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GRANVILLE E. PAULES
INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: Today is November 7th, 2006. This oral history is being conducted with Granville Paules in Alexandria, Virginia, for the NASA JSC Oral History Project and for the NASA Headquarters History Project. The interviewer is Rebecca Wright, assisted by Sandra Johnson.

We thank you for allowing us to visit with you today and gather your history. We'd like to start out by you sharing with us how you first became interested in space.

PAULES: This is an exciting opportunity for me, too, because I've always wanted to have this sort of experience. I've got kids and grandkids and so on, and you never quite tell the whole story in any one way, but when I was really young, this was in the mid-[19]40s, late 40s, when the TV was just beginning, and something called *Tom Corbett, Space Cadet* was the thing. The first black-and-white TV, and I got really hooked on it. This friend of mine built a three-story wooden rocket, and we ordered all this stuff from *Tom Corbett, Space Cadet*; had consoles, how the space capsule would be laid out, all that stuff in this mockup, this wooden spacecraft. That was just fun, kind of like a playhouse, when we were kids.

I stayed very interested in it. I got involved in the Astronomy Club in junior high school, and that just pushed even harder. Had a very energetic and enthusiastic teacher who took us out many nights when it was cold. We lived in central Texas, and you'd really get to see them. Got to see the planets. He had an eight-inch telescope that he had built. It just continued to make us

feel really excited about space. So I thought, "Well, in my lifetime I want to be involved in going to the Moon." Well, it was really a funny time, because I went to college, an electrical engineer, and stayed involved and interested in the space program activity throughout the college time. I was in the Naval ROTC [Reserve Officer's Training Corps], so I would be commissioned, spend my time on active duty, and I could make a career out of it, or I could change and do some other thing.

Well, somehow, I always wanted to be involved in space no matter what my career would do. I graduated in 1960. Well, '57, Sputnik [Russian satellite] went up in October. I had stayed fascinated with all that, and during that period I collected articles from newspapers and magazines, and taped them all together on the walls, kind of like a chronology. It ran across the wall from the first few days after it went up, and all the front-page articles we could find from the Austin [Texas] papers, and taped them all together, and then as things changed, and how the program was going. It went around the wall and up over the ceiling. It was throughout my three years there from the time it happened until I graduated; it was fun to keep track of.

I wrote papers on inertial guidance, technical papers, while I was a student. That was just becoming an important concept at that point, in the late [19]50s. So I paid a lot of attention to what was going on in the space program.

I went on in the Navy; became a missile officer, which was what I wanted to do, and that was a really good technical background for getting in the space business. I made a career decision to actually resign my regular commission, which is the same as you'd get out of the Academy, so they assumed I was going to stay for a career. So I had to resign my commission, and I left the Navy from active duty after four years. I resigned in 1964.

The real reason I did is because the space program was—they'd gotten through Mercury, and I was a naval officer on the ship down in Australia when [John H.] Glenn [Jr.] flew over in the first Mercury capsules, and we were over by Perth, Australia, where the tracking station was, and we saw some of the NASA support people and astronauts that went out to that tracking station. That just kind of got me more hyped.

So I stayed real interested all through the Navy. I resigned my commission, and then as I was going to make a transition, I started interviewing in the last few months before I left the Navy. I didn't really want to stay on the West Coast. I wanted to be really involved, and I got offers from several industry organizations, and an offer from NASA, ultimately, in that it was kind of close. This is part of a funny story.

I stayed in touch with a friend of mine that graduated a year before me at the University of Texas [Austin, Texas]. He went on down and went to work in Houston [Texas] at JSC [known then as Manned Spacecraft Center, Houston, Texas]. It hadn't even opened up. JSC was still spread out at that point around the town. He was a mathematician, an analyst.

I stayed in touch with him while I was in the Navy, and because I knew a lot about telemetry and missile systems and so forth, I just wrote up a description of what I'd like to do. There wasn't a job offer that I saw out there, so I just wrote up this position; it turned out to be a position description almost. I sent it to this friend of mine, and he passed it around, and ultimately, to Glynn [S.] Lunney.

So I'm here in the middle of late February. I'm getting ready to resign in summer. So in late February Lunney calls on a Sunday morning. I'm out washing the car, and my wife yells out the window that, "There's a Mr. Lunney on the phone from NASA."

I didn't know Lunney; "Okay."

So it was a phone call interview, and he said, "Well, we'll get you an offer," because he had my write-up. The write-up turned out to be really close to what became a Guidance Officer's position, a lot to deal with analysis, real-time analysis, command and control. I'd done a lot of that as a Missile Officer. So it was a good match. I left the Navy as the ship sailed back to the Pacific, and went to NASA in the middle of August.

WRIGHT: It's a great time to move to Houston, isn't it?

PAULES: It was. We had relatives down there all along, but I still had forgotten how warm it gets, how hot it gets in Houston. The day I was going into the employment sign-up; you go sit in the Employment Office and check in—there were three of us together at the same time checking in. One of them was Jay [H.] Greene, and the other one was Chuck [Charles F.] Deiterich.

We all joined that day and started work. Each of us—it's really funny—all three of us ended up working in the "trench." Jay was a FIDO [Flight Dynamics Officer], and Deiterich was a RETRO [Retrofire Officer], and I was a GUIDO [Guidance Officer], the three positions that make up the trench. Lunney had hired all of us, and we all showed up the same day. It was just a coincidence.

Gemini launches had not started by that time. Mercury was over, and we were in that gap between Mercury and Gemini, and so I went directly to Apollo. I never worked on Gemini. They had already started all the flight control procedure development, getting the position—what you had to do, you had to sit down and system-engineer the way your console would be laid out, and all the way you wanted data portrayed and organized.

The advantage, the real clear advantage to doing that, if this is a lesson learned for anybody, is having the flight controllers, the people that are very involved on the ground side of understanding what's going on out in space, is having them involved from way earlier in the program when the systems are being designed and implemented on the spacecraft. You can't assume. It turned out any time there was an assumption that the engineering development people, spacecraft builders and so on, got out ahead of what would be a potentially important flight control concern, you would spend a lot of time going back and reengineering it often.

So the idea of having flight control people and people involved in mission support involved very actively up front, and that was really important to us. We were able to do that, and it made a big difference in the way the crew interfaced with the spacecraft systems work, the kind of telemetry data that was important; when you synchronize so you've got data about this at the same time you've got data about that system. It was a valuable system engineering expenditure by everybody involved. Most of the flight controllers were engineers. You didn't have scientists or anybody else in there; you had engineers. The vast majority of them were electrical engineers, because most of the time you're doing electrical systems of some sort.

So it was a good experience through that period as Gemini was starting to fly.

WRIGHT: You mentioned that there was more than just you, so can you share with us the process of how the engineers were able to share their information and come up with a final product, and what that process was of mixing and matching your ideas together?

PAULES: Okay, yes, and you probably got an earful from Lunney on how this worked, but everything was done in a very teaming arrangement, like we had each of the functional

responsibilities, the Flight Dynamics Officers, the Retrofire Officers, the Guidance Officers, all were in branches functionally aligned, not mission. They weren't aligned by mission; they were aligned by function.

So our boss at the time I was there was Charley [Charles B.] Parker. He was there from way back, just at the end of Mercury, all through Gemini and all through Apollo. He was extremely valuable in terms of teaming us and getting us very comfortably working as pairs. The guys with the most experience would be on a mission, and you'd have the next most experienced guy working with him as a teammate on the guidance console.

So we had a Guidance Officer and a Yaw, those two positions. Guidance was primary and did the talking on the loop, and Yaw looked at certain other parts of the guidance area and developed the command loads and that sort of thing. Then they worked together as a pair.

