternately throughout the 6 stack

readouts. The ones that are canted inward away from you are hard to read.

Borman The fuel cell, as Jim said, was an interesting thing. We finally lost stacks 2A and 2C about the 11th or 12th day. Stack 2B remained on and I'm sure there is a whole history written on the ground of the things they did and tests they ran at McDonnell when we were in the air to see just what they could do and how far they could go with these fuel cells. I thought they did an excellent job,and we ended up being able to run them the whole time. As a matter of fact, we turned on our Squib batteries about the 10th day—used the Bus Tie switches and were running entirely on the fuel cells the latter part of the flight.

Borman The onboard cues for monitoring the electrical system are adequate. We found out one thing in this flight, that is the Delta P lights really don't mean a lot. We had been told before the flight never to purge if you had a Delta P light. We ended up violating every single one of the cardinal rules that we had.

I think the thing to note about the entire electrical system was the fine work done on the ground. They came up with solutions. They evidently were running similar type cells at MAC, St. Louis, and they kept them working for longer than they should have.

Fuel cell operation, as far as I was concerned, Section 1 was ideal. Section 1 maintained its share of the load the whole flight. Section 2, we lost stacks 2-A and 2-C eventually, I believe on about the 12th day. I was a little concerned on the 13th day with the status of Section 1 because we had had a delta P light on Section 1 for the first time and we had been running almost 24 hours.

But, the ground came through and read us up a technical report from St. Louis that explained the whole thing. It made me feel a lot easier when they did that. Rather than having the ground comment blindly on it, "the fuel cells are going to be good for 24 hours," I would like to get a

little background information on it. How else could we know it was going to be good for 24 hours, and what had they done to prove it would be good for 24 hours? They read it to us over CSQ, it eased my mind a lot because I wasn't anxious to miss the WASP. On the 13th day, I wanted to be able to go the full 24 hours rather than have to land in the Pacific. So the whole story of the electrical monitoring, as far as I am concerned, was great work by the ground.

The main batteries held constant between 22.5 and 22.7 amps for the entire mission, and we checked them once a day at the GO/NO GO stations. When we turned them on 2 hours before retrofire they carried their share of the load and were operating fine when we were in the water. We turned off the squib batteries about the 10th day and used the bus tie switches. We ran entirely on fuel cell power for the last five days. When the squibs came back on, the voltage was 25.5 after they had been turned off for five days. They operated properly for the last 2 hours of the flight.

8.7 Onboard computer

Borman During the launch it was absolutely a nominal case. The pitch status, yaw status, and roll status, were zeroed except for a brief period at guidance initiate when they went out about 2 to 3 degrees, and then zeroed. We had no violent

pitch down at guidance initiate. Attitude indications were nominal all the way through. At insertion, the nominal velocity on address 72 was 25,804 and when we read it up, it read 25,804. The orbit maneuvers using the computer and the platform were right on the money. The accelerometer bias did not vary, and we burned them off on the IVI's by inserting them through the MDIU, and it came out very well. I did not burn on time, we burned on the IVI's.

Borman The updates were all made in the PRELAUNCH mode as agreed on before flight. There was no problem, no misunderstanding, I think FOD did very well in this regard. I know that in Gemini 5 there was a little mix-up, but we had none of that.

Borman Retrofire occurred automatically at the exact second. All four Retros fired and the IRS was right on the money. Reentry guidance was nominal. It was very similar to the simulations that we had flown. There was one little anomaly in the guidance, in that we were given back-up reentry angles of 50 degrees. We computed with our onboard charts a reentry angle of 50 degrees, back-up angle of 50 degrees. But then after tracking, the ground called up a 35 degrees which proved to be closer to what we actually flew. I am still not aware of the reason for change; why it changed from 50 degrees to 35 degrees. The important thing is that it did change and the ground was able to update us in real time, and it agreed very well with the actual case.

Borman The MDU worked perfectly the entire flight. Computer modes, PRELAUNCH, ASCENT, CATCH-UP, RENDEZVOUS, REENTRY, were all perfect, no anomalies in any of those.

8.8 Crew Station

Borman Controls and displays. The sequential telelights operated exactly as programmed. At minus 2:56, they came on to the second. They all turned green when they were punched, no problems there. The event timer was used only intermittantly throughout the flight for timing, and for the last 20 minutes. It worked fine. The IVI's also worked exactly as planned. The Flight Director Indicator was again, a nominal case. One slight difference between the simulator and the Flight Director Indicator in the spacecraft, was the little outer roll gimbal indicator in the simulator always came up to the top. I'd grown used to flying the reentries by using that as a lift vector. In the spacecraft when we got all set up for reentry, low and behold, the outer roll gimbal was down at the bottom, so I had to fly the reciprocal of it. But it was just a minor change and I ended up acclimating to it with no problem. I think it is just a function of how you happen to go through zero. If you go through zero just a little bit to one side, the gimbal goes to the top, and if you go through the other side, it goes to the bottom.

Borman GLV fuel and oxidizer pressure gauges were nominal. The concept of sticking the decals on the outside of the gauge is poor at the best. But, we all know this has been done, and they're not going to change the gauges, and it worked fine. I would suggest never going this way again. I think we ought to change the meters in the future.

Borman The altimeter worked fine. The only problems we had with the altimeter was when we were oscillating violently on the drogue, it was not indicating descent. As soon as the drogue oscillations steadied out, the altimeter came down very well. Rate of descent indicator was likewise. As a matter of fact, I can't tell you what the rate of descent was after we opened the main chute. The main chute was so good when we looked at it. We didn't see any gores or frays. And when we went to single point release, I didn't even look at the rate of descent indicator. Did you?

Lovell I couldn't see it.

Borman Did you even think about it?

Lovell No, you mean to tell me you didn't look at the rate of descent indicator?

Borman We could tell from the altimeter we were going down very slow. The accelerometer seemed to give us slightly lower values than the recorded. I think on the reentry the highest value we got was 3.9 g's. During launch the highest that

was recorded on the accelerometer was about 6.75 g's. I understand that the actual value was over 7. On the nominal profile, it is.

Lovell Was the reentry a little higher than 3.9?

Borman I don't know, I doubt if it was, it was so near full lift. Switches and circuit breaker panels. We had a couple of cases knocking off circuit breakers. We did have one fuel cell control circuit breaker pop on us twice.

Lovell I am not real sure it popped. I don't know whether I hit it inadvertantly twice.

Borman No, you didn't. The second time I watched it pop. Other than that, I thought the switches and circuit panels were well located. I think it is very important that we have those guards on there, particularly with changing suits.

Lovell The fuel cell switches, the power and control switches, should be LIFT to move switches. They should be over center locks that you have to lift to move them up. There was a guard over it, but still it was so easy to reach up there and hit those things. I was always worried about throwing the control switch off, which would have really fouled up the fuel cells.

Borman You mean like the squib switches? ...

Lovell Yes, like the squib switches. I think that is the way they ought to be because you never touch them unless deliberately.

Borman Yes, that is a switch that is never moved unless there is a failure in the fuel cells.

Lovell They should be a little better type of switch than they are.

Borman Mirrors. Operating without suits on, I found that I seldom needed the mirror. I don't believe I used it more than 2 or 3 times except to check and see how far my beard had grown. How about you, did you?

Lovell Well, they were good for things like looking way back in the corner, and shining a light back there.

Borman I was mobile enough that without a suit on I could turn around very easily and see all around. There is no question you need the mirrors. I am not suggesting even remotely that you take them out. With the suit off it cuts down the need for them. The swizzle stick we used once to pry up the center line stowage bracket. When we opened the center line stowage after launch, the bottom bracket sprung down about 3/4 inches, and we had great difficulty to close it. We only closed it twice during the flight after that. We just kept it velcroed partially shut.

Lovell I think the boost acceleration sprung it out of position.

Borman Either that, or when they put that fix on there to beef it up, it resulted in an out-of-tolerance situation. I hope that the people did not force it shut and then let us take off that way. That was a pain in the neck to get it shut.

Lovell We had to use the levers of the swizzle stick to get the thing back together again. This was bad. We also used the swizzle stick to keep the manual heater switch down on the FC H_2 which is a real big pain. It is a very small switch and you have to hold it for a long time. That gets to be a lot of trouble.

Borman Lighting, indicators and instruments. There is one instrument in the spacecraft that should be lit that is not. That is the digital timer. That is the most valuable instrument onboard. We used it continually, it never varied one second in 339 hours. We never had to reset that once. It was exactly on the money. We checked it periodically and it never gained or lost a second.

Lovell But it had to be lit.

Borman It should be lit because it is right on the center panel, and there is no lighting on it except for the bright light from the back. Many times at night and when you are trying to maintain dark adaptation you end up having to use the flashlight on it.

Lovell It should be a red light for night work. In the day time you don't need it because the cockpit is lit up anyway. It really ruined night vision to turn on that flashlight to find out what time it was.

Borman The left panel was fine when it was lit up with the display

light. The center panel and the right panel were all right. There is no question that the lighting system on the LEM is superior.

Lovell We used the red lighting more than I thought we would ever use it. We never used it in simulations. The red lighting turned out very nicely when we started looking out the window, using the stars, getting oriented and things of this nature.

Borman The pedestal, console and circuit breaker areas just aren't lit. Same way with the water management panel, when you wanted to check that,the only thing you could do was use your flashlight. It was not a big problem. The little flashlight that CSD developed, and put in, was one of the most valuable pieces of gear we had. We used it continually throughout the flight, it is much more valuable than finger-tip lights. I see no reason for fingertip lights because you're not going to fly with gloves on most of the time. If we would have had them, they would have been stowed. This little flashlight turned out to be a little jewel. The utility light I did not use once in the whole flight.

Lovell I turned mine on once to see if it worked.

Borman The flashlight was much easier to get to. We velcroed it right in front of us, and it was very handy. And at the end of 14 days it seemed as bright as it was before. One

of the serious deficiencies in the flight was the dirty window.

Lovell I just talked to John Brinkman about the film. He said a lot of it was good, but a lot of it they could tell the window was dirty.

Borman What about the booster film?

Lovell They haven't processed two rolls of film yet and they don't have the Polaris launch yet. The Houston one turned out sort of hazy and I thought it was a clear day. He told me there was haze on the ground.

Borman Did they see Houston all right?

Lovell They could make out the International Airport.

Borman You took that with the 250 mm. lens.

Lovell The high speed film. They don't want to process it until they talk to us to find out what kind of exposures we used. We had all kinds of exposures. I think the picture that was in the paper was from the 16 mm. camera.

The window was very dirty. And I have a ... a picture was taken of it. Shows the ...

Borman Jim drew a sketch of the window in the S-8/D-13 log.

Lovell There was a greenish, greasy film over the whole thing right in the center. Outside of that was a sort of a haze or fog effect. Right along the outer edge, it was clear. If I focused on the nose of the spacecraft it would be blurry.

Just off the nose it would blurr out. There are two theories, one group of people say it's the nose cover that is ablating on launch, others say it is staging.

We saw quite a bit of flame at staging and it looked like there were several streaks there caused by staging. There is also a general deposit like a stagnation point right there that might have been built up during the entire launch, which might be the nose cover. So, it might be the combination of both.

Borman It might have accumulated due to the urine dumps throughout flight. Several times we saw urine crystals come back and hit the nose cone. We never saw them actually hit the window. I am not sure that some of it, that was practically invisible, might have hit the window. It did seem to get worse with flight. My window was not nearly as bad as Jim's.

Lovell Frank's was better than mine. Whenever I could I would give him the cameras to take a picture. He did a lot of the Apollo landmark and S-5 and S-6 pictures while I was controlling the spacecraft.

We have to improve the windows somehow. We've got to have some sort of cover or get some certain type of material. The windows were perfect when we got in the cockpit. The problem they had on GT-5, where they had fog and humidity because of the difference in temperature when the White

Room was dismantled, was not there this time.

Intensity control was good, no problem. We had two white lights in the center cockpit, this was our request a long time ago, and after using it I think we made a mistake. We never did use the thunderstorm light that we stuck in place of the red light. Right now Frank and I think we could have used the red light again because we both did use red lights a lot more than we thought we were going to, for night work. It gets your eyes accustomed to the night, and you can see the airglow and stars a lot better. If you have bright lights on in the cockpit, at night, with glare off the window and your eyes adjusted to the white lights, you could never see out. It's just black.

Onboard data: checklist cards preparation, excellent. I think the people who made them up, Chuck Stough, has to take a personal bow because I think that he did an outstanding job of making up all the onboard data books and cards. They are very, very good. What we did was, tear off the lift-off cards prior to reentry and just had the reentry section, so we wouldn't get mixed up. There are several minor things which we could change to make it a little bit more compatible, like getting one card with all the data on it so we didn't have to flip the cards back and forth when MCC gave it to us. As a matter of fact that is exactly what I ended up doing,

I took the core card, and after I read the various cores for the reentry parameters, I got the nominal IVI's, also the bank angle updates and things of this nature, all on one card. Then I went back to the other section and transposed them in there.

Borman One of the most important things about the checklist on this flight was the fact that we had them about a month before the flight. We used them in training, and the people responsible for that did a great job, Chuck Stough and Ted Guillory.

Lovell That is important. On GT-4, because of the newness of the system, we were still rearranging cards and books just prior to the flight. Learning from that flight, on GT-7 we really gained a lot by having the cards and books early in the game so we could train with them.

Checklist cards usefulness was outstanding.

Borman The maps and overlays were fine. We carried the larger orbital display map. I'm not really sure we needed it. It was a little cumbersome in the cockpit. It was all right, but general areas would have been just as readily available on a small map. When we were doing the Apollo landmarks, particularly those with coastal features, I thought Apollo landmark maps were entirely adequate. I did not see any reason for photographs. If you really want photographs, the

best way to do it would be to fly over them with an airplane and then change the scale to whatever you wanted it.

Lovell The photographs were important, but I don't think you have to spend valuable fuel and time to get them. An airplane can do the same job getting photographs that we need for Apollo landmarks.

Borman That's right. No question about that.

Lovell I found it difficult to move the map overlay.

Borman It got better as the flight went on.

Lovell Yes, because we wore it in. The overlay we have, with periods, orbits, and the map underneath, I think that can be improved. We needed a very simple device with two rollers on the end, or some system a little bit more elaborate, but a lot easier to handle.

Borman I don't know, it worked all right toward the end, Jim. If you get it too elaborate, or too easy to roll, then it is going to change on you.

Lovell It has to have a system where it can't change.

Borman It was valuable. You knew where you were all the time.

Lovell We used it more than we used the star charts. Mainly, we used the star charts for the no platform burns, for retrofire position, and for SEF and BEF positions.

Borman By and large the maps and overlays were well prepared. They were available early to us. We knew how to use them and it

was a very, very fine job by FCSD people responsible for them.

Borman Data books: We were using a system that was started in GT-4, furthered in GT-5 and I think it is working out very well. If there is any derogatory remarks on it at all, it is the required amount of logging you have to do. It is really a double entry system. But, hopefully this will cut down the postflight activities and give people a better idea of what they are looking for. I would not suggest even for a moment that we change it. We did delete some of the redundancy to endeavor to save voice tape. We tried to log everything in the book, but many of the things we did not put on voice tape that were already in the book because we wanted to save the tape. We only had 20 tapes for 14 days. Everything that was done is in the books. Most of the critical things that were time significant are on the tape.

Borman Star charts, Polar and Mercator. We used the Mercator almost exclusively.

Lovell I'm not saying the Polar was not any good, but the Mercator was very adequate and we knew how to use it. I enjoy that particular type of chart a little bit better.

Borman It was preference more than anything else. We did check the Polar out during flight and it was apparently accurate. I didn't see any reason to change those star charts either,

did you?

Lovell No, I think we have enough stars on there. I think they're adequate.

Borman Stowage at launch was a little gruesome. When we got in we found all the stuff stuffed on the floor over our feet. Once we got into orbit and started going through our pre-arranged procedure there was absolutely no problem. We used the food bags to put the refuge from each meal in. We usually stored three meals in the front until we were ready to dispose of them, and then we would put them behind the seat. We filled the debris guard areas we had behind the seats in about eight days. After that we stowed the used ones in the bags we had. For reentry, we placed them over the seats as we had done before. It worked fine.

Lovell When we first started training for the flight, there always seemed to be a de-emphasis on exactly how much we were going to stow. For instance, the size of the food bags was a lot smaller than it turned out. The size of the tissue we used was a lot smaller. I think that we ought to look at it realistically early and make sure that we get the right sizes. We were led down the path there on that first stowage review in St. Louis.

Borman Yes. We caught up with it on the third one though. We doubled the size of everything.

Lovell That is right.

Borman We took an actual meal and ate it and got the refuse.

Lovell It was very fortunate that we did this. It caused us to look for new places to stow things.

Borman As it was it worked out real fine. The cockpit was cleaner when we reeentered than when we left. Another item that was very helpful from the cockpit cleanliness standpoint were these by-pass hoses with the screens on them. They acted as vacumn cleaners on the whole flight. All the garbage and refuse would get collected on them. We could clean them off and put them in the bag and it worked great.

Lovell We never had any large amounts of dandruff or anything floating around.

Borman The harness we took off. All you can say about the harness is it is a necessary evil. Once you get it off, it is tough to stow. Jim, you sat on yours, didn't you?

Lovell I stowed mine between the seat and the back of the ejection seat because it was a dead space for me.

Borman I stowed mine on the outboard side of the seat. We never took the life vests off the harness.

Borman Waste disposal and stowage. We used the aft food boxes for the defecation gloves and the urine sample bags. Jim filled up his first and then I started filling up mine. We ended up putting one day of food and some other refuse in the

left-hand food box in addition to the defecation gloves and the urine sample bags. One thing we might note is the horrible odor every time we opened those boxes to put something away.

Lovell It was a necessary evil, Frank.

Borman We were a little concerned when we opened the vents on the boxes for the reentry that the smell might be with us for a couple of hours, because we had to open them early before we put our suits on. But evidently the vent is just fine. It is large enough that it equalized the pressure, but it is not large enough that it lets the odors escape into the cockpit.

8.9 Biomedical

Borman Oral temperature measurements and thermometer, no problem. Although, it seems strange to me that we have to have a TM temperature. That thing got in the way.

Lovell Yes, the tube got in the way and floated around, and you almost poked your eye a couple of times with the thing. It is a thin probe. It is very awkward because there are two of them. One is in the lightweight headset, and if you do not have the suit on, you have to stick it down through here. If you have the helmet on, it is supposed to be sticking out here, and it gets in the way. If they want inflight temperature, we should take along a regular

thermometer. We had a lot of glass in the cockpit. I do not see why we cannot carry some sort of a plastic thermometer. It seems ridiculous to me to have to TM a temperature.

Borman I must admit I did not even know I had a blood pressure cuff on except when I filled it up. It did not cause any skin problems or anything. It is probably as good a way as we can go.

Lovell It seemed like I pumped up my cuff a lot more inflight than I had to on the ground for the same measurement. Sometimes we would not get the comment that, your "cuff is full" from the ground until after your arm was quite puffed up. Sometimes your arm really got to be sore. I do not know what you can do about it.

Borman We used the M-3 equipment not only for the medical or the crew status passes, but we used it regularly three times a day. It is a very valuable piece of equipment. It came in very handy and it certainly was useful for this reason. I guess there is some reason for it for medical data. I did not understand why we could not stow it the last day. We had already checked and they said, "All right, go ahead and stow it, you do not need it." Later they said, "You have to unstow it. We want to get one more pass on you the last morning of the flight." After 14 days of flight I did not understand why we needed it, but we did it. Jim left it out,

actually. You left it right over the circuit breaker panel, didn't you? Did it come out during reentry?

Lovell No. There was no problem.

Borman There is no water problem.

Lovell There might have been a little air in it because we got air in the food all the time. I do not know how it got in because the food packages were evacuated. We would put the gun in and pump it up with water, and yet there was air in the food every time you opened it up. There was probably some air in the water, but it did not bother us too much.

Borman No. I thought it was a minimum amount, too. The water tasted good. It was cool. The gun, as we have already commented, was very adequate. I think it is inconceivable that we continue to have to log drinks the way we did. I think if people want to know how much water you drink, you can read them off the counter on the gun, and that is it. We went crazy logging these things by numbers and counter numbers and everything else. It is operationally unacceptable.

Lovell For flights that are not primarily medical all they have to have is a counter reading once or twice a day for the systems people. They could just divide it by the number of crew and come out very close to what the actual consumption per man is.

Borman The food, I thought, was by and large very good. One

suggestion on the food is that they try to reconfigure the meals so that Meal A is more like you would think of as a breakfast, with maybe some toast, cereal bars, and sausage patties; rather than fish, potato soup, and clam chowder for breakfast. The idea of making our day like a regular Houston day was a very, very valuable one. It would also be rather nice to have the meals correspond to the type of meal you would eat on the Earth. We ought to have a breakfast that is breakfast; and so on with lunch and dinner. One breakfast we had shrimp, sauce, peas, and I think potato soup. This is all right, but it would be more desirable to have had something like cereal cubes and sausage patties and things like that, something you are more used to.

Lovell The disinfectant pill crumbles. They would crumble when we got them out. The pieces would float about, and if they got in your eye they burned because it is a chlorine base pill of some sort. It happened to me once early in the flight, and it happened to Frank towards the end of the flight. We had to use the exhaust hoses to vacuum down the spacecraft to get rid of these things so we would not get them in our eyes. I think that we can probably go to something better in the future. There is a lot of room for improvement in food. It was good. It was adequate. We

lasted 14 days. We could have lasted a lot longer on the food. But that does not mean there is not room for improvement.

Borman The concept, as far as packaging and everything goes, is good. What is lacking now is really an adequate quality control for uniformity. If everyone of the food bags had been as good as the good ones, there would have been no problem. Some of them did not have velcro on them, some of them burst, and that sort of thing.

Lovell You could get the soups out of the spout very easily, but trying to get tuna salad and shrimp and sauce out of there was a real job. We should change the size of the spout according to the type of food we have. We noticed at the beginning of the flight that dry solids were especially bad.

Borman Yes. Beef bites and bacon and egg bites are horrible and should be deleted from the menu.

Lovell GT-5 reported that the beef bites were crumbly. Every single package of beef bites that I got out was crumbs. They would float all over the place, and you had to get out your exhaust hose and gather them all up again and throw them away. If we did not have that technique, did not have the screens on the exhaust hoses, they would either go into the ECS system or float around. I could see where GT-5 got an awful lot of crumbs floating around.

Borman Sleep periods. This is one of the areas where we really made a wise decision. We decided that we would sleep simultaneously on the regular Houston schedule. We did slide it back every day to correspond with the precession of the orbit. When we were scheduled for house-keeping and sleep, we would close up the windows. We found that the polaroid filters were not adequate, so, we cut up an aluminized food bag and placed it between the window and the polaroid shield. Then, it was really dark inside, it cut out the heat, and this left us with a real simulated night. As far as we were concerned, it was night time. We would get up the next day, go to work, and it kept us regular. It kept us relatively on a constant type of schedule. I thought it was very, very good.

Lovell We are going to have to go to that for any of the long flights, any of the lunar missions. For any of the long flights we are going to need to use a regular Houston or Cape day and not change the routine.

Borman On Apollo, with three men, you probably will have to stand a watch.

Lovell True. But still, you are going to have to keep from getting too irregular. I thought sleeping in zero-g was very comfortable. I slept like a log that first week.

Borman Yes, I had troubles sleeping. The M-1 was the culprit. It

was a pain in the neck. We decided to leave it on though on the theory that if we turned it off the first thing the experimentor would say was, "Well you turned it off. It was not a valid test." Then some crew in the future would have to fly with the thing. So, we left it on for two weeks and listened to it "clank". As far as I know it didn't do any good. Maybe that's the end of the M-1. Invariably, in a state of semi-consciousness it would rouse me again. I did not like that.

Lovell Sleep configuration was very easy. You just clasp your hands together and hold them there. When you wake up your hands are still clasped together. There are no pressure points. You can have a book up there, go to sleep holding the book, and wake up the next morning and the book is still right there, still at the same page. It was outstanding. If mattress companies ever find out how to make a zero-g mattress they would really have a fortune.

Borman Sleep period mission briefing. It followed the way we were briefed. Very good.

Lovell Flight controllers were very outstanding. Keeping quiet during the sleep period. As a matter of fact, they even called up Wally one time and told him to be quiet. Yes, they told him to be quiet. It was our sleep period.

Borman Everything went fine.

9.0 OPERATIONAL CHECKS

9.1 Apollo Landmark Investigation

Borman — We should first mention the weather because this casts some reflection on the whole idea of Apollo landmarks as a navigational aid. The weather was the big bugaboo in this flight as far as achieving any Apollo landmark photography. I do not know whether it was the particular targets we were trying to get or what. Invariably, there were clouds.

Lovell — As can be seen from the map, anything south of 15 degrees north latitude in Africa is no good for Apollo landmarks because it is invariably cloudy. South of 15 degrees north latitude is invariably too cloudy for Apollo landmarks.