New people—in the old [Mission] Control Center, there was kind of a ledge that supported the next row of consoles up; they were stair step. But there was a ledge about this big, and the people in training could walk in, plug their headset in, sit behind the two guys on the console, and listen to all the conversation, and see where you get comfortable and where the tough spots are in a flight plan and the hard things about commanding which you've got to be aware of, how you interface with all those flight controllers that are out of sight down in the computer rooms, off-site, out in [NASA] Goddard [Space Flight Center, Greenbelt, Maryland].

The telemetry folks and the command system, the communication system folks, were all headquartered at Goddard. Half the time we didn't know what they looked like or who they were until there would be a sort of a postmission team gathering. Sometimes they'd all gather, and then you'd meet some of these folks that you'd worked with. But it was very team related,

and it was a very mentoring kind of process all through the whole effort of being a flight controller.

Then when you became a mission participant, like Apollo 11, you became very tightly involved and closely associated with all your other teammates, the other kinds of functions, the EECOMs [Electrical, Environmental, and Consumables Manager] and the fellows that work on understanding the actual systems on the spacecraft. We worried about trajectory control. The whole trench focused on getting the spacecraft from where it is right now to where you want it to be next.

If that meant going to the Moon, landing, all those maneuvers you had to do, all those were—in talking with [Jerry C.] Bostick and Lunney, you probably got a good story how the trench works, but it's important to understand that all three positions in the trench, again, were yet another team, but now you were cut in a mission, sort of crosscut. Now you're focused on a particular mission. You take your function, and you match that with the Flight Dynamics Officer and the Retrofire Officer, and you become a really tightly knit team again. You had shifts, like three or four shifts, depending on how it was set up, but your shift, you stayed with your shift all the way through, generally, all the way through the mission.

The really important thing in building a relationship on teaming was through the simulation process, another major learning experience. Simulations are extremely valuable to everybody, just to develop your confidence that you weren't going to be concerned about any kind of a problem that would show up. You just got comfortable that no matter what happens, don't overreact. Take your time. Make sure you've got the data right. You've got the people that are most effective on the team and the flight control team all involved in helping solve the problem. That's how the Flight Director just kind of orchestrated the whole process, and that's

why you had such great Flight Directors. The ones that were really good were the old flight controllers that had worked their way up and became Flight Directors. They were extremely good at teaming, real-time analysis capability, and that sort of thing.

You worked closely, again, with these back room support, like another training experience was as a new person learning the ropes, you'd actually sit on a support console in the back room and feed information to your lead out in the front. So in our area, where you were doing a lot of data analysis, we had a number of relationships set up with different support groups off-site at the contractor teams.

In our case, the GUIDOS worried about the guidance system performance, that the computer was working right when you put computer loads in, it says, "This is your next maneuver," and it had to learn the platform correctly so the spacecraft would be pointed in the right direction when you fired the engine, and all the trajectory calculations to make sure that you loaded those into the computer on board. All the maneuvers were done by a computer on board, in Apollo. So they'd effectively authorize it by the crew for the computer to take control of the spacecraft and send it on its way, and these would be because you had sometimes really short little burns, ten-second burns, and sometimes they were three- or four-minute burns.

But the team activity between the FIDO and the Guidance Officer were critical. The FIDO said, "I know what the trajectory is, and I know where you need to go next in terms of the trajectory." So they would do all the trajectory analysis work, and then through the computer guys down in the Blue, the IBM [International Business Machine] monster computers, they would convert all that into command loads for the spacecraft, and then we would send those actually from the console. You would send it. It would be as simple as having a load all set to

go, and you punch a "Send" button, and it would be sent straight to the spacecraft through the ground loop.

You would always have to make up a backup in case the command loop went down and you had to read it to the crew, so in Apollo 13 all of that kind of stuff became extremely critical, because they didn't have a command loop. They had to do everything manually.

So you had to have worked all these kinds of details. Any one bit would be extremely important in making sure the spacecraft went where it belonged, or the platform was aligned correctly so that the maneuver was done right. So you didn't want any errors in that command load, and so if they had to do it manually or on orbit with punching it into that computer with a keyboard, a very basic sort of keyboard, the most primitive sort of thing. But the idea is you had to read them this very detailed list very carefully, and then they would hand put that in, and then we'd have a very careful readback and make sure it was right before they punched "Execute," and the spacecraft would take off and do its thing.

So very close personal ties. You knew the crew personally. You knew the guys that worked the computer downstairs personally. You knew the guys on your console on your right and further down. The Retrofire Officer was always effectively over the shoulder, watching, and he had to compute maneuvers to get the crew back safely from any point in the orbit. So from where they are right now, he always had a maneuver that would get them back to Earth on this free-return trajectory. Did you all ever hear that term in some of your stuff?

It's a technical item, but it was really important for safety purposes. When they were heading for the Moon, the very first maneuver, coming out of Earth orbit, would put them on a trajectory that would loop around the Moon. If they could never start the engine again, it would just make a loop and come right back, and the angle would be just right to hit the atmosphere,

and they could return to Earth. So that was called a free-return trajectory, and the Retrofire Officer was constantly computing free-return trajectories for any maneuver you were in the middle of. So if something happened right then, he would have a backup maneuver for them to do, and sometimes you had to do it with backup systems to get them back safely.

The whole issue is we're going to the Moon, and we're going to land safely and return safely. So safety in return and getting the crew back was always a really major issue, and the trench worried about that a lot.

WRIGHT: It must have been an interesting time for you to go to work, because you walked in with a job description, or I guess you could say a job objective, of something you wanted from a child, that you were going to send men to the Moon.

PAULES: Exactly, and then got to do it. [Laughs]

WRIGHT: And you got to be put in with the trench, which kind of took on a personality of its own, didn't it?

PAULES: Oh yes, I have a jacket that I got when I left Houston after the Apollo missions I'd worked on, and they put one of the seals from each of the missions I'd worked on, and it was a very important thing. I keep it. I drag it out when we go to all the Apollo reunions; I wear it.

WRIGHT: You mentioned about the training and how as part of the evolution that people could train by watching, by sitting on the ledge. But Apollo was a new phase that you had just walked into. Did some of you train by watching Gemini?

PAULES: Yes, I did. They started the Gemini missions, and actually the Control Center was still at the Cape [Canaveral, Florida] when we started the Gemini first training missions. So I would go down with Will [William E.] Fenner, who was one of the GUIDOS then. He was a senior kind of guy; worked for Charley, too, but he was my mentor for me to look over his shoulder and follow along with everything he did. So I learned basically the protocols and the things that were important to worry about, and from watching the Gemini experience and actually going to all the technical meetings they were holding on details of command and control, I effectively developed a lot of the procedures and protocols and techniques we used in Apollo for guidance.

I was the Lead Launch Phase Guidance Officer all through Apollo. I developed all the procedures, all the displays. I was lead for the major interface with [NASA] Marshall [Space Flight Center, Huntsville, Alabama], the booster developer, for what we call guidance switchover, where if the booster guidance system failed, the spacecraft can actually take control of the booster and keep it from going awry, and that was a real big political issue with Marshall. They didn't want anybody touching their guidance system.

But it was one of those experiences where you again work with a lot of people that are not directly aligned with your function, but support it, like the booster console was down at the end of our row, and I became an honorary BOOSTER, they called it, because I worked so much with the Marshall guys. It was, again, an experience of working closely with the Gemini people,

and mission after mission you'd go sit through; like if Fenner was on, I'd go work through some of the key phases of his missions, the ones he was active on, the rendezvous missions and so on.