Borman — Right.

Lovell — All of South America is out. As a matter of fact everything south of 15 degrees north latitude all the way across the map is no good. We found out that North Africa and South-west United States and parts of Mexico, as previous crews stated a long time ago, (that includes Saudi Arabia, Pakistan Valley) have predominantly clear weather in the morning, but not in the afternoon.

Borman — The Red Sea area was one of the clear areas all the time. Even the South-west U.S. and Mexico were clobbered most of the time on our flight.

Lovell Right. Weather is the big bugaboo on Apollo landmarks, or using earth landmarks for Apollo.

Borman The acquisition data was good. The pointing data was good on all the experiment updates, except for one. They missed the time on an S-5. We caught it, and did it ourselves because we knew where the area was supposed to be. The pointing data given was great throughout the flight. The updating was fine. We had no problems at all. Pointing instructions were good.

Borman Concerning taking acquisition photographs for the Apollo landmarks, it was pretty darn hard to determine anything when we pitched 30 degrees down to pick up the landmarks. We could not pick out the air fields or anything. We would point the camera and take a picture, but we did not know what we were taking pictures of. We could not see it with the naked eye. I am thinking of the airfield in Brazil. We took this acquisition picture without any idea of what we were taking a picture of until we finally got to the nadir. Then, we looked down and could see the runway. I think it was in Belam Province in Brazil. The weather was a very definite factor in photographing the Apollo landmarks, and of course, it would be a very definite factor in using the Apollo landmarks.

Lovell We had to use the sun angle that we had at the time we got

over the target.

Borman Evidently the people who called them up were taking this into consideration, because the sun angles for all the Apollo landmark attempts were good as far as photography goes. Sightings were tough on a lot of them, primarily because of clouds.

Lovell Apollo landmarks of interior Africa, which they gave us several times, (like islands, lakes, Leopoldville in the middle of the Congo), were very difficult because there is nothing down there but jungle and little streams and things.

Borman By far the best landmarks are interfaces of beaches and water.

Lovell That is right. Sandy beaches with blue water. There is no doubt about that.

Borman There is good contrast, and with a good map you do not need the photographs. I do not understand the value of the photographs, I do not see why they do not engage the Army Map Service to aerial photograph these areas and print the pictures according to the scale they want. It would be a relatively easy job to do and certainly would be much less expensive than taking the fuel to do it on an operational mission.

Borman The designated targets were clouded over more often than not. We did take some alternate targets and pointed out

some prominent features along coastlines in Africa. We have them logged and we will be able to go over them with the Apollo landmark people. Even an area like Dakar, which you would think would be a relatively clear area, we tried three times to photograph and each time it was cloudy.

Lovell Mostly in the afternoon.

Borman The maps and Apollo landmark data package was all right. One of the problems with the maps was it is difficult to orient the map segments on the page, so that several of the targets were anywhere near the middle of the map. You might end up with a map with an Apollo landmark right on the edge of it. It is then difficult to associate the surrounding terrain with it. The big map that we had in the front of the book solved a lot of this problem. We could get the big picture from the big map and then go to the detailed one for the detailed pictures.

Borman Photographs, 350 and 352, the Cairo area, you don't need a photograph of the Nile River running into the Mediterranean. That was one of the most prominent features we had. The Suez Canal, the Red Sea, and the coast of Arabia were loud and clear the whole flight. The junction of the two rivers, the white Nile and the blue Nile, were also very prominent. Again, you did not need a photograph to

determine those.

Lovell The Red Sea and the Gulf of Eden as it goes into the Arabian Sea were very prominent.

Borman Yes.

Lovell The 90 degree bend was very, very prominent.

Borman We have a difference of opinion here, but I thought the maps were entirely adequate. Mountains were, as far as we could tell, adequately portrayed, although, we did not have any landmarks that were in the mountainous area. Most of ours for some reason were in the tropical areas and they were cloudy all the time. The cities that we saw were by and large over the United States.

Lovell We did not really see much in the way of cities. We saw the Australian cities at night, we could see the lights from them.

Borman We saw small towns along the coast of Mexico.

Lovell Also South America. I wonder what the difference in altitude does to visibility of landmarks? I am sure that your visibility is going to really go down. I think that is what happened.

Borman Maybe, although when we were in an orbit of 120 by 178, I could not tell the difference. One difference of course, is we were in the darkness at 178. When we were really looking we were around 120 to 140. I never got the feeling

that I was going up hill or going down hill in the elliptical orbit.

Lovell We saw one good airport. I thought it was Ellington, and it turned out to be Houston International.

Borman We also saw that one in South America very well. It stood out loud and clear, that white runway on the Apollo landmark. When we finally got over it there was a break in the clouds and at the last minute we got a picture of it.

Lovell Airports in general would stand out.

Borman Coastlines are the answer. They are by far the best landmarks you have. I do not think islands are too good for landmarks unless they are relatively large; small islands are tough to pick up.

Lovell And they are usually covered by clouds.

Borman Color contrast between land and water was very good, particularly along sandy beaches. We had onboard some photographs that were taken on GT-5 with the actual scene we were viewing. We were able to compare the color of these photographs. We found it then to be very, very close. One strange phenomena is that greens don't come through. The very green jungles of Brazil and Africa appeared almost a brownish-mustard color. The predominant color is blue, even at night time with a full moon.

Lovell I thought the jungle even looked blue, bluish-brown.

Borman Perhaps, the colors were a little deeper in the photographs than were the landmarks but photographs are very adequate presentation of colors. I think probably any variance in the photographs is due to variance in sun angle.

Lovell We understood the targets well enough, I don't see any problem there at all. We didn't use the maps with gloves on. You can hardly use anything with gloves on.

Borman The best thing you can do with gloves is take them off and stow them as soon as possible.

Lovell The Apollo Landmark Book size was adequate. Any smaller size in maps gets to be too thick or too small, and you really can't read them in detail. I did like the big map of the world broken up in four sections, because that gave us a good approach to the targets. We could use that much better than we could the orbital plotboard.

Borman Probably all you need is that big map cut up in four sections and then a small scale map of the specific area. We don't need the darn photographs.

Lovell It's the thickest thing we had to stow.

Borman Spacecraft control. As far as tracking ground targets, you could always achieve the rates in PULSE mode. Fuel was nominal. PULSE was no difficulty. We tried to take everything at a 90 degree angle. We had no problems with spacecraft control to acquire and take pictures of the Apollo landmarks.

Borman Certainly this factor of weather leads me to believe that the whole idea of navigating Apollo by a landmark needs to be reevaluated. It seems to me that a much more desirable feature would be a series of radar beacons placed throughout the world, similar to the ones that are used by SAC, or some type of electronic gadget not dependent upon clear weather. You cannot choose the weather you want, and in our fourteen day mission, for about eleven days we had lousy weather. The number of primary targets photographed. How many did you photograph?

Lovell We have nine Apollo landmarks logged in the Apollo landmark section:

Sequence 85 - clouds at nadir.

Sequence 137 - no luck, clouds overhead.

Sequence 94 - unable, because of clouds. Took a point of land nearby.

Sequence 58 - Cloudy.

Sequence 70 - Okay.

Sequence 85 - Just weather is the remark.

Sequence 108 - Clouds, resulting in poor picture.

Sequence 130 - Weather.

Sequence 97 - Weather.

Most of the landmarks they gave us, that were down below the 15 degrees north latitude ended up with weather.

Borman The number of primary targets photographed was 1. Evaluation of sequence 350B and 351B, I maintain that the maps are entirely adequate. We evaluated them looking at the Cairo area and the Dead Sea, and I see no reason for the photographs. Jim has a different feeling about that.

9.2 Cabin Lighting Survey

Borman We did not have. We have already talked about the lighting, glare, the dirty windows, and so forth.

I felt that this was a pain in the neck, and I would like to make sure that somebody got some useful data out of that.

We went around the earth in the HORIZON SCAN mode once with the HF transmitter on, and I wonder if there is anything at all going to be learned from it.

Lovell I am beginning to wonder whether the HF system is worth the cost to put it into orbit.

Borman You might be better off with another UHF set.

Lovell That is right. Go to something that is compatible, like single side band.

Borman HF was adequate when UHF was adequate. As far as any over-the-horizon transmission with HF, there was not any.

Lovell It was very, very poor.

Borman The reception on HF during the flight was very poor.

Lovell Right.

10.0 VISUAL SIGHTINGS

10.1 Countdown

Borman We did not have any visual sightings. No wasps, bees, bugs, or anything in the spacecraft.

10.2 Powered flight

Borman I did not look out at lift-off.

Lovell I think we went through clouds, didn't we? We went through an overcast.

FCSD rep It looked like Frank steered it right through a hole in the overcast.

Lovell Could anyone see us after we went through the overcast? Or was that the end of it?

FCSD rep No, the hole was big enough so that you were in sight.

Lovell Could you see staging?

FCSD rep No, you disappeared from sight before staging.

Borman At BECO the spacecraft was enveloped in a yellow flame. BECO and staging are so close that you cannot tell the difference. Engine 2 ignition was very smooth, no noise, no banging. The horizon came into view just like the simulator. Very, very adequate presentation. At SECO I did not notice a thing, just a stop and a cessation of noise. I did not see

any flames, debris or anything. Although you did at Fairing Jettison and Spacecraft Separation.

Lovell — On Fairing Jettison, I saw debris fly, especially during the turnaround.

10.3 Orbital Flight

Borman — As for man-made objects sighted, we took sightings of the booster. We had no difficulty in sighting the booster at turnaround and in station keeping with it. We maintained the flashing light in sight throughout the first orbit, we saw them on the second orbit, and the third orbit during the night phase.

Lovell — But you could not tell distance by the flashing lights.

Borman — No. As a matter of fact, I think it would be impossible to tell distance at night unless you have some sort of illumination.

Lovell — Yes, if the lights are illuminating the vehicle, by spreading it over the vehicle, maybe you could tell. You cannot tell the way they are now. We picked up Spacecraft 6 on the final rendezvous phase, I guess at about five miles. Is that right?

Borman — Right. Again, this is entirely dependent upon where the sun is. Spacecraft 6 was able to see us a long time before we could see them, because we were in a position where the sun

was reflecting off our adapter, and they were in a position so that the sun was not reflecting off their adapter. It is a strange phenomenon, but it is entirely dependent upon the sun. Once we acquired Spacecraft 6, it certainly was no problem of maintaining a visual on it. It was no different than it is on the ground in the daytime.

Lovell I agree.

Borman We sighted two satellites. We saw the Minuteman reentry at exactly the right time and exactly the right place. It looked like a meteorite.

Lovell Very brilliant. It broke up toward the end.

Borman Very brilliant, it broke up toward the end, and there were several different pieces flying around. I was surprised at the speed at which it went in. I was also surprised at the control authority required to track it. We did get on it though before it broke up and went out. I hope they got good data on it.

Lovell We saw, what we think, were two satellites moving.

Borman Yes, we took IR readings on one of them. It was a definite satellite in a polar orbit. We took photographs of two satellites in the polar orbits. One of them was below us, crossing from left to right, and the other one was above us, crossing left to right. We picked them up first in the handle of the

Big Dipper. It was definitely a satellite, and we tracked it on the IR and we used the recorder. It will be interesting to see if they got any data of it. We were never close enough to see any satellites and to pick them out as far as definite features.

Lovell They were just points of light.

Borman Just light points. There certainly was not any problem viewing the ground. As we have already mentioned over the radio, we were able to see the Astrodome. The horizontal markings, or the east west markings, on the S-8/D-13 pattern stood out loud and clear when we acquired it. It is very akin to flying an airplane at high altitude. Roads stood out well, rivers stood out well, and beaches particularly well. Towns were a little more difficult to determine, but when you had them you could easily see the layout and apparent size. Also, the atmosphere made a vast difference. If there was any sort of haze or cloud, it definitely cut down your vision. When we finally got over the Himalayas in daylight, it was easy to see why it was so clear.

lovell Haze does affect sightings from space as well as it does from airplanes. It is very similar. If the area is pretty hazy, it is going to decrease the contrast of the ground, and makes viewing ground objects very difficult. Where you have

excellent viewing is where the air is clear. It is the same way with airplanes. But, I think you have a better chance to look below than you do in an airplane. There is a better chance of seeing something, but you still have the haze problem.

Borman When we first got up and had a full Moon, we did not see many more stars than you see on an ordinary flight at thirty or forty thousand feet. However, during the latter part of the flight with a quarter Moon, we found that there were more stars visible. We have a drawing here of the number of stars we could see in the Pleiades, which has been recorded.