So it was really a very close, personal training program. You didn't have a school you could go to on this stuff. You could go to some. The builder of the flight computer would have training courses on how the computer worked and all the internal vagaries of the where the bits shuffle around. So you had some formal training; it was very systems level. It was not at the procedures and techniques level. You had to build those from scratch, and then you pass that on to the ones that would come behind you.

WRIGHT: You got a chance to see all of your procedures and all of your work come to fruition. Talk to us about the experiences with those first unmanned launches and how you prepared.

PAULES: Yes, an unmanned launch; those were some of the most exciting launches that I was involved in, because there was no crew on board to save the mission. You had to do it all from the ground.

We started with fairly simple missions, the basic [Apollo/Saturn, AS-] 200-series launch vehicle rather than the Saturn V. The first two or three missions, 201, 202, 203, were all unmanned, and because of delays in getting the launch vehicle ready and a few other hiccups along the way that were systems delays in getting ready for the launch, we got to simulate 201 125 or 130 times with Lunney and John [D.] Hodge as the Flight Directors.

So you had plenty of experience, and the idea on 201 they didn't have a sophisticated guidance system on the spacecraft, and the spacecraft is basically a heat shield test. They just wanted to make sure all the spacecraft systems would work properly on reentry. So they lobbed

the spacecraft way up in a big arch on the vehicle, and it turned around, and it would come back in. But the problem was they had such a basic, simple little control-guidance system on the spacecraft that we were worried about the gyros being affected by this really high-G [gravity] launch phase, and they were in the real mission.

But all during simulations—this is the advantage of simulations—they would pick different gyros that would behave badly. So by the time you got to the point where the spacecraft was kicked off the launch vehicle, you knew how well it compared with the launch vehicle, because that was a really good platform, and so we designed our displays and so on to compare spacecraft guidance performance against the booster guidance performance. Then if things started drifting and everything, we'd know exactly how much error there was in this cost-effective guidance system.

Then I had to transmit that difference information and turn it into something usable by the guy behind me, who physically controlled the spacecraft to get it in the right attitude. They had programmed it to go to a certain attitude with this simple little program on board, so if everything worked, we didn't have to do anything, just watch and say, "Yeah, it's a go." But it drifted far enough off that the fellow behind me had to actually make a correction to the attitude for reentry so that it captured correctly in the return to Earth, where it didn't bounce out.

So those are the kind of things that got to be exciting, and the simulations were extremely valuable in building our confidence when you had to do that. And then it actually happened. So that was good. That was an interesting mission.

The [AS-] 501 and 502, they were the unmanned Saturn missions, and that was a whole step up in complexity, because we went into Earth orbit just as if you simulated going to the Moon and you did the big maneuver that put it on a go-to-the-Moon trajectory. Then you'd do a

maneuver. What they did is they just turned the spacecraft around quickly. Instead of going to the Moon, they'd turn it around and do another maneuver that would slow it back down and it would come back to Earth. Then you'd get these real high-G—the reentry corridor is like a little narrow window that the spacecraft has to come back in and get captured in the atmosphere.

Well, on 501 everything went very well. We didn't have any problems of any kind. You just were amazed, and I have a tape that may be useful to you all some way that it's a recording of Walter Cronkite. He was down at the Cape sitting in the Launch Center when the Saturn V took off, and all the ceiling tiles fell out of the roof, it just shook the building so badly. The big window with all the windows that open up, if you remember seeing that place down there, well, the roofing tiles, all these soundproofing tiles, started falling down. Cronkite was going crazy, talking about all this stuff falling out of the ceiling. "The building is falling down!" [Laughs]

Saturn V was just amazing, because it's such a complex vehicle. Everybody was sitting there on their toes, because we really didn't know if it was going to work just right the first time. Well, it worked great, and everybody's confidence was just unbelievable. We were so happy, and then 502 came along. Well, on 502—now, it was unmanned again. Have you heard the 502 stories?

WRIGHT: No.

PAULES: Oh, 502 was amazing. What happened there is launch phase was going well, and then after—there are three stages that you launch, the big Saturn V bottom booster, and then there's a middle stage, the S-2, they call it, and then an S4-B, which is kind of the last major booster stage, and then the spacecraft is all stacked on top of that.

Well, the first stage went fine, and the launch is perfect. We're just rolling along. It gets to the second stage. Well, all of a sudden, several seconds—we can check all the data and get the numbers right, but in the second stage two engines went out. It has five engines. There's a center one and four around it. Well, two adjacent engines went out simultaneously, just quit a third of the way up in launch phase.

Well, several things happened because of that. In our mission rules—you've heard of mission rules. Well, there's a mission rule for the BOOSTER that says, "Two adjacent engines out is an abort." So he has an abort switch. So he sat there, and Cliff [Clifford E.] Charlesworth was the Flight Director. We were sitting there, and I was looking at the data, and I could see the nose of the spacecraft tip up quite a bit, because it had to adjust for this two adjacent engines out. It was burning with three engines, so it was kind of flying like this into orbit instead of like that [gestures]. So the engines all corrected right around the center of gravity, and it just went fine.

So there was this quietness in the Control Center for several seconds, and then Charlesworth said, "BOOSTER, isn't two adjacent engines out an abort?"

The BOOSTER at that point, [Frank. L.] Van Rensselaer said, "Flight, it looks okay," and they asked me, because I was looking at the guidance system, if it was going way off track or anything.

I said, "No, it looks stable. We'll just watch it." So we sat there and watched it.

What happens is the fuel is in one set of tanks, and so the engines just burn till all the fuel is gone, and so it just burned longer and longer and longer, because usually it's burning with five engines. Not this time; you only had three, so it took another couple of minutes to burn out the fuel. So we were in a reasonably good place on the trajectory. If you ever go back and look at this trajectory plot, you know it lofted and did some funny things.

Well, now the third stage takes over automatically, okay, it turns out, and everything looks good, except now the trajectory—the guidance system on the booster had a time-out at a certain point, that it would shift the sensitivity of some of the equations that were controlling it. The booster designers had never expected this second stage to last so long, and so they had a time-out that occurred much earlier than it really needed to. When this third stage took off, it was extremely sensitive to trajectory off—it wasn't in the right place. It knew where it should be, and it wasn't there. So it kept trying to work real hard to get it back where it thought it belonged.

What happened, if you go back and look at the movies of 502—and that ought to be in somebody's history—out the window they had a camera mounted in the spacecraft so that you could see the attitude of the spacecraft and what was going on, and see the horizon of the Earth. Well, what happened is the trajectory control guidance equations would, first, get the altitude right; get the insertion altitude, so many miles. It would get you there.

Then it would sit there and adjust the trajectory so you had a perfectly flat—you'd go into orbit—a perfectly circular orbit. That meant tuning the attitude at the end a little bit. Well, it got real close to the end, and all of a sudden it just, "Hey, we're not at the right altitude," so it lofted too high, and it went up above the 100-mile altitude and had to be brought back down. When it did, the whole booster guidance equation started pitching the spacecraft around real fast to get the nose down somewhere right at the very end of the burning sequence.

What you'd see, you'd see the spacecraft—I'm seeing it pitch over. I can watch the attitude going like this [gestures]. It's going to take a dive back toward the Earth, and then it cut off. It ended up in the right orbit. It was offset quite—the other side.

What happens when you're fiddling with an orbit on this side of the Earth, the other side of the orbit is what gets changed a lot; 180 degrees away is where the big effect shows up. So it ended up in an elliptical orbit that wasn't quite right. It was okay, but it had caused so much trouble, and when they looked at the movies, they saw that the spacecraft was settling into the right attitude, and then all of a sudden it just started pitching over and it just went through about a 100-degree pitch maneuver down over several seconds, which it never should have done.