Lovell The big thing to remember here is the fact that the Moon has a big effect on the number of stars you see and which ones you can use for celestial navigation.

Borman Right.

Lovell If the Moon is full, it is the predominant feature in the sky, and any stars near the Moon at the time are washed out; and they are very hard to use for sextant sightings.

Borman Right. Same way with the Milky Way. It is not very apparent when the Moon is full.

Lovell In reverse though, when the Moon is full the Earth is a very good reference.

Borman That's right. It's a blue reference with white clouds, very

visible. Cloud coverage, there was a lot of it. The first three days were relatively clear and from then on there were lots and lots of clouds. About the only area that was consistently clear was the Sahara and the Red Sea area. The States were cloudy, as was Mexico, South America, Southern Africa, and a great deal of the ocean was cloudy.

Lovell The entire area of the Pacific Ocean was cloudy.

Borman Again we can reiterate that it would be pretty tough to count on being able to observe specific landmarks at any given time. The horizons were interesting. In the daytime I never noticed much of a difference between the horizon. We've drawn pictures of them with little notes beside them that have been carried back, and which will be published. We noticed the difference in the horizon and the air glow layer between a full Moon and a no Moon. When we had a full Moon there was a definite Earth layer, then almost a normal blackness, and then a definite band of air glow. When we had no Moon or a quarter Moon, the area between the Earth and the outer air glow was more milky.

Lovell That's right. For sextant sightings the best thing to use, during a full Moon, was the bottom part of the air glow or the Earth's horizon, which was probably the upper air hori-

zon. And with no Moon, the best sextant sighting spot to use was the upper air glow, because it was the sharpest of the two. The area between the upper air glow area and the earth's horizon was too milky during a no Moon to get a good sharp contrast (you could see stars through it), but you couldn't find out exactly where the horizon was. So it varied between full Moon and no Moon.

Borman Very drastically too. Also, your ability to pick out the earth, and determine yaw from earth's passage with no Moon, was zilch. With the full Moon it was just as good as it was in the daylight.

Lovell The Moon is very bright up there, very bright.

Borman Both attitude and translation thrusters firing were apparent. The aft firing thrusters were not apparent. But the forward thrusters were apparent at night and so were the translational, up, down, sideways. The attitude thrusters were also apparent with puffs, sort of like subdued flashbulbs appearing out to the side of the window. They were just little flashes of light in the background, and we couldn't determine anything from them.

Lovell We couldn't determine anything.

Borman But you could on Spacecraft 6.

Lovell On Spacecraft 6 the thruster firings looked as though they

went out about forty feet against a dark background. You could see this light haze going out about forty feet. It wasn't a bell shaped pattern, as we thought it was going to be, but it was like a garden hose, straight out. At a distance we could not see the bright flash of ignition in the chamber itself. All we could see was the haze going out. But as we got in closer, we could start picking up the bright flash, mainly because of attitude I suspect, as we were getting closer to see it. It had no effect on our spacecraft at all. They actually fired about twenty feet away with their forward firing thrusters to us, and departed.

Borman They got in back behind us in the adapter and fired their forward firing thrusters and made the curtain jiggle. I don't know how far away they were when they did this. I hope they can tell us, and give you some idea of the effect that these thrusters might have on the EVA Mission. It's just like firing a rocket at night. I guess that's the way we expected it to look. That is exactly what you are doing, firing a rocket at night.

10.4 Reentry

Borman We retrofired in the darkest, most dismal part of the night sky, and we didn't see anything. We didn't see Adapter Separation. We didn't see any of the retros fire. We didn't

see Retro Package jettison. At reentry we didn't have a lighted horizon at 400,000 feet. We didn't have a lighted horizon until we were below 400,000 feet. This was not particularly to my liking; although we picked it up about 330,000 feet. After then, it was all right.

Lovell We saw ionization.

Borman Yes, we did.

Lovell The whole window started to be just a glow outside. Then it got into the rings of this ionization layer. It started out to be just glowing.

Borman When we went subsonic it looked like there was a bunch of steam and flame that engulfed the nose section. I think this may have been when the spacecraft finally went subsonic, right before drogue deploy. You could see the spacecraft oscillations, and you could reference them with the drogue, which was relatively steady. You could also reference them with the sky. You didn't have any stars or anything, but you could just pick out the motions across the sky. At times it was pretty violent. It would be interesting to see the magnitude of the oscillations and the rates.

Borman The drogue deploy was very evident. We saw the drogue chute. We saw the R and R Can come off, and then I saw it following us down in the parachute, off to one side. Main chute

deploy was very nice.

Lovell Main chute deploy, very enjoyable to watch.

Borman During landing and recovery we had the S2F in sight before we ever hit the water.

11.0 EXPERIMENTS

11.1 Celestial, Space, and Terrestrial Radiometry (D-4/7)

Borman I think we have more valuable data on D-4/D-7 than all the others put together.

Lovell Right.

Borman Updating techniques and communications procedures were excellent. Everything called up on D-4/D-7 was right on the money, including the time and pointing locations for the reentry vehicle.

Lovell They did an outstanding job of giving us the right information onboard.

Borman We were perfectly trained in equipment setup and usage. Jim didn't have a question about it. I think there was no problem at all.

Lovell We got everything going. I hope that we got some good data.

Borman Cooled Spectrometer checks were nominal.

I don't know what else to say, as far as we know, everything was perfect, it's all logged, they have the records, they have the TM.

Lovell We saw the needle go down when we jettisoned the fairing cover after the fifteen second timer delay, after we did our separation maneuver. I saw the cover go by when we jettisoned.

Borman Did you?

Lovell It is right above the right hand window.

Borman I did not see that. The booster measurements were no problem at all. It was just like the way the simulator worked. It was just fine. Very good. We had no problems making the reticle measurements. They were very close to zero on both the IR and the spectrometer. Power-down procedures. Did you have any?

Lovell No. Booster background measurements were no problem at all.

Borman Okay. The Milky Way measurement without the cooled sensor was performed exactly on time. We had no problems with the equipment. No problems with any of this.

The Void was very easy to pick out and to take the readings. The Zodiacal light test was deleted in real time. We substituted Sirius for the Zodiacal light.

Borman The star measurements were done with no problem. Night land measurements are noted on the tape and in the log book. We did have some problem with these because the night land was covered with clouds. So we were trying to skew the spacecraft along and avoid clouds. I'm afraid that we may not have always missed the clouds. The same situation existed with the night water measurements. We had very good luck on the Polaris.

We had good luck on the Polaris and good luck on the booster. We should have had pretty good luck on Gemini 6. We were able to track it. We had good luck on the sled.

Lovell We hope we had good luck on the sled.

Borman They called us up from the ground and said they had a thousand percent on that.

Lovell You could track the Polaris launch in PULSE.

Borman You could track everything in PULSE except the reentry vehicle. The reentry vehicle was pretty fast and you had to go to DIRECT.

Lovell I have to give credit to the personnel, the experimentor, Brentnall.

Borman He hustled and he did his work. He made sure that we knew what we were doing. It was well done.

Lovell This is the first missile that was ever launched from a submarine, their ORI, I guess. To launch at the exact time so that we would be in the exact position, I thought was an amazing piece of coordination among all people involved.

Borman I just hope they got all the data.

Borman We always had the ACQ off when we were transmitting. The only possible problems that we could have had with this experiment was when we lost our tape recorder. We could not put some of the data on tape. We had to always take the data over a receiving station.

Lovell Or use the recorder.

Borman Or use a recorder.

Lovell One problem which we did have and which I was not briefed on was the fact that I inadvertently left the gear on one time and it gave a nine second pulse on the main ammeter system. We could not figure out what this glitch was coming in on the Main Bus.

Borman This was right after we lost the thrusters. We thought there might have been something in the ACME bias power or something in the inverter that was breaking down and putting out a glitch. We called the ground to tell them we found it and they said that it was exactly what the ground had thought it was.

Borman Cloud illumination lightning; we got some good lightning shots for them. Day land measurements, we got. Ascension Calibration was done twice.

Lovell Listen, that was done twice?

Borman Yes.

Lovell Was this the NADIR to 35 degrees West?

Borman Yes.

Lovell Of course we never saw Ascension so I did not...

Borman Yeah, we never saw Ascension but it was the location of the area where we wanted to find.

Lovell I think we did that once, or did we do 19 once?

Borman Yes, it is the same thing. Cumulus clouds. We got some cloud measurements. Star measurements, the only the thing we got there was the lightning. Celestial measurement. We got that. The stars, we did not get the Zodiacal light. We got the stars, the milkyway, the void. 23 Moon measurements. We got the Moon. We got all the missile measurements. I do not think it is necessary for us to record it off our log book.

Lovell We missed the Titan launch.

Borman Yes, we did not get the liftoff because of clouds. But we picked them up when we picked up their contrails.

Lovell Yes.

Borman We also threw in an extra satellite. It will be interesting to see if they got any data out of that. The

Sun measurement was done. That was a real interesting one, because in order to get the Sun, we had to put up the polaroid lights, and wear sun glasses, and then point at it.

Lovell Hot Earth Measurements: we had that big fire in North Africa that was there all the time. That was a target of opportunity. We got Hot Earth Measurements of this fire in North Africa.

Borman The tape recorder was used properly. Voice recorder usage was adequate.

Flight control procedure: the only time we had to do anything at all different was to go to DIRECT to pickup that reentry vehicle. The rest of the time it was a very well organized, well briefed, well trained, and I thought a well-run experiment.

Lovell That is right. I thought it was quite a bit of data and work to do in that experiment.

Borman As a matter of fact, I think the equipment on these represented about 3½ million dollars. So it was a pretty hefty piece of equipment.

11.2 Star Occulation Measurement (D-5)

Borman Now we go from the sublime to the ridiculous. The star occulation measurement D-5. The equipment

never worked and we fooled around with it for hours trying to make it work. I am sure somebody is going to sit downstairs now and ground check it okay, but, it did not work.

Lovell We did everything and we traded it back and forth to make sure that both of us saw the same results.

Borman We had been briefed on this, we used it in the set up at St. Louis where we had seen how it changed. We had had adequate briefings. We had accurate presentations on it.

Lovell Primarily you could not calibrate the equipment, the reticle would not change from red to green.

Borman We made a couple of measurements where we just used the calibration knob at a certain setting and let it alone. But this equipment was inoperative. I thought it was a little strange, too, when they called up and said, "We have just found out that this equipment is sensitive to RF interference." "Turn off all your transmitters and see if this affects it." I think we ought to know before we go charging into the 3rd or 4th day of flight that the equipment is sensitive to RF interference. It seems to me that perhaps there was not a very good Qual. test done on this piece of gear. I have

nothing else to say about the D-5 except the equipment did not work.

Lovell Well, star acquisition and identification, which has nothing to do with the equipment, was outstanding with the chart. Actually, I would like to put in a little pitch here, for the simulator, because the visual part of the simulator was a big help. It gave us a good idea of what we could expect in flight. And the Planetarium's work was very valuable in conjunction with the simulator. I think that we did not waste time with any of our star recognition stuff. They did come in handy. As a matter of fact, if you really get to know that celestial sphere, you can really get around without the earth.

11.3 Simple Navigation D-9

Borman Jim used this test exclusively. He was trained at Ames. But we actually used the sextant down here before the flight many times with the experimenters. We used it in the simulator.

Lovell Let me give some comments on this sextant. There are a lot of comments on the tape. Number one, the D-9 sextant alignment

was fine, the stop watch was an excellent idea. The lighting on the sextant angle reading was too bright. It was a white bright light. Everytime you read the sextant out you lost your dark adaptation because we were looking at this white light. And all it had to be, since the spacecraft is dark anyway if you are looking at stars, is red, or dimmer light to read the angle out.
The reticle was fine during the first part of the flight, and then for some reason it became a double image. I found out that I never used the reticle during the full Moon or even at half Moon I could see the dark lines without having to light up the reticle. One of the big things about the sextant, the mechanical aspects, was the fact that the light was not split 50-50 between the upper prism and the lower telescope. It was a 20-80 split and therefore one image would be bright and the other one dim. This was fine if you went from the start of the horizon where you would have a bright star and a dim horizon. You had a control, but if you went from, say, two stars to measure the angle between two stars to check the alignment of a sextant, (because the angles are already known) one star would be bright and the other star real dim if you got them within a certain angle of each other. But as soon as you got that other dim star, then the bright

star, you could not tell when they were overlapping.

Lovell You had to have two stars of the same magnitude in lock. So, I had practiced and trained in the one with the 50-50 split which I thought was a lot better than this 20-80 which we finally ended up with. And this also is true when you took star to Moon limb shots because they had it arranged that most of the light came from the Moon. Eighty percent of the light passage was from the Moon and they had filters to cut that down. And 20 percent came from the star. Well, the filters were not dark enough for the Moon, and as soon as you got those stars somewhere near the limb they just faded out of view. You could not see it so you had a hard time getting star to Moon limb shots.