Nothing broke. They separated the spacecraft and the booster at the right time, and we went on. But everybody was scared to death that something really had happened that we couldn't recover from. But once we looked at the trajectory—then the next thing that happened was we didn't have all the big satellites with the communication system tracking the spacecraft like you do now. You can track it all through the launch phase in orbit and everything. You never lose contact with the spacecraft.

Well, in this case, there was a gap, which we expected, and they had a ship. Remember, they put ships out in the ocean when it would fly over to critical phase to where the telemetry would come down, and you'd see that it was going through the right maneuvers, and the flight controller had a control panel. He could actually turn things on or off if they needed to.

Well, it comes over, and what happened is the flight controller—now, this is going to be a story about the FIDO next to me, and me. So what happens is it comes over and comes in sight of the ship, and then we hear the guy on the—I guess he was effectively a CapCom [Capsule Communicator] on the ship. He was talking to the Flight Director, and everybody could hear his loop, and he said that he had commanded the spacecraft engine on for this very, very long spacecraft burn. It had been lofted into a big orbit on the second booster burn, so it was way up high. It was turning around, and it was going to come back and do this really fast reentry to get

up to what would be effectively a lunar return test of the heat shield on the spacecraft. That was its objective.

Well, anyhow, the thing goes around. It comes in sight of the ship. The ship says the engine is supposed to be on at this time; it didn't come on. So he punches a button to turn the engine on. Well, that was just the telemetry delay, which we had never seen before, and it was like six or seven seconds of telemetry delay. He got nervous; thought the engine was supposed to have been on. He even corrected for some of the telemetry delay, but it wasn't enough, so he pressed the button. I'm hearing all this in the loop, but the guy next to me should have been listening more closely. He wasn't, the FIDO.

Lunney was the Flight Director. He said, "Well, the thing's been commanded on," and what happens is once you command it on, you have to command it off, because you have taken control away from the computer. Now, the computer is aiming it right, but it has given up the right to turn off the engine at the right velocity.

So what happens is—this is the flight controller story—so what happens, the thing has turned around, and it's burning away, and Flight says, "Okay, Guidance." That's me; I was Guidance at that time. He says, "Can you get us the correct time to cut it off?" So I was watching all the velocity stuff, looking at the spacecraft data. We figured that we had about a six- or eight-second delay, and so I was going to have to adjust for that, looking at the data, correct for about so many seconds, and figure out when they should cut the engine off.

So I did that. We had it all figured out. Then when we got to counting down, I counted it down. Everybody was sitting there waiting for this to work, because we had to yell over the loop, and the guy out there had to sit on the switch, because he couldn't tell when to turn it off. So I was going to it, and did the "ten, nine, eight, seven, six," all the way down, and by the time I

got to "one," everybody said I was yelling so loud it blanked out all the voice loop, so you couldn't talk in the [Control] Center. [Laughs]

Oh, the other thing was, here's the important difference. The guy at the ship didn't turn it off. The FIDO was the only guy that had an engine off switch on his console. He actually had an engine off switch. He had an abort switch, too, but the engine off switch, the FIDO was supposed to turn it off.

So we're sitting there, and I look over here at the FIDO. I look at him, and I said, "Did you turn it off?" Because it was like three seconds after I yelled "zero." I looked over, and I expected to see him just—and he looks at me, and it just all of a sudden dawns on him he was supposed to turn it back off. So the thing burned about eight seconds too long, and I don't think he ever sat on a console again. But it was really a stunning thing for a—they got it turned off, but what it did is the engine burned so many seconds longer—it had plenty of fuel—that the reentry was so hot that it was a real heat shield test. It really was a heat shield test. Poor guy that was sitting next to me; he never lived that one down.

That wasn't a simulation, either. I don't know that we had ever simulated it. You never, ever simulate exactly what happens to you in a mission. You simulate a lot of other things so you say, "All right, I've got this problem. How do I fit what I learned into solving this problem?" I can't recall ever having, of all these anomalies that we had and different things that would go on, I don't remember anything being like you actually simulated. But you could patch together things out of simulations and go, "Well, back then we did this, this, and this." That's what happened to Apollo 11 with the alarms going off.

WRIGHT: Did you have much attrition or substitution in the Control Room because of people not fulfilling what needed to be done?

PAULES: No, never. We never had, even in real time. We had one case where somebody got really ill, and after launch in the first phase you stay on and you do the first several orbits. I'm sure it was nerves. But that was the only case where I know of anybody that the backup had to help him get through that first phase.

But the rest of the time usually you simulated enough that the Flight Directors knew who to put on different missions, and they would have their big caucus and decide who was going to team on the next flight and who the backups would be and that sort of thing. So you always had backups in case you—you could always have an automobile accident or something and lose people.

But we never had attrition of any significance in the trench, for sure; in fact, any of the flight control teams. I never remember much. The only time you ever had a problem is if somebody got sick, usually. Usually you do enough sims [simulations] that things like this case that I told you about wouldn't happen. That was the only glitch that I recall that was kind of a flight control glitch. I'm sure there were lots of others, but that was the one I remember.

WRIGHT: And you got good data out of it.

PAULES: Yes. Oh, we did. We got really good data. Nobody was concerned. I think I have copies of all my flight control postflight reports of what happened during the mission and all that

stuff. I've still got all those. I don't know that those would be useful to anybody. They must be in the archives somewhere.

WRIGHT: Maybe.

PAULES: But they aren't easy to find. I went one time and tried to do some research on one of the missions to be sure which mission some things happened, and I couldn't find anything in the history files about that. So I don't know that people—they were in the record. You always had files. You had to turn it in, so it went somewhere.

WRIGHT: Well, we'll ask about that and see.

PAULES: If they're interested, I think I still have some of the ones for the guidance position, anyway.

WRIGHT: That would be great. But while the unmanned testing was going on, of course, there were tests with the first crew, and the nation lost the Apollo 1 crew. How did that affect what you were doing and impact the morale of the controllers?

PAULES: Well, yes, it affected everybody. You know all the crew, and you had a lot of meetings with the crew. That, again, wasn't designed to be team-building; it was designed to be sure we had the procedures and the techniques and the flight mission rules right, and everybody in that room understood them clearly. So there were a lot of team meetings, and the crew was always

there. The backup crew was always there, and the lead for each mission team, on the flight control teams, were all there, and then selected other people that were going to be critical in the analysis during the mission. They were there.

You'd end up with rooms full of 110 or [1]15 people going through detailed mission reviews, mission rule reviews, mission procedure reviews, and the MPAD [Mission Planning and Analysis Division] guys, Carl [R.] Huss and crowd were all there to diagnose what would happen and looking at alternate missions if you had a problem. So big room, big meeting, but you got to know everybody, and it was really like family. When we lost those three guys, that affected everybody. It was hard.

I was on the console. This is the one where [Virgil I. "Gus"] Grissom called the spacecraft a lemon, had a lemon hanging in the spacecraft. There are a lot of ways to look at the outcome of that. We were all affected, of course, by the thing, but the whole attitude was you've got to go forward, you've got to keep moving. I just left the console and handed off to Will [Willard S.] Presley, who was my relief on the shift that was coming up after we were doing all the prelaunch tests down at the Cape at that time.

I left the console and had gone and met my wife. She's a teacher, a schoolteacher over at one of the schools; she taught all the astronauts' kids, by the way, a lot of the astronauts, so she's got a story of her own. But we were driving out to get something to eat real quick. It was late afternoon, and I heard on the radio that there was a fire in the spacecraft. There weren't any details. They said they were still checking on the status of the crew. So we just turned around and went back over there to see what we—because I was just off the console and knew kind of what was going on and the state of what had happened.

So we went back, and it was clear we had lost them. Then you lock up the teams that's on the console quickly so you can debrief and make sure everybody knew exactly what was going on; reconstruct as much as you can from the—it's like *CSI* [Crime Scene Investigation] or something here. You're really trying to get all the data while it's still fresh in everybody's mind. It was a tough, tough time for everybody. It was a big setback.

You'd think it would have been a really major setback, but what was interesting for us down in the "trenches" is how management dealt with it and [Christopher C.] Kraft [Jr.] and [George M.] Low and all the major players up in the front building had to make decisions if they really wanted to meet [President John F.] Kennedy's goal of going to the Moon in that decade. The delays were going to be pretty significant in some missions, and so they replanned the way we structured the missions, based on the outcome of that thing, like doing Apollo 8 with no LM [Lunar Module]. If we had had Apollo 13's problem on Apollo 8, we may never be here having this discussion if we'd lost the three crew going to the Moon.

Anyhow, the thing that was important, it did affect everybody, but it just made everybody more serious about doing it right and making sure we got there and didn't lose the picture of where we were going with the program.

The thing that was an outcome, and it was probably significant and beneficial, is that it gave the LM guys time to go back and fix all the problems. They had been on such a fast track to get the LM ready to go that, in discovering all the wiring harness problems and all the things that created the fire in the atmosphere and so on, that they changed on the spacecraft, it gave the LM guys, the engineers at Grumman [Aircraft Engineering Corporation, later Grumman Aerospace Corporation], time to go back, and they were forced to do a major safety and quality review on their spacecraft to make sure there weren't any similar kinds of problems coming up.

Well, they found thousands of things that they had to go back and fix and do better in more quality ways, handling the wiring and so on. In that sense, we probably got a much more reliable and trustworthy LM because of the sad lesson learned out of the spacecraft problem. So we never had problems like that with the LM, and never did again with a spacecraft, till we got to [Apollo] 13, and that was a different kind of problem.

WRIGHT: Before we get to 13, you actually got to use all your procedures and all your practice for a manned flight on Apollo 7. How did you prepare differently, or what was the mindset as you moved on?

PAULES: It was my first experience, of course, with a manned program, a manned flight, and it was different, because you had to deal with a crew; the interface and all the training stuff. [Walter M. "Wally"] Schirra [Jr.] was kind of an interesting guy. He was kind of a hardnosed guy; the "my way or no way" sort of Schirra, a little bit sometimes. Now, that's not fair, actually. He was, all those guys were, really bright, bright guys, and if they didn't like the procedure, there was probably good reason for changing it, because they had to make it work.

But anyway, our first experience there was we were on a flight, and we had to do some realignment. There was concern about being able to see the stars with the optics because of the backglow, and we'd never flown out in the Apollo. This was Gemini experience, and so now we're in the Apollo world, and we're trying to see if we can see stars with the Apollo optics, because they're critical for realigning the platform, the inertial platform, so the spacecraft can be pointed in the right direction to do maneuvers.

We were in the middle of several experiments there to realign the platforms and so on, and then there were some procedures that had to be changed for the crew. They had to send up new procedures and so on. One of the crew got a head cold, and they were having a hard time communicating, and he was not feeling well. It was just a mixed bag of not a very good day on the spacecraft, and the crew starts just chewing out the flight control team in real time on the thing.

Lunney is one of these unflappable guys. You just can't upset him, no matter what. And nobody can talk to the crew except the CapCom; that's the deal. So the CapCom is trying to calm the crew down, and this went on for several revs [revolutions]. Finally "Deke" [Donald K.] Slayton has to come over there, sit down on the console, take the headset away from the CapCom, and chew out Schirra in real time, and just get him to calm down and be quiet. "The ground crew is doing a wonderful job of trying to keep all these problems straight and everything, and you guys need to work," and he just read him the riot act. I'd never seen him do that before. It never happened again.

Anyway, Schirra, who had always—he and Grissom were the two fighting over who was going to the Moon, landing on the Moon first. That was the deal. But we lost Grissom in the fire, and I think that incident with Schirra must have cost him his opportunity to really be in the front edge. But down where we were at the working level, you'd kind of witness some of this stuff going on, and it was all part of the experience. Everybody learned, "Okay, well, we'll get all this set of procedures straightened out again, so we don't have this happen." That was the first manned mission. Everything else went fine.

This guy that was the telemetry command fellow at Goddard would have to tell us when we were going to have acquisition of signal and loss of signal if you'd go around the Earth,

because you didn't have total coverage all the time. So some of the command loads were fairly long and complex that we had to get up to the spacecraft, and I was really fast at commanding. I could really get commands through the system, up, and verified that they were right and good to go.

We had one pass, I guess it was over Bermuda, where we're kind of at the edge of the Earth, and so you got really short little look at Bermuda there, and you had to get off. So we were getting tight on—this was the same mission. We had to reload a load of stuff in the computer. I said, "When's AOS?" acquisition of signal. He told me exactly what minute and second it would be, so I started commanding.

The way the command system worked, it would send until it got a MAP, what they call a Message Acceptance Pulse, back that the spacecraft had received. So I started sending the signal before it actually said we had acquisition, because we had a long load, and it was not clear we were going to get it all in. Then got it all in, and just as it dropped out of sight and the spacecraft went over the hill, I was able to verify the whole load got in. So this guy called me "the fastest gun in the trench." [Laughter] Anyway, that was the excitement of the first manned mission for me. Everything else was pretty nominal on that mission for me. Some others had different other problems, I think, that they ran into.

There were other missions that were really exciting, when we got the 500 series. Apollo 12, have you talked about Apollo 12, the one that got hit by lightning?

WRIGHT: Yes. We can talk about that one now, but I was curious about what you thought after Apollo 7 and learning that you were going to go behind the Moon with Apollo 8.

PAULES: Oh, with Apollo 8.

WRIGHT: Yes, that whole decision, and your work with that.

PAULES: Yes, see, that was all really a hype and very exciting. I was on that mission when they went behind the Moon. But again, I've been on several of the very interesting first-of-a-kind missions. I was the guy on the mission when they went behind the Moon, so there was a little fine-tuning maneuver we did. The understanding of the gravity effects of the Moon, we're still learning about those, and so you weren't absolutely, perfectly clear about how, when you go looping around the Moon, exactly what the effect on the vector, the spacecraft vector, would be.

We had done enough simulations. You had enough math models. They'd had the unmanned spacecraft try to land on the Moon. So we were pretty clear, but the main thing is doing it the first time, and these guys on that Christmas Eve go zipping out there. Everything is perfect. We had no problems at all with Apollo 8 all the way out. It's just that eerie feeling when the guy goes behind the Moon that first time. That's the first time that humans had ever been out of sight of Earth. There was this quiet period while they're behind the Moon the 20-some minutes or so that you don't talk to them.

The procedure is as soon as they're supposed to be in radio contact, the CapCom starts calling them. Well, they call and call, and it seemed like at least a minute after they should have been in view before we ever heard from them. So, the place gets quieter and quieter while you're waiting for that first voice contact back from those guys. Then they went through all the little comments that made all the history. It was a very exciting time for all of us. That was pretty unique for a few of us.

WRIGHT: Then, of course, [Apollo] 9 was the trial of the separation and taking the LM out.