Lovell We noticed one big thing in navigation with the sextant. With a full Moon, you are going to have a hard time using the stars under the Moon. It just blanks out the light. It is just too bright, it dims the stars and ruins your dark adaptation. On no Moon nights or quarter Moon nights, most of the stars come out and the navigation is a lot better. We found out also on full Moon nights as we said before, that we'd use the bottom Earth's horizon, which is probably an upper air horizon and had the sharpest line of identification for angles.

Lovell On no Moon nights, the whole air glow layer seemed to be of the same consistancy. And the sharpest part was the upper air glow layer where we could bring stars down to it.

Borman Did you find it difficult at times to get the stars acquired at the angle?

Lovell Right. We found out, due to the window design, that if the stars were not lined vertically with one another, if we were taking star to star shots or star to Moon shots, it was hard to get the sextant lined up. The best way to hold the sextant was the way it was developed originally: just up and down. If you had to move it around here to get a star over here, or horizontal or angle shots, you had to move the spacecraft around to get the window in line, to get all the view. Now we could shoot angles up to about I think 45 degrees, if we had the right window alignment and had bright enough stars. But anything above that and most of the time around 35 to 40 degrees, one of the two, either the upper prism or the lower telescope would get in the way of the rim of the window and get lost to view. Then we couldn't do anything with it.

Borman I remember there were a couple of times when you picked up the wrong star too.

Lovell Yes.

Borman Even though you know the star very well, using the system of estimating the angle in ahead of time, you leave yourself open to picking the wrong stars.

Lovell Yes, one of the big things about the sextant is you have to be sure you can identify the star when you are looking inside the sextant after you get the thing down because you might get the wrong star. That is why you should use stars in sextant navigation that have identifying features in the field of view of the sextant. For instance Capella was a very good one because it has the 3 little stars around it, I guess there were 2 stars, I forget.

Borman Three stars.

Lovell Three stars, but anyway you could tell Capella when you looked through the sextant.But,a star that was all out by itself, even though it was bright,you really could not tell whether that was a star or not until you went out and looked again,and that was sort of difficult.

Borman We did not have any radar but I know darn well,if I was out trying to effect a rendezvous, I would much rather have an operating radar with range and range rate than I would that sextant.

Lovell Well the thing is: there are a lot of factors that affect this thing: window glare, the fact that we had to turn on white light everytime we got a reading, because

we had to read the digital clock to get an exact time of the reading, the reflection from the Moon, all that stuff complicates visual sightings.

Borman How about picking out a proper horizon? You even had trouble doing that, What horizon were we going to use?

Lovell That is right. We don't know what horizon we are going to use.

Borman The horizon is dependent upon the Moon.

Lovell So sextant sightings are going to be very difficult.

Borman And the accuracy of this instrument, as advertised, is phenomenal. But the accuracy to what? If we do not know what horizon we are measuring to. Did you mention the fact that the green filter cuts out everything?

Lovell Well that is right. Yes, the green and blue filters, one of the modes as a matter of fact, was to use the green filter for the horizon. Unfortunately you stick the green filter in there and then look for the horizon and it is gone.

Borman Everything is gone. There is nothing. All you see are the stars up above, you do not see any horizon.

Lovell So the filter idea was useless as far as the sextant goes.

Borman Also the blue filter, you stayed dark adapted and then tried the blue filter in daylight as was requested.

Lovell That was a little scientific experiment which we were asked to do: to see if we could see the blue horizon line, blue air glow in the daytime by keeping dark adapted and using the blue filter.

Borman The results were negative.

Lovell That is right.

Borman Anything else?

Lovell I think we hit everything on the sextant.

Borman We had no equipment malfunctions with the sextant other than the fact that you got double vision.

Lovell And the sextant was not as bulky to operate on the spacecraft as it is on land. It is a pretty bulky piece of equipment, but it is not bad.

11.4 Visual Acuity and Astronaut Visibility and Vision Test (M-9)

Borman Updating techniques and communications procedures: This was an area that was outstanding. It seems redundant to comment about it everytime, but is is true. Equipment set up and usage for the vision test and the M-9 experiment, no problem. We tried this in the simulator and we tried it in flight and it was the same.

Lovell The photometer left a little bit to be desired.

Borman Oh, I think we are talking not just about the tests that

we did every morning. The vision test and the other one.

Borman The M-9 vision test also caused no problem. As a matter of fact we did a little interesting experiment of our own. We used the brace, the head brace and the bite board everytime but once, and then we compared the results, with and without using the head brace or bite boards, the last day. We noted this in the log book. There was no difference in the outcome, so I have begun to wonder if it is necesary. One of the great points of interest, was trying to observe this ground observation at Laredo and we picked it up 3 times, I believe. Acquisition is very difficult, because of the poor terrain features. I never did really see the smoke pots, but we did see the dashes that they had in the block. We had a real good pass at it and we had it acquired excellently and I called off 3 numbers and they are listed in the log book, I think there was a 3-1-3 or a 1-3-1.

Borman I would be interested to know if I was right on any of these because you could see them. I should have been able to see them on that one. 1-3-3, I guess it was we called off. No, 3-1-3 ground observation.

Lovell I had one pass where I saw it and by the time I got to see the squares or the rectangles we were already by it

I guess from what I could see of the thing, I think it was a 2-3-4, that was all I had of it. Basically, we had a picture from GT-5.

Borman We had pictures from GT-5 with us in the cockpit to help us acquire it.

Lovell We could see the red ground with no strain at all. We knew where to look and it was just difficult to find.

Borman You might mention that if they had gone to Yuma, if we had not had to change our launch trajectory, it would have been great. You could pick out the area of the Salton Sea there even from where we were, 3 or 4 hundred miles south, it stood out like a sore thumb.

Lovell I do think though that for the amount of time that you are over the target, the amount of squares they were expecting you to read are too much.

Borman Yes.

Lovell Because you just cannot read that much. You have to acquire it, examine it, and then by that time you are going over it.

Borman The window measurements. We did this; it was called to do it twice, but we did it three times because of the fact that the tape recorder was shot and they had to get real time TM. They did not get good TM on one pass, so we did it again at an opportune time. Unfortunately, the photometer

had not had a chance to warm up for 10 minutes. We were at such a low fuel state then that it was either then or never, so we did it, and I hope they got the data. Now this window measurement business was always a little nebulous to me. I am not sure exactly what they were going to get out of it. But it seems like they are scratching.

Lovell I do not understand the procedures too well. I mean I went through the procedures, followed them exactly, but the photometer left me out to lunch. We tried to get the dope, but I do not see what they are going to get out of it.

Borman We did not have much confidence in that. We did it exactly the way it was practiced. We did practice it in the simulator and it is recorded on voice tape. They came back though and said that TM did not make much sense to them, and I think that is probably right. Voice tape recorder usage, by and large this was another experiment that was well handled, preflight and during flight. We admit that we spent a lot of time on this one and with all the visual acuity data they got ahead of time, and were briefed by the principal experimenters many, many times. I thought that it was handled as well as it could be handled. The site in Australia. We were over Australia

in the daylight--of course the site was not manned because of the few passes we'd have to have. When we were over Australia we didn't have attitude control.

Lovell We might mention one thing. I think with the long flight like we had, if we had the fuel we could have become more skilled in observing the site and probably have gotten better results.

Borman No, we could not have on this one, because after the 3rd day the clouds were the factor the whole time. We had only 3 days to observe that, and everything else was cloudy.

Lovell Okay, it was cloudy, but I suspect that the more passes over the thing, you would get better. But we just did not have the fuel and the weather was bad.

11.5 Synoptic terrain (S-5) and weather (S-6) photography

Borman Synoptic terrain and weather photography. On unusual or significant subject matter. Well, it turns out we did not have any unusual or significant subject matter as far as I know. We took the sequences and we took a lot of it as general photography that was not even called up. Most of the time, it had to be done in drifting flight. We were sorry about this, but there was not the fuel available. The two sequences that were called up (where we were allocated the fuel from the ground) we took them. I hope they were well done. We did get some

pictures over Brazil that have never been gotten before. They were not called up. We took them with the IR color shifted film. We got some pictures of Mexico that were not called up.

Lovell We got a good sequence over North Africa.

Borman We got several good sequences over North Africa.

Lovell But I am sure that they have been used before.

Borman We also took a sequence along the southern coast from New Orleans through Florida using color shifted IR to evaluate the film more than anything else. I hope this comes in handy. We got some shots of the island chains off Florida, to see if they can determine any effect from the hurricane that went through, Betsy.

Lovell As a matter of fact, we got a strip sequence of Cuba too.

Borman All these are targets of opportunity done without attitude control, but they were all targets that were listed before flight. We got the mouth of the Amazon, and I think that is the first time that has been photographed.

Now on the S-6 the weather photography we tried in the last pass to take a successive revolution picture of weather development. We got one good shot over the Andes. We also got some good shots of wave clouds over the Andes during the latter part of the flight. We looked for hurricane or tropical storm Alice in the

Indian Ocean but we never did see it.

Lovell We had an S-6 weather to get that too, but we never did see it.

Borman Air to ground relay of data was good. Voice recorder usage, this is one area where we are not redundant. If we had time to record all the photographs we put in the log book and not on the voice recorder in an effort to save tape. Everything that was done, though, was logged either S-5, S-6, or in general photography. Now, another item that is going to degrade this was the scum on your window.

Lovell Yes. The window is an area which we are going to have to work on.

Borman As it got worse and worse, we shifted so that I was taking the pictures, but I had scum on my window also. The major problem though, here was just lack of fuel. We could not orient the spacecraft to control it the way we wanted to.

11.6 Protron Electron Spectrometer, Tri-Axis Flux-Gate Magnetometer.

Borman We turned the switch on and left it on. I think we should have reams and reams of data, although unfortunately with the tape recorder being shot, I do not know what good it is going to do.

Lovell Well, they got real time telemetry over the station.

Borman Right.

Lovell After seeing GT-6's film of our back area, the straps hanging off our spacecraft looked like they were all intertwining in that boom area. It could probably foul up that boom somewhat in future flights. I mean in a future flight if we still had that same problem it might foul up that boom and tear off that wire. There is a wire that goes out to the end of that thing.

Borman All the experiments we talked about so far were well presented before hand. We knew exactly what we were going to do, and the only reason we weren't able to do it was 1) weather, 2) lack of fuel, and 3) in the case of the D-5, the equipment broke down. I think we got a substantial amount of S-5 and S-6 done. As a matter of fact we got everything done that was called up and we got a lot more done just in general photography.

11.7 Optical Communications (MSC-4)

Borman Optical communications, MSC-4.

Okay, acquisition of the ground target. I have never been better locked in on White Sands in my life than

we were, when we went by there, and saw two blinks of the laser. We had the photograph in front of us marking where the laser was located. We saw Holoman, we saw White Sands but we never did see the beam except the short flashes.

Lovell The magnitude of this laser is a lot less than either Frank or I suspected after our briefings by the experimenters and by actually looking at one at Houston. Obviously this laser at Houston was a lot shorter and can be very much magnified.

Borman Tracking was no problem.

We acquired one over Hawaii; we were able to track it easily. The problem is acquisition of the light.

Lovell The light beam is a lot smaller point than we suspected.

Borman And then again the big bugaboo in this whole experiment was weather. Ascension never got up, we never got ground equipment at Ascension.We never got really good passes at White Sands because we were always about 300 miles South. And Hawaii was available to us on only 2 passes. We acquired the laser on both passes, but were not able to get the handheld laser on the beam on the ground.

Borman Okay, how about the field of view?

Lovell The field of view. Well, let me talk about the equipment. Basically the equipment was fine, except for the telescope:

No. 1) it did not have as much light gathering as was required for this particular equipment. It should have a larger magnification. 2) It had a green filter over it which was supposed to enhance picking up the beam, but all it did was fade out everything. You could not see terrain features and you needed to see terrain features to find out where that beam was located.

Borman Yes, to know where the beam was.

Lovell You could look out and....we had photographs of the area where the beam should be coming from. And we could acquire it by our naked eye by just looking out and seeing it. But, as soon as you went to the telescope of the laser, everything faded out to this green color. Unless you just happened to pick up the beam you're lost and I never was able to pick up the beam thru the telescope. The filter was just too strong. I much prefer to have a clear view. So I could pick out the terrain features. The reticle of course....

Borman Of course, we knew that was shot before we took off.