PAULES: Yes, taking the LM out. I was involved in the launch of 9. By then we were really working hard on [Apollo] 11, and I was on the mission team for 11 then. I had two roles in 11, the launch phase, and then I was the Yaw on the landing phase.

[Apollo] 9 was a nightmare of many unplanned experiences from the guys that were involved in that, because you were really trying a lot of new things, a lot of new things, and they all had to work. If they hadn't been able to bail out a lot of the problems they had in 9 and validate that it would work right, I'm not sure we'd have done [Apollo] 11 when we did, 10 and 11. [Apollo] 10 was the real test, because you had to separate and do the maneuver and then come back together.

But [Apollo] 9 checked out a lot of things. That got a lot of people sick. That was the one that one guy got real sick on the console in the first phase when we had to do all the complex maneuvers and separation. That was the only time I ever saw anybody that really—it was too stressful on some people, but they got it all pulled together. That was a good mission. I wasn't involved so much in the details of that one. I was over the shoulder, because of the LM protocols that we were learning. That was another learning mission. That would be one to talk to guys like, well, [John S.] Llewellyn [Jr.]. You've done Llewellyn, right?

WRIGHT: Yes.

PAULES: I saw his name on the list. And you've done Deiterich. The RETROs got very involved in the alternate mission problems with [Apollo] 9. Dave [H. David] Reed, have you done Dave Reed?

WRIGHT: No.

PAULES: He retired. He resigned from NASA and went to work when I did up at the Transportation Systems Center. But he was pretty stressed out on that particular mission. He was a real cocky guy. It really was a humbling experience for him, because it was tough for the FIDO. He's a FIDO.

WRIGHT: Although you weren't directly involved on [Apollo] 9 and 10, as you were preparing for 11, how did you learn the lessons that they had learned on these missions to incorporate into what you would need for 11? How did you all share information and know that that information was distributed to all who needed to know?

PAULES: I did two things. I always created my own personal console position checklist for all the key events and the things that we had to do, in order chronologically. So that was something that was outside the flight plan. You had the flight plan to give you general guidance, and then you'd update it if something changed. The flight plan was pretty detailed on maneuvers, details about maneuvers, but not procedures. Procedures, you had your own console book.

I had developed all the ones through the unmanned missions for all the launch phase, and they were used by everybody as we moved into the missions and other guys would start taking

on launch vehicle positions and Yaw. The Yaw position was always kind of a learning position to move up into the guidance position. I was the Guidance Position Officer for all the unmanned, and all but a couple of the Apollo missions up through [Apollo] 13, I was the lead, the Launch Phase Guidance Officer. That took you through translunar injection, so you were the lead all the way through getting them on the way to the Moon.

Then things would change as we got into the rendezvous phases near the Moon. I was Yaw, supporting [Stephen G.] Bales. He was the Guidance Officer, and I was Yaw, in that case. But what we'd do is, like in Gemini or in the earlier Apollo missions, you always had your procedures meetings with everybody in your functional group, your Guidance Office. So everybody went to all the procedures meetings when you were developing a new set of procedures and review them with you, because who knows, you may get called in to sit down there and do that job.

There was a lot of mentoring and involvement of people. When you were developing new procedures, you'd dry-run them with folks, mostly guys that were likely to have that position and do that function. Learning the LM guidance system, technically, it was the same protocols, but in terms of the specifics of the programs for lunar landing and all that, very different, very different.

So you had to learn all those, and you spent a lot of time learning those with the guys who designed the software up at MIT [Massachusetts Institute of Technology, Cambridge, Massachusetts]. So there'd be a lot of trips to MIT, and you'd sit down and go through all the software with them, and you'd talk about "what ifs," all kinds of "if it fails here, what if it fails there, what do these alarms mean," and all that stuff.

Then you'd go through simulations, and when you do simulations, there would always be this person that could be a backup sitting on the ledge with a headset plugged in following all the details of the simulation. So you're learning by OJT [on-the-job training] more than anything. It was purely an on-the-job training process. Those procedures that somebody else had would be used in a procedures book, and so you'd make your copies and adjust them the way you wanted them, so they were very personal.

I had something I was going to bring. I couldn't find it last night. It was on Apollo 7. We didn't have all the computer programs for calculating backup procedures if the computer failed, for getting the crew in the right attitude to reenter safely. They were in a circular orbit, so there shouldn't have been any problem.

When you're going around, and if they had to go to alternate sites around the world because of a problem, you need the computer to calculate the correct attitude of the spacecraft so it comes in right and it does all the right yaw maneuvers. You needed to align the platform, the inertial platform on board, correctly so that it would handle the spacecraft, and it wouldn't get in a position where it was what we call gimbal lock. This inertial platform can only go so many degrees in different axes, and so you align it to get the most reasonable midpoint of where any extreme would occur, rolling and rocking around, pitching.

You always had to align the spacecraft platform, depending on where you were going to come in, and we didn't have a computer program to do all that, so in terms of these procedures we all developed, I had a great big wheel. It was made out of cardboard with plastic and stuff on it that had all the key stars that they might see. I put them in the right star field orientation, and then if they were to see a certain star and they could identify it, we could tell them what angles

they needed to put into the spacecraft backup system to reenter properly. That was all a handmade thing. It didn't depend on any computers. And that was [AS-] 204.

WRIGHT: Astronomy Club came in handy?

PAULES: It did. Oh yes, and we learned a lot about stars. The Guidance Officers knew a lot about the stars, because you had to know what stars they were talking about, or if they had to have a backup star, they'd say, "I've got this or that. What do you think it was?" The crew knew stars, too. You needed it. They were very dependent on those stars so you knew where you were in inertial space.

But 204, that was one of my manual techniques that I developed. I only needed it for 204, Apollo 7. They got the computer programs working right on the ground for the next cycle, so we didn't need it again. But that was just one of those things you do as a backup procedure. We had a lot of backup procedures.

In fact, one of them that was very useful, we did it because we weren't sure you could see stars in deep space. They reported seeing a lot of little speckles and stuff, so it was very confusing in the early stages of Gemini. When they looked out into deep space, they'd see these flickery things, a lot of starlight, and it was just reflections off of space stuff floating around Earth. Once you got far enough away from Earth, you didn't see any of that. But we didn't know what was going to happen, so we made another backup procedure, and this is one Charley Parker did. It was really clever.

When you look at the Moon and it's not full, it has a shape to it, so if it's in a crescent shape, you get this kind of horned effect. So the two points on the Moon turned out to be very

good, easy-to-see points when you couldn't see stars. You could look at the Moon, and what we had is this backup procedure where they would turn the spacecraft physically and use that one-power telescope out the center. It was boresighted and bolted to the top of the spacecraft. They could boresight that, and they would rotate it so these sort of crosshairs in the telescope were lined up on the tips of the Moon, and it was centered in the center of the Moon.

Then we said, "All right, if the spacecraft is aligned that way, your attitude in inertial space is, roll, pitch, yaw, these numbers." They would punch that into their computer, their little hand computer, because the assumption was that the platform and the spacecraft computer had failed, so they had to do everything manually, and this little eight-ball thing, they could control manually. They could set it.

We'd give them the readings in pitch, roll, and yaw to put in. "You're sitting at pitch, roll, yaw zip." They'd punch those numbers in, and the ball would go to those angles. Then to do a maneuver, they had to do a maneuver, they'd light the engine, and it would burn for a minute and a half. Then they would go to all zeros, zero pitch, zero—they'd fly the spacecraft around to where it was all zeros, roll, pitch, and yaw, and then do the maneuver. It was real simple for the crew, but it was a very clever backup procedure, and it allowed us to get them back safely if you lost this computer and the inertial guidance system.

A real deep backup, but that was used on—we did that on Apollo. We checked that out on Apollo 8. We did it for Apollo 8, because we really weren't sure what they were going to be able to see when they got really far away from Earth. The Apollo 8 backup procedure, but it was used on [Apollo] 13, and we had to reconfigure it for 13 to use with the LM.

WRIGHT: It was a very aggressive schedule.

PAULES: Very, yes.

WRIGHT: The day that you walked in the door to the day that we landed on the Moon.

PAULES: Yes. I made it my whole lifetime to be dedicated to getting to the Moon by the year 2000. That was what my goal was. I figured we could probably do it, and reading all of the Willy Ley and all of the science fiction guys, they figured you could make it by 2000. Here we were back in the early 60s. "Yeah, we've got 40 years. We'll make it." Made it by [19]'69. [Laughs] But it was a really compressed schedule.

But I was critical. You know, everybody would ask how it was. Well, I don't know how many people have talked with you much about it, but it was hard on families. We had four people announce they were getting divorced in Lunney's branch at the Christmas party. It was the one around Apollo 8, I believe. Four of them, and that was a huge percentage. So it was always hard on people. You were gone—when you did simulations, the prime upcoming mission had daytime prime time, but the follow-up mission, the next mission, had all the nighttime. We'd do simulations. You'd get over there at midnight, and you'd sim till eight or nine in the morning.

But then we got to play golf in the daytime. [Laughter] [Philip C.] Shaffer and Bales and Charley Parker and a couple others of us, I think Gary [John G.] Renick, we'd all go out and play golf, because you were still hyped after you got off of sim. It was too early to go to bed, but you had to be ready for the next night shift, so we'd go out and play golf for a few hours and settle down and then go back; finally get some sleep and go back to the console. But when you had a

lot of tight things going on, or you got in some critical situation, you had the bunkroom upstairs. They had a men's area and a women's area, although almost all the flight controllers at that point were men. They're like bunk beds, and they had restrooms and showers. They had lockers, and if you needed to, or if you lived a long way away and you didn't want to leave like [Eugene F. "Gene"] Kranz, the senior Flight Directors, half of them stayed there most of the time, because you never knew what might happen. Kranz, he didn't live that far away, but it was just his style.

WRIGHT: Well, you had worked five solid years, from 1964 to '69. Share with us what it was like being in the Control Room for the launch and then, of course, for the landing on the Moon.

PAULES: Oh, for the landing on the Moon? Well, the landing on the Moon, now, we'd gone through [Apollo] 8, and that was really exciting, so you were kind of past the really hype of the first time around the moon. [Apollo] 10, everybody was pretty confident that the LM was going to work well, so you weren't as nervous about things not working well. But there's nothing like that first time when [Neil A.] Armstrong goes down to land, you know.

I had launched it. I was the lead Launch Guidance Officer, and I was really paying a lot of attention all through the phase till it got to the Moon, making sure when they did comparisons between the spacecraft guidance system and the LM guidance system that they were still working well; we didn't have any problems with the LM, and it was going to work well when they took off. Then when you separate in orbit, after you get to the Moon and they separate and you start doing maneuvers with the LM, you've got a lot of chances to look at it and make sure the systems are going to work right.

Well, I was on with Stephen Bales for the actual landing cycle. I was what was called Yaw then, and again I worried about the commanding to the LM, the loads, the landing site information, all that sort of stuff. As they started landing, the alarm—you've probably heard about all the alarms going off and so on. Kranz has probably talked a lot about this. It's been documented in many books, the sequence of details.

But what happened is we had run into this in simulation where the computer software actually behaved the same way in a simulation similar, not exactly, but similar. What happened is the computer is trying to do too much, and it gets overloaded in this internal minor loop, and it got locked up, and it sends off this alarm, which says, "I'm too busy. I'm going to do this." So what they had to do when that happened—it actually happened on Apollo 11 as you were coming down that a similar alarm went off.

So what we had checked out with the simulation, and we'd done a lot of work after that sim kind of blew up on us in the second week of June, we had MIT run a whole lot of other checks to see if we had to fix the software on the spacecraft or do something differently. Well, by that time it was too late to really make any changes that anybody was going to be confident you'd get in and get right without screwing something else up. So we flew with it that way.

What happened is the alarm went off as they were coming down; they had the same thing. The radar was trying to do this, and the com [communication] system was trying to do something else, and so all they had to do was flip a switch that turned off the search for a particular function, and that relaxed the computer, constrained the computer settled down and was doing the right thing. So everything was going real well as they came in.

Now, the really exciting difference was, of course, the actual landing, but what I always remember when I'm sitting there—and now by this time I've been through a lot of missions and

was feeling pretty confident that you can get through anything. But Armstrong comes down to land, and you're sitting there and you're listening to it, and the guy behind us is counting out the number of seconds of fuel left before abort.

Now, there's something as they're coming down where their velocity coming down toward the Moon is so high—it is at a certain level or higher—that if they were to abort at any point in that stretch, if they had to abort at any point in that stretch while they're going this fast, then that fuel left in the spacecraft to take them back up—they abort and drop the bottom part and fly back up with the LM module—they don't have enough fuel to actually make it back into orbit, and so it's called a little stretch of the "dead man's curve." You really don't want to get down into that stretch. So you really want to slow down. It's just kind of a curve. You try to keep them above that curve, so their approach velocity slows them down, and then they sort of hover. They're not really supposed to hover much. They're supposed to go down and slow down and stop.

Well, Armstrong goes down, and he sits there, and then you hear him just hovering. He's wandering around the spacecraft just above the surface of the Moon, and afterwards it turned out there were boulder fields and all kinds of things. He wasn't sure he wanted to put the wheels down on that and have it tip over on him or something. So he just hovered around; it's like he's humming away. You didn't hear him humming, but you could just sort of sense that must have been what was going through his mind after it was all over.

The guy behind us is counting the fuel down, and it was down to the point now you're past all this threat of dead man's curves and everything else, but he hadn't landed, and we were down to like eight seconds of fuel left—eight seconds. Well, it turned out when they finished measuring it, it was like more than that. It was thirteen or fourteen seconds, which seems like an

eternity when you're doing some of this stuff. But it didn't seem like much to all of us in the Control Center while we were listening. So the only voice you heard was the guy behind us counting the thing down.

In that Control Center there's usually a background hum of voices talking, people talking, you're talking to the guy behind you. Not on the loops, but it's just kind of quiet talk between people, flight controllers, while you're doing things. Or somebody talking on this loop to a guy, not the Flight Director loop, but to one of your support guys in the back room. So there's always the hum of voices; not loud, but there's something going on.

Not during this phase. When he was landing, it got so quiet in there that it was just like they had turned off all the electricity and all the people, and everybody was holding their breath, literally. Everybody held their breath; I did. And Charley Parker was sitting behind us at that point. He was our Branch Chief, and he was sitting behind us, and we were all sitting there in that last probably 20 or 30 seconds. I'll bet you nobody breathed, and this guy, the only thing you heard was this monotonous, "22, 21, 20…"

Finally when he said, "Touchdown," you could hear everybody breathe. [Laughs] It was really funny, like a big inhale. [Demonstrates] It was a real experience. So that was really important to all of us. Then you go through the quick countdown to make sure that the LM's working right. You don't want to abort right then if you don't have to. They got settled in, and everything went fine after that. That was a pretty straightforward mission. That was a good mission. Enjoyed it. And, what do you for an encore after you do that?