Lovell We never had a good check of this thing though, at night, and I wish we had had a good night pass over something, but we never did. Because I feel that we probably could have probably picked up the beam a lot better at night.

Protective glasses. To tell you the truth the one time where I was really trying to get onto the Hawaii pass I took them off. I did not use them. And they were in the way, they were cumbersome and together with the telescope, it was just too hard to find.

Borman I used mine, but I did not put them on until right before Jim was supposed to transmit.

Lovell Of course, I had them, I had them on and I transmitted and found out that I could not see anything so I just pulled them off and started transmitting by going back... because as I understand it the operator really does not need them if he is right next to it.

Borman The big word on this one as far as the reticle goes, we should go back to that is for the day time you do not want that green in there. At night time you are going to need a lighted reticle. You cannot see the reticle at night.

Lovell That is right. So you need a better acquisition device on the laser, a better, bigger telescope with more light gathering and clarity of the terrain of the target. I would imagine PULSE mode would be great for tracking the thing.

Borman Yes. I tracked one at Hawaii very easily. No problems. The tracking is a nominal task, there is nothing to it.

But the other business of acquiring is very difficult, particularly with the reticle set.

11.8 Landmark Contrast

Borman We did one of these with the D-5 photometer. We knew it was bad, but we put the calibration needle in the full "up" position, told the experimenter that we were doing this and took the data. Now, they will have to check it to see how it worked.

Lovell We did just one.

Borman We had an equipment malfunction. Right. No sense talking about it anymore. Spacecraft control was no problem. We accomplished all the mechanics of doing it, but unfortunately the equipment we knew was malfunctioning before we did it. Right?

Lovell Right you are.

11.9 Cardiovascular reflex conditions (M-1)

Lovell Got that started at, I think it is 3 hours and 8 minutes, or something like that.

At 2:39, I turned on the M-1 experiment.

Borman Okay. Procedures and operational problems. We had the hose coming all the way across your whole lap to get into your right leg when it should have been put in the left leg.

Lovell That is right.

Borman Periods of operation. The thing was operating continuously for 14 days. And I might point out it is a pain in the neck. Because of the clanking noise. Even though it seemed you would get used to it; many times just as we were about to drop off to sleep that thing would clank, and wake you up. The only reason we did not turn it off at sleep

period, was that we did not want to have the people say, "Well, you did not run it the whole time so the experiment was not valid." We left it on and put up with it in the hope that we could get rid of it once and for all.

Lovell Obviously, it did not work.

Borman So far as we know it did not make any difference. And it did not seem to make any difference inflight or post flight.

Lovell It was a waste of time.

11.10 In-flight exerciser (M-3)

Borman It is a valuable piece of equipment. We used it not only for the crew status passes, we exercised with it 3 times a day and I thought it was very worthwhile. It is a simple piece of gear but it is a good device. Right?

Lovell Although, I imagine we can improve on exercise equipment in the future spacecraft.

Borman Perhaps, the biggest deterioration that we noted in the muscles was in our legs, and that exerciser was——I do not know how you can improve on that much.

11.11 In-flight phonocardiogram (M-4) and In-flight sleep analysis (M-8)

Borman Well, the equipment problems with M-8 were that the thing is operationally incongruous. You cannot have those

wires on your head and stringing down the back of your neck, and not expect to catch them on something in a small spacecraft. Now, we found that we couldn't keep the helmet on. I kept it on for two days, but my head became extremely hot, and I was uncomfortable. So when I took it off I ripped all four of the leads off. And I think that the whole thing is extraneous anyway. I felt after 14 days I was perfectly capable to judge my own condition, and my own awareness, and my own degree of alertness I did not need that bunch of wires hanging on my head to tell me or to tell somebody on the ground how awake or how asleep I was.

Lovell Inflight phonocardiogram, I have no comments because it was stuck on me at prelaunch, and it stayed on me during the entire flight.

Borman Well, did it bother you? Did you get any sensor problems?

Lovell No.

11.12 Bioassay body fluids (M-5) and calcium balance study (M-7)

Borman Urine samplings bags, well, actually the bags were pretty good. We had one break around the head. Marking was all right and stowage was fine. I might point out that the tracer accumulator we changed with no problem. The mixing bag was all right, but they left out the most important thing here, the condom device that we used to

urinate into is unsatisfactory. We ended up with urine all over ourselves everytime we tried to use it. It was sort of happenstance. If you lucked out, you didn't get a leak. But based on the experience that we had up there, I would think that the way to go is a simple overboard device where you vent right to the atmosphere, and urinate into a tube. Essentially the same thing you do in C-47.

Borman We carried the flow meter along and the Delta P across the flow meter and the filter can be incorporated with it. I am sure this is enough to allow you just to urinate right into a relief tube right overboard. I do not see any reason to go through this stage where you have urine all over yourself 4 or 5 times a day. A very unacceptable device. Do you agree?

Lovell Right. I think we can improve on the urine dump system tremendously.

Borman I think they ought to start looking into just a dump right overboard. You do not use a rubber condom or anything.

Lovell Because that things puts back pressure which is really sort of dangerous I think, and besides that, it is uncomfortable. And when you have back pressure...

Borman Yeah. When you have a big enough receiver and you urinate

a stream into a vacuum, it is going to go right on overboard. I do not understand why...okay. The defecation bags were fine. And we really used them this time. The defecation bags were really put to use in this flight. I think we used a total of 15 of them.

Lovell Yes.

Borman And they were fine. I have no comments on those. It seems to be the best solution you can have to the situation.

Lovell For this particular type spacecraft.

Borman For this particular type...For the Gemini Spacecraft. I do not know what other approach you could have to them. I thought their marking was easily done. The finger hole I never used that at all. One of the big assets, we might as well put it in here, was the fact that the food that we ate caused well formed bowels, so we did not have any loose stools or any of that problem. I never had any occasion to use that finger device in there at all. Any other comments?

Lovell No.

Borman The water intake, the water counter number. The gun was satisfactory. The recording that goes with it is completely unsatisfactory. I think the only way we should

consider using that gun again is to read down a daily counter number, and let the people use that as a--we ran into a regular nightmare. Recording drinks used and drinks....

Lovell It was too much.

Borman I think our water intake was adequate. And again I do not think this is something we need to be hounded about from the ground. A person seems to have enough problems without being reminded that he is drinking enough water; I do not see any reason at all to have this complicated bookeeping system. The food intake was not a problem. We recorded the food. One thing we might note, the food was packed out of sequence. So when we got it out, we did not end up eating Day 1, meal A, B, C, Meal 2, A, B, C, but we did always eat Meal A first, Meal B the second meal of the day, and Meal C, the third meal of the day. Although, it might be day 1, meal A, day 13, meal B, and day 6, meal C.

Lovell Also, while we are talking about food, we better talk about the stowage of the food. It was right up to the maximum.

Borman That is right.

Lovell And in fact it was a little bit overboard for 14 days.

Rather tightly packed in. We really had to work to get it out.

Borman But again, this is one of those things we were operating right up to the maximum capability of the spacecraft, and I guess we had to expect that, even though we did get it out. So I would not say it was unacceptable.

11.13 Miscellaneous

Borman Celestial and terrestial observations, and significant observations or anomolies affecting other operational or experimental data.

Lovell Well, we got to see Mars just near the sun by looking at it just at sunset.

Borman Mercury you mean. Mercury. We saw Mercury. And we made some other observations here for the scientists.

Lovell Zodiacal light came in loud and clear after we found out how to look for it.

Borman Right.

Lovell We could not see the Gegenshein though, we knew exactly where to look.

Borman Okay. We also made several night passes counting meteors. One at 215 hours plus 23 minutes, 25 seconds, I made one night pass counting meteors for the entire 30 some minutes. And I saw 1 meteor under Taurus and Pleiades and it was below us, and it was short and white. The

next night pass, ending at 217:17 I counted discrete flashes of lightening for the entire pass. I counted 206 discrete occurrances of lightning. This was with the spacecraft level in HORIZON SCAN mode, looking out one window with no yaw control. Now, we also saw individual meteors at different times in flight that are recorded on the tape recorder. But unfortunately we did not see this great shower that was supposed to come out of Gemini.

Lovell I saw two in a period of about 10 minutes out of Gemini. They headed below us, of course.

Borman Alright, the meteors. Another significant observation that we made was a brilliant display of the Aurora. The Southern Aurora over Australia. And we have some pictures here.

Lovell Sketches.

Borman Sketches of what it looked like, and we will cover this in the scientific debriefing.

Lovell And we measured the time it took for stars to occult to the air glow layer, and for Venus to go through.

Borman I think this would be best to discuss when we talk to the scientists.

Lovell I think so.

Borman Do you have anything else that was significant? As far

as operational experimental data?

Lovell No.

Borman We already mentioned the fact about the air glow changing with the Moon. Oh, I tell you one thing that is significant and we looked for it time and time again. This was the complete inability to observe stars in daylight.

Lovell Oh, yes.

Borman I hope we put that one to bed, because we tried and tried and tried. We strained, we squinted, we looked at all angles.

Lovell Looked at all the angles.

Borman Looked at all the angles, and we were never once able to observe a star in daytime. Now you can observe just at sunrise and just at sunset, but never in the daytime.

Lovell When that Sun comes up those stars go.

Borman That is right. And you get a black horizon--I mean a black sky above a blue horizon. I do not know what the reason for this is, but I will vouch for the fact that you can't see it.

Lovell Right.

12.0 PREMISSION PLANNING

12.1 Mission Plan (Trajectory)

Lovell Well, of course, it varies here, this is the last.

Borman It changed. We had one all wired and written up for a 72 degree launch azimuth and this changed with the addition of the GT-6 mission. But I thought the people were very flexible, and adapted rapidly to the change.

Lovell Well, we are talking about the mission plan, and they are talking about the trajectory alone. There is no doubt about it that our mission, as originally set up for our fuel, was adequate. But, when we introduced GT-6 and the rendezvous mission, the amount of experimental work which we had to do also was not reduced at all. This compromised the results of our experimental work by having to use the fuel for the rendezvous. Although, I think the rendezvous was important, or that it was higher priority, I would like to have it put on the record, that the results we gathered from the rest of the flight were not as good as could be expected, because of the fact that we just did not have the fuel.

Borman 110 pounds of gas went down the drain, too.

Lovell Yes.

12.2 Flight Plan

Borman I thought the people did a great job there.

Lovell There is no doubt about it. The only way you can plan a mission of this length of time is real time flight planning. Call up the data you want for the day, it is a regular work day schedule. Call up what you want, and we will put it down and we will work at it; we will run it off that night.

12.3 Spacecraft Changes

Borman I do not know of one major change in the spacecraft that we wanted that we did not get. GPO was very cooperative about everything. Of course, the big thing that we wanted, that we got after a hassel, was the ability to operate suits off. We planned this from the beginning with our first stowage review, and we finally made it by going the route of getting the suits that we could take off. And I think this contributed much to the satisfactory completion of the mission. Don't you? I have got personal notes here that were made during the flight. Every other page it says suits off was the only way to go, "I do not know how I stayed in the suit for six days," and so on. The suit I am sure has done more to increase the bugaboo of physical deterioration in space-flight than any other single item. Far more than zero g.

12.4 Mission Rules

Borman They are routine now. We have no real arguments.

Lovell The only thing I can say about mission rules is the fact that they can be changed by the Flight Director to suit the situation. There is enough flexibility in them that allows the mission rules to meet the problem at hand.

Borman Although, we did not have any problems that required us to change them.

Lovell No, we did not.

12.5 Experiments

Borman The only experiment that I thought was not well presented pre-mission was the laser. That was a sort of half baked preparation for quite a while, and at the last they brought the equipment down to Houston and it came out pretty good.

Lovell When we were first introduced to the equipment back at the stowage review up at St. Louis, we didn't know enough about the experiment to really analyze the equipment, to find out whether it would be adequate or not.

Borman That is right. We should have picked up the reticle lighting on that.

Lovell Because we did not pick up the reticle lighting and we did not pick up the green filter.

Borman No. The green filter looked all right when we used it on the ground. It is just the fact that we were not able to observe from far enough away to pick it up.

Lovell That is right.

Borman The lighting contrast. . . .

Lovell Also, experiments to the M-1 experiment was sort of a last minute glitch.

Borman Yes.

Lovell We had a lot of compromise. Not compromise but a lot of failures.

Borman Putting the M-1 into the ECS system you mean.

Lovell Although, I will have to admit that the whole thing worked out fine. The mechanics of the M-1 experiment did last 14 days and was absolutely no problem as far as operation of spacecraft or the ECS system.

Borman Right.

Lovell It did complicate the pre-mission planning.

Borman Every other experiment I thought was well presented. The experiments division, with Dick Moke helping out did a good job. I was very, very satisfied in other words, with the whole business.

13.0 MISSION CONTROL

Borman Describe and discuss updating on the status of spacecraft and mission.

13.1 GO/NO GO'S

Borman Once a day operation, where we read out certain parameters in the spacecraft, reported them to the ground, and they have a GO or NO GO for the next area.

13.2 PLA and CLA updates

Borman They were extremely easy to handle. They came up in blocks of about 6 or 9. No problem, since we decided to use a rolling reentry in the event of contingency landing.

Lovell We had very little writing to do.

Borman Very little writing. And I might add, based on that reentry, if I had to do it again, that is exactly what I'd want: a rolling reentry, if I did not have a load in that computer. Because I think it is very difficult to look out the window and observe a horizon during a reentry. At least it was during ours; especially during a night reentry.

13.3 Consumables

Borman My goodness, we had 30 per cent O_2 left when we jettisoned the adapter. 30 some per cent FC O_2 and about 40 per cent FC hydrogen. The OAMS were a little different situation. We cut that off at about 2 per cent. I was a little disturbed on the real-time flight planning in the last couple of days when they were sending up for more experiments than they knew we had fuel to do. And telling us to sift them out. This sort of puts the onus of not doing it on the pilot. I guess in the long run it is the best way to do it, but they would call up and say, "well, here is a whole lot of updates that you can do if you have the fuel." Well, they knew darn well, we didn't have the fuel.

Lovell That is right.

Borman In many cases it turned out to be weathered anyway.

Lovell And we had been briefed that there was a rather large error in the quantity readout on the quantity gauge, and fortunately for us it looked like it was in our favor.

Borman We also had the Volkswagon tank which helped out. So we knew exactly where we were then.

Lovell But we should, in future flights, make sure that the spacecraft has enough fuel for adequate BEF alignment, and for at least a couple of revolutions with enough reserve to make

sure that in case something goes wrong with the thruster, they could utilize more fuel to keep that alignment.

Borman Right. Well, as it worked out, we came out all right, anyway. Because we just said we were not going to do anymore if we got to 5 per cent to 6 per cent. Then they came back and said that one time, I said, "Well, we're at 6 per cent," and they said, "we thought you would go ahead and go to 5 per cent." And this is an awful nebulous thinking.

Lovell Besides the gauge is hard to read to that accuracy.

Borman That is right. Okay. We have already discussed, I think, the consumables on the fuel cells and the batteries. We turned off the squib batteries, about the 10th day. The fuel cell consumables were never a problem.

Lovell Main battery voltage was never really high, I thought. I have been led to believe that 22.5 volts was sort of a minimum voltage for a battery. They were up about 23 or 22.8 in the early part of the flight, and they were down to about 22.6, I guess, towards the end of the flight.

13.4 Flight plan changes

Borman If there was a flight plan change, the only one that I know of, that we were not aware of, was the one of updating our perigee in the first burn. We thought we were going to burn it to 102. It came out we burned it to 120 and I'd like to

know whether this was programmed, or whether we just burned too long. Other than that the flight plan went very well.

13.5 Systems

Borman One of the items that I objected to a little bit in the flight, and it was the natural tendency with people on the ground; was the tendency, when we had a little systems malfunction, to explore it to the greatest depths without regard to the rest of the mission. For instance, when we had the failed thrusters and we were very, very low on fuel, they wanted me to put a 3 second direct burst through the thrusters; so they could get TM on what was happening. Well, this is fine, except when you do this, you are introducing the problem of the thrusters sticking, and losing all your fuel there. Or at least you are squirting out 3 seconds of valuable fuel, which is a heck of a big chunk in DIRECT. And if you were to induce ignition or even with three seconds of just venting fuel through the thruster you pick up a great rate, and then you have to stop; so you would use a tremendous amount of fuel this way. I will say when I refused to do it, though, they acceded, so it was all right. Another thing I didn't like, was this idea of blowing the OAMS squib. Remember? "This isn't in the flight plan"--"if you feel like doing it, I want you to blow

the OAMS squib just to see if you can hear it." At this stage of the game we were depending upon the OAMS fuel for realigning the platform. I thought that by then we were in a stage of the mission that we were operational rather than interested in blowing something to see if we could hear it.

Lovell Especially for a night alignment.

Borman Right. And I agree with you a thousand times it would not make any difference, but on the thousand and first time, it might have made a difference if we lost our OAMS, and I could not see any reason to do it; so we did not do it. Another item, that I did not like, came up as far as flight plan changes go. The request that was put in as part of the flight plan, and never was in the flight plan. That was to get a blood pressure over Guaymas after retrofire. As it turns out, we tried to do this, but we could not find the horizon and so we did not do it. I would strongly, as a matter of fact, I would not even consider it. After retrofire, as far as I am concerned, the blood pressures, and all the other non-operational equipment can go by the wayside.

Lovell Right.

Borman Right then the important thing is to get on the ground.

Lovell Yeah, actually the retrofire time, the triple orbits before

retrofire, when you are getting ready for reentry, should be exclusively devoted to that. We should be doing nothing else.

Borman Right.

13.6 Experiments real-time updates

Borman Experiments real-time updates: all we can say is that it was done fairly well.

14.0 TRAINING

14.1 Gemini Mission Simulator

Lovell Since there were three crews that had been through these simulators quite extensively, and only one that required any more knowledge or any more operation of it, we decided to use the simulator at Houston as a systems trainer. Most of our basic training in the early phases of Gemini 7 was done on systems. We used the Houston trainer to gain knowledge of the systems. Towards the end we also used it for launch and reeentry training.

Borman We made no effort to keep it up to stowage configuration.

Lovell We made no effort to keep the Gemini Mission Simulator at Houston in any kind of a GT-7 stowage configuration. We just merely used the flying portions of it to get acquainted with systems and procedures. It was a procedures and systems trainer.

Borman We got a lot of good reentries.

Lovell Well, that's procedures. We got a lot of good reentries, and we got a lot of good lift-offs with the trainer. One thing that helped us out quite a bit on procedures was the visual displays.

Borman For stowage we kept the wooden mock-up in Houston up to our configuration. It came up better than I've ever seen it before. We did several exercises on the Gemini Crew Station Mock-up. We used that as distinct from the simulator for stowage.

Lovell The stowage mock-up was also used for experiments, to copy down updates, to put together equipment, to find out what electrical leads went where, and to practice using equipment inside the spacecraft. That way we didn't have to tie up the valuable Gemini Mission Simulator, that had a lot of electronics attached to it, with training that required only a simulation of space and environment. We acquired a pretty good knowledge of the systems with the simulator.

There's one area of procedures and systems training which can be improved, and that is the use of more correct procedures between ground and simulator. A lot of times we got into the simulator to do a reentry or launch, and we didn't get the parameters which you normally get from Mission Control. There have been five manned launches, with tapes on all of them, where the communications between the ground and the spacecraft are well documented. We ought to incorporate those in training. So you could copy down updates, you could get the 0.8, you could get systems failures and how the ground handles them, and things of this nature. I think we could simulate them a lot better now, especially in Houston.

Borman I think Lynn Taegart was doing that.

Lovell Lynn was attempting to follow that procedure. We requested that they get some tapes from MCC from GT-5's launch, but by the time we left there, they hadn't yet arrived. Launch was very realistic.

Borman I don't think that we flew a simulator with our roll program in it and it really didn't make any difference. I guess what we are saying about the

Houston simulator is that we don't have to keep it right up to the final configuration. It's a basic trainer.

Borman It helps a lot to get in there and get the work done, rather than not be able to get in it because it is being modified to bring it up to the latest configuration. As long as the math flow is proper, and the basic parts are there, you can almost leave it the same for every launch.

Lovell It should be updated as far as basic systems. We had the fuel cell panel put in ours; we wouldn't want batteries, because of a lot of systems training on fuel cells. That is important. We don't have to have every little item like on the Cape simulator for initial simulator training.

Borman I was very pleased with the Cape simulator. We've had very good work out of it, and it was right up to the latest stowage configuration. I believe we were only shot down on the simulator once. It wasn't working perfectly every time we got in it, but at least we got valuable training out of it.

Lovell Right. One area that does need improving is the coordination between the simulators, the Cape and Houston.

Borman You're talking about SIM NETS when we ran with Houston, which was almost a total waste of time, on our part.

Borman That's right.

Lovell We wasted an awful lot of time just waiting around, because there wasn't the coordination between the two.

Borman It was not the coordination, it was just the interface.

Lovell That's what I mean, the interface. They weren't connected properly. We did get a lot of bum dope; it wasn't the lack of training, it was the lack of proper training.

Lovell Station keeping with the booster occurred down here at the Cape only. I thought that was fairly realistic when it was working. I thought it helped some.

Borman I thought it helped a lot.

Lovell Retrofire: procedure-wise was very good. The horizon, visual display, really is a big item. It made all the difference in the world between what we had before with no display and what we have now. As far as training goes, that is a very big item. The Houston Simulator ought to have a visual display as soon as possible. Retrofire reentries were all as programmed.

Borman We had visual at Houston; we just did not have the targets. We had the stars at night.

Lovell We had the stars, but we had the occluding disc, and we did not have the horizon.

Borman Reentry on the Mission Simulator was good, a very close approximation to what we flew in the spacecraft. I think that was very valuable. On GT-4, we had only flown about two or three reentries. We had to go up to St. Louis to fly these.

Lovell GT-3 and GT-4 were both that way. Essentially what we are saying about the Gemini Mission Simulator at Houston is that it is the basic trainer for systems and procedures. The one at the Cape is a fine mock-up for the final flight plan simulator. We go right through

the numbers in the flight plan, and the SIM-NETS with the entire network.

14.2 DCPS (Launch abort simulator)

Borman We used it and it was very effective. It never worked closed loop as well as it was supposed to.

We did not have any visual with it, but nevertheless the runs that we got there I thought were invaluable; we certainly could not do without them. The noise and the sensations seemed as close as you could get to them without running on centrifuge. It was a good program, the tapes were good.

Lovell I think it is a very necessary simulator. It was not working completely like we wanted it to work, but it was just being put into operation when we were at Houston. We did not have much of an opportunity to use it.

14.3 MAC Engineering Simulator

Borman We ran a whole week at MAC, two days on reentries and three days on station keeping, and that was a very worthwhile week. It was concentrated effort, and the station keeping simulation was as close to what we saw

as you could possibly get. It was just fantastic. It was really well done, and the reentries were also. We got a real good feel for the reentries. We had the people from FOD and the people from FCSD up there at the time. We understood not only the procedures for flying the reentries, but the why's, the how's, the limitations of the systems.

Lovell Well, that's where we dug out the procedures actually for the reentry technique.

Borman That's right. That's where we developed the procedure of following the roll needle up to 3 G's. That was probably as good a week in training as we had the whole time.

14.4 Translation and Docking Trainer

Lovell In the little work that I did, it is representative of the actual case, if not more sensitive.

Borman It's more sensitive. It is a more simple task to dock in space that it is in the Translation and Docking Trainer.

Lovell As long as it is more complicated there is no problem.

Borman I was really surprised at that.

14.5 Planetarium

Lovell The Planetarium is one which I have to admit I degraded for the last trip. I said I didn't want to go and we weren't going to go. Then we decided we'd better go, and I think right now it was well worth it. The last trip to the Planetarium was the best one.

Borman We got more dope on the actual orbit. We had settled on our flight path, and they displayed it, and it was amazingly accurate.

Lovell We worked out our initial burn at the Planetarium, the stars we were going to burn on for our perigee adjust burn. I took a chart along that I made up at the Planetarium to use for the zero, seven, and fourteen days in the celestial sphere. It worked out fine. When you go there, that's what you have to do. You have to take the azimuth that you are going to launch on, take all the charts that you are going to have; and run through that type of mission. To go there and just learn all the stars might be okay for basic training like we did several

years ago. After you get assigned to a specific mission, you better start learning the stars you need to use for certain burns and things of this nature. That's a good place to do it. I thought perhaps, since we had the visual display, that we could eliminate the Planetarium because the visual display had more real feel for it, and it does. However, the visual displays in the simulators don't carry the magnitude of the stars that you can actually see.

Borman And they are not flexible enough.

Lovell That's right. They are not flexible.

Borman You can't change them.

Lovell So the Planetarium was helpful.

Borman Spacecraft orientation. As Jim said, we studied the burns and made the first two burns on the stars. The Planetarium was very helpful for this. Remember, you were all set to find Corvus and then Spica and we had it all lined up before we ever launched.

14.6 Systems Briefings

Borman We had one hundred and twenty - six hours and thirty minutes of systems briefings and

it's all well documented and scheduled. Another thing that was very helpful to us was Mike Brzezinski, the way he scheduled all the systems briefings and all the training. We didn't fool around with any of it. It was set up well, and went like clockwork. I think this was one of the real fine points of our training. Mike came down to the Cape a week early and the whole schedule was set up a week before we got here, and with very little change after that. He did an outstanding job, and as far as I am concerned, that's the only way to run it.

Lovell — That's right. There's no sense running around doing it yourself when we have a nice, well run organization that can do this work for us.

Borman — As far as any figures or numbers on the time spent in the different phases of training, they are all available. If anybody wants them we have the final report, and we have a weekly report.

Borman — It was very helpful to us to just have to deal with one person, rather than dealing with the Planetarium people, the people at MAC, the people at the Cape. The only thing we did at all was contact Mike. We

never contacted anyone else. We didn't go direct to anybody.

Borman — We might mention that the systems briefings were really of two types. We had preliminary systems briefings by our FCSD people at Houston. At McDonnell, during the SIMS flights and altitude chamber tests we filled in the dead time with systems briefings from the people at McDonnell. This was a good way to go also. For instance, while one crew was flying the MAC Rendezvous Simulator practicing station keeping, the other crew was getting systems briefing. So, we didn't have any dead time. It worked out well.

Borman — The station-keeping, on the booster was more difficult than it was on GT-6, primarily because the booster was venting, and tumbling and translating. Also because of the fact that we really didn't have a lot of time. We were having to use fuel in order to get set up before night, for the separation burn. However, once we got it squared away, there was no difficulty at all staying with the booster at a distance, I'd estimate from about sixty to one hundred and fifty feet. During

the booster station keeping we did observe the ablative skirt on the engine. At one time it appeared that there were two points right at the edge of the skirt that might have been rolled in. It looked like maybe there were two approximately twelve inch sections that might have been rolled in. It may have been shadows cast off the booster. By and large, I would say that the engine looked very well.

Lovell To me the engine looked brand new. It had a gold cast to it. It looked perfectly good to me.

Borman I did not notice any venting out of the roll nozzle, which is unusual. We thought the venting came out of the relief for the PSV valve on the side of the booster. We just discussed this with the Martin people. They were a little surprised to hear this. The venting we saw came out ninety degrees to the longitudinal axis of the booster.

Lovell It looked like it came out right at the edge of the tank.

Borman And this is the Pressure Sequencing Valve drain. And the next one is, "If so, what was its condition?" It looked great. "Did you get pictures?" Yes,

we got pictures with a 16 mm. We did not get pictures with the Hassleblad because we could not unstow the Hassleblad at this time.

14.7 Flight Experiments

Borman Simulations: The one we used most frequently was the GMS for the D-4/D-7 tracking.

Lovell We also used it for the sextant.

Borman Although it wasn't a good utilization, we used it for the D-5.

Lovell Just for procedures. Most of our experiment simulation was done in the mock-up. The wooden mock-up.

Borman Translation and Docking Trainer. We used the Translation and Docking Trainer for some tracking training with the laser. It was not all I had hoped it would be. Nevertheless it did give us training and convinced us it would be no problem in tracking with the laser. This was borne out by the flight that the main problem would be acquiring it. We picked up the fact in the docking trainer that the reticle is not visible

at night. The Translation and Docking Trainer was helpful in station keeping. We didn't really do any training at McDonnell for the experiments.

Lovell — We did mostly the station keeping and the reentry at McDonnell.

Borman — And you went to Ames.

Lovell — Just for the sextant. The sextant briefing at Ames I thought could have been done at Houston. I got more information out of Bob Silva on the roof of the Cape here, than I did really out of Ames. The two simulators I used out there really didn't help me out at all. I think the simulator and a star field in the Gemini simulator plus work outside on the roof would be more valuable than Ames, which I passed on to Wally and Tom.

Borman — We had many briefings... Total time spent on experiments is two hundred hours and thirty minutes. A great deal of that time was briefing. I felt, that by the time we took off, we knew not only the procedures for every experiment, we knew the hows, the whys, and the wherefores. I thought we were

adequately trained on every experiment. If I could comment on the one experiment that I thought was handled in a sort of, I won't say haphazard, but at least a rather free style, was the laser. We didn't get real proper training on that. I didn't get to look at the laser until later in the game. The ground equipment at Ascension never did come up, and I think that if we are really going to make this laser work, we are going to have to put more emphasis on the people who are running it. It seems to me that here we need some special procedure for training experiments. It seems to me that we went to some places where Mike was stuck with the position of trying to scrounge people and equipment or the individual experimenters were stuck with it. It seems like maybe Lilly should have been able to work with some section in our organization to get the training that we wanted and get it set up. The way it is now, for training on experiments, you almost have to depend on individual experimenters and a lot of the time they don't understand at all the problems of operating a spacecraft. Did you have that feeling ever, Mike?

FCSD Rep Just with the MSC-4. We did have a problem getting

the equipment. All the other equipment seemed to come in well.

Borman Yes, but we always depend upon the experimenters for the training. You know, like on the sextant. Maybe this is the way you have to continue to go.

FCSD Rep This is the way the program is set up, for the experimenters to actually do the briefing.

Borman Yeah, and then the hardware training. That is the way it did work. That's probably the best way. The S-8/D-13, we went to the trainer. I guess what we are really saying is that we should emphasize to the experimenter that they have a responsibility for providing training and for providing training hardware.

Lovell That is the big thing. The experimenters, or the experiments group, has to provide the training to get adequate results from their experiment. Otherwise they are not going to get adequate results.

Borman That is right.

Lovell And the training equipment and the training periods have to come early enough in the program so that we work out any problems that evolve. For instance, a classic example was the laser when we ran into the reticle problem. We did not find out until too late in the game

to change anything. We could not put a lighted reticle on the laser.

Borman In all fairness, we ought to point out about the laser too, that it was severely handicapped when we changed the launch azimuth. Because initially they had not planned to work anywhere except at White Sands. Then with the change in launch azimuth, White Sands went down the tube pretty well, then they had to scrounge around and try to get to Hawaii and Ascension.

The experiment equipment, by and large, I thought was readily available on this flight. Thanks mainly to Lou Allen and the pressure he put on the people. Training equipment was pretty well available, early in the game.

14.8 Spacecraft systems tests

Borman We covered a lot fewer of the spacecraft systems tests than previous spacecraft had, based on our experience on Spacecraft 4. Let me see exactly what it was. Spacecraft tests, 169 hours and thirty minutes for the Prime Crew, and 193 hours and 30 minutes for the Backup Crew. I do not think there is any reason to cover things

like Systems Assurance and so on in St. Louis. It is a waste of time. At St. Louis you should plan on covering the SIM flights, the Altitude Chamber and the Horizontal SEDR. And, down at the Cape, I thought even though we cut out six days of testing and we did not have a Wet Mock, I saw absolutely no impediment at all to our launch training. I do not think that any of it is necessary. I do not think we cut out one necessary thing.

Lovell I think that you could use your time more wisely in simulator training, in recovery training, and in training you are really going to use than in study of some of the systems assurance tests where you spend hours in the spacecraft just throwing switches. You reach a point there where you are not learning any more.

Borman I think you should follow, at St. Louis, the SIM flight, the Altitude Chamber, and the Horizontal SEDR. And down here at the Cape, we want to do the SIM flight, the Joint Combined Systems test, the EIIV test, and finally of course, the SIM flight and Stowage Review.

Lovell That is something which we put in, and I think ought to be included in all..the stowage is one thing that changes constantly right after launch, and it ought to be put in just before launch. A week or so before launch to make sure everything is correct.

14.9 Egress training

Borman Briefing, Gulf Exercise, and Survival Gear. All went off well. We had it done on Spacecraft 4, so we only went off in Static Article 5. We did not use the Boiler Plate No. 201 and it worked out fine. We had the helicopter pickup.

Lovell I think the helicopter pickup was well worth it though, because it was exactly what you do on recovery. Might as well do it in practice.

Borman And that is strange how that got thrown in there. That one time on Spacecraft 4, we just thought, well, it would be nice to come back by helicopter, rather than back by ship. And it worked out to be very valuable as a matter of fact. I think that is good training. I think that you should have the Gulf exercise. No question in my mind that you should have that.

Lovell That is about the most realistic type training you can possibly get.

Borman We were well trained in the use of survival gear. Of course, I think that it is a very good idea. We had it laid out here in the crew quarters all the time we were down here, and we stopped in and took a look at it.

We were thoroughly briefed on the ejection seat by NASA people. I thought we were well prepared for that.

14.10 Parachute Training

Lovell I think that all the parachute training that is required is launch off the island for a water landing. I think that is all the Parachute training you need, because that is most likely where you are going to land. You are going to land on land during an abort, so there would be all kinds of people to help you or you are not going to make it anyway. Guess you would be too close to the booster. I think the water landing training is very important, especially when you are using new equipment like our new suits. If we had the 4C suits again for this flight, I think that, since we had rotated so early from Gemini 4, that we could have eliminated that and not have any real problems.

Borman I think that all the training should be conducted with training suits on. It does not make much sense to go out there in a swimming suit.

And we might mention that we had one suit out there for

our training. We switched in and out of a single suit, wet, or not wet, and got it all completed by one o'clock.

14.11 Launch simulations

14.12 Reentry simulations

14.13 Simulated network simulations

14.14 Network simulations

Borman Launch simulations, Reentry simulations, and Simulated Network Simulations, and Network Simulations, at the Cape down here, for us, were a total waste of time. We have already mentioned this earlier, but because of the fact that the simulator was not playing with the MCC, I would not say the launch simulations were a total waste of time. We did get some launches, but I am afraid that the time spent was not profitable.

Lovell We wasted an awful lot of time on that. It is not that they would not be profitable. I think that is really where you get the good training because you get...

Borman I am not going to recommend eliminating it. I would recommend fixing it so that it plays properly.

Lovell That is right. Because you get the actual operating with the people that are going to be conducting the flight, get the communication procedures down, get the whole bit. Unfortunately the whole bit was not working.

Borman That is right. I think this is recognized by all sides. I understand that Gemini 6 was much better after we left.

14.15 Flight plan training

I really do not think you would call that training. It is sort of procedures that you go through, and I hope that the people that come behind realize how big a hand they can have in making the flight plan and how early they should get into the business, because there are so many people with their own little inputs. If the crew does not get in early and keep things under control, you will end up with an impossible situation.

Fortunately, I think, that the people that you have to work with now, Bill Tindall, and Barney Evans, are pretty good. One of the first things I would recommend to anyone to do, is to start talking to the Mission Planning people as soon as they get assigned to a flight. From then on, keep their fingers on the flight plan. I think that is reflected in the amount of time we spent on ours. 133 hours was spent in that training just on preparing and reviewing the flight plan. I think it paid off because we ended up with one that was reasonable and one that we could work with. I would not call it training though, as it was sort of doing flight planning.

15.0 CONCLUDING COMMENTS

Borman What else do you have to say James?

Lovell We are back home, that proves the mission was a success.

Borman There is one thing that I have to say I think the system we have set up here in FCSD now to handle these flights, this task force organization, is outstanding. I was very well pleased with the support we got from everybody.

Lovell I do not think we could have done it ourselves and having gone through it before when we did not have the

organization set up this way, it sure made a difference.

Borman And every part of the Center came through. It was very effective at the stowage mockups and the Design Review to have Kenny Kleinknecht or Chuck Matthews right there and to make a desicion and then it stuck. That was very, very helpful from the very beginning there. The first day we went to that stowage review up there, we had the basic concept solved and we had the ECP's in to get the stowage the way we wanted it. It was very helpful. I do not think there was one thing that we really wanted in the spacecraft that GPO did not provide.

Lovell Everybody was very cooperative, I thought.

Borman But that was another item that I strongly recommend the crews to do....is attend Management Meetings...particularly while the spacecraft is in St. Louis. You will find a lot of decisions are made and you can get in there and get your voice in. The people listen to you as long as you are not unreasonable, and you will end up making an awful lot of money in a very short time if you will get to the decision making.

is keep a close tab on what goes on at the CCB. Jim Bilodeau is the best point of contact there. He kept us informed. For instance, let us say we wanted another stowage bag in the right footwell. Rather than just going through the back door and trying to get Carl Stone to make up a bag, we immediately submitted a requirement to the CCB. We found that time to react on this thing was amazingly short. You could get one in on a Thursday and it would be acted on by Monday. Then, after you had this clearance through the CCB, things went smoothly. I guess what I am saying is the system works and just plow in and use it. That is it.