That was the thing Bales and I, we looked at each other when it was over and said, "Well, Jiminy Christmas, what do you do for an encore?" Because all the rest were going to be pretty similar. We just laughed at it, because the hype was so high at getting us from [19]'64 to '69. I

mean, your whole life was dedicated to being a part of that, and everybody was committed. That's why there were so many family problems; you just really spent more time with the flight control team than you did with your family, almost all the time, literally. So that stretch was hard on a lot of people, but everybody was committed to doing it well. It was an interesting time.

WRIGHT: Very historic that you could come back with [Apollo] 12 in just a few months and do it again.

PAULES: Do it again.

WRIGHT: After a lightning strike.

PAULES: Right. Well, the lightning strike, I was on the console when we did that one. That was an exciting thing. It got hit twice. We didn't know it got hit twice till later, but that one did cause some trouble. It turned off all the electronics in the spacecraft. So here the booster is working fine; it seems to be immune to anything. It puts them in the perfect orbit to go do the next maneuver, but we all agreed they shouldn't take off for the Moon unless we were absolutely sure that computer on the spacecraft was okay and the platform was okay.

So we did another one of these "fastest gun in the trench" things, where we had to dump all the memory on the spacecraft computer to the ground, and then do a bit by bit check of the memory to make sure nothing was amiss. We had to get all that done in a matter of minutes, because they were like one rev away from heading for the Moon. We'll probably have to check

this, but I think we did delay one rev, and then let them go a second rev later, and not on the first opportunity, just to be sure.

Then they had to realign the platform. The platform—all the electronics shut down, and the platform kind of rolls over on its side, and so they had to get the star shots out and get the whole platform realigned. That is something that you had simulated something like that at some point; not in that point in the mission, but they had done it before. So the crew was pretty adept at getting it back, and then we confirmed that they had the alignment right and gave them all the stars they needed to use to do the alignment.

We had to calculate those real quick and give them a list of stars to go after. That helps them get the right stars so the platform was easy to align and that with those stars. Then they, based on the command load we sent them about going to the Moon, they always aligned the spacecraft guidance system perfectly with the booster guidance system, so that if you have a problem with the booster system, they could take over. That was this guidance switchover stuff. So that was part of the protocol that you had to do. It was the sort of a procedure they would do an alignment check in orbit anyway, but when it dumped over on its side, they definitely had to do it.

That was a pretty tense little couple of hours there, but after that Apollo 12 just went really well. There were some other things that other flight controllers had to worry about, but not the trench so much.

WRIGHT: You talked earlier about working so closely with the crews, and these two crews were totally different.

PAULES: Very.

WRIGHT: Did that have an impact, or how did that work with you guys?

PAULES: Well, it would impact you, I would think, if you walked in as a flight controller, knew your business real well, and you were handed a new crew. You really do need to know one another well, even though the flight crew would know all the console position guys, the working-level guys in all the whole console, know by name, because we had been in so many meetings together.

That was very valuable. They would say, "Well, check with Bales again." Now, Bales didn't talk to them. The CapCom talked to them. But if they were questioning something about the guidance activity or something, they knew who to talk to. And even though the crews were very different—and they were really different—you got comfortable with them. You know what their sensitivities were, and where it would get to [Buzz] Aldrin [Jr.] would certainly react one way, differently than Armstrong would.

[Charles C. "Pete"] Conrad [Jr.], Conrad is an old white-scarf guy. He was just right out of this school. It was a shame he got killed. But probably if he had to be, getting killed on a motorcycle is the way he'd want to do it. [Laughs] But he was one of these—nothing, nothing scared him. He'd do anything, and he loved sims that would go to hell in a handbasket, you know. [Laughs] Anything that would break, he loved to fly it out. But he was very different.

Now, Armstrong, we just knew Armstrong was going to get picked for that mission, because he was really cool. I didn't know him personally very well until the Gemini VIII experience, where they docked [with the Agena target vehicle] and then the thing went totally

out of control, and he had to pull it back. The attitude control system wasn't working correctly because of a wiring interface mismatch, and whenever you do the hand controller, it would fly the spacecraft in the wrong direction. So what he had to do—he was spinning around. They had pictures, again, out of these overhead cameras, and you'd see the spacecraft spinning right at one rev per second. So it was click, click. It was really going fast.

They had this little panel, those little tiny banana switches; they're about this long [gestures], and they're not designed for what he used them for. There's a little switch for each jet; there's two switches. One is to thrust it in one direction, and so you turn it on or off, and it's a little quad of four jets in four different places around the spacecraft. He had to turn each one of those jets on manually while he's spinning around like this until he got the spacecraft motion stopped, and then they could—they came back and said that—nobody saw any of this, because it all happened over the Atlantic, the South Atlantic and coming around past Australia. So nobody knew what happened until they came up on the other side, and here they were all shut down, and nothing was working right. They said, "What happened?" [Laughs]

Armstrong comes on, and, "Dah, dah, dah, dah, well, we had to do this, blah, blah, blah." [David R.] Scott was so shook. He was his partner on that one. I didn't think Scott would ever fly again, but he recovered. Armstrong was so cool in pulling it off and then working his way through. They had brought them back early. They landed in the Pacific. They weren't supposed to, but they got them back early. But the next thing that happened is he's flying this little LM test thing [Lunar Landing Research Vehicle, LLRV-1] out at Ellington [Air Force Base, Houston, Texas]. Did you see pictures of what happened there?

WRIGHT: Yes.

PAULES: He stayed with it. It lost another one of those side jets; it had four jets, one on each of the sides of this to balance it when it's flying, for attitude control, and when he did his maneuvering, it would feel like a real LM. Well, one whole quad quit on him, and so the thing went out of control, and he tried to rotate it around in the axis it was rolling over on, rotate the spacecraft around so he could correct for that motion, and land the thing.

It was clear after a while this wasn't going to work, so he finally decides to abort, and the spacecraft is tipped over about probably 30 to 40 degrees off the horizon. When he aborts, he shoots out to the side, and his parachute opens, and his feet hit the ground, and he walks away. He never got shook or anything about any of it. He stayed with it a long time. Most of the guys would have gone to abort immediately and get off that thing. [Laughs]

WRIGHT: Well, speaking about accidents, this leads us to Apollo 13. After two successful launches and landings, you were somewhat a part of Apollo 13; not really at the first, but I believe that you became a big part of the recovery.

PAULES: Well, I actually launched it, and then I was already—I had a group that was starting to work on Skylab, and I was chosen to lead that group because we were dealing with major interfaces with Marshall again. We were going to use their S4-B as the lab. So all the interfaces I had developed quite a good reputation of working closely with those engineers at Marshall over the years of trying to get the guidance system interfaces worked out.

So, a similar kind of problem. We were going to be controlling the Marshall booster from manned spacecraft interfaces. We had a group that was working on how to develop

software systems to manage resources. There's a lot of things to deal with, like power and air-conditioning and crew timelines and so on, so we had started working on the procedures and the interfaces with the control systems on how you'd manage all that. That was becoming my major function already by that time.

I did the Apollo 13 launch, got it on its way, and then was off the console. I figured I was done. Then, they had NASA Select, which was always either a radio channel or a TV channel you could watch or listen to, and I always had it on when I was home. Well, I was home when I heard that something had happened. Then I listened to it for probably 20 minutes, maybe, as soon as something had happened.

They usually had the public affairs guy talking about what's going on, and I was listening to what—they actually played the crew loop. You could hear part of it. Then I would hear the interpretation of, "Well, the crew was asking are we going to be able to go to the Moon," and "Well, we'll get back to you."

It was clear from what I was hearing there was no way. These guys, it was serious, and quit worrying about going to the Moon, guys. You'd better start worrying about getting back, seriously. You could tell if you'd been in the business at all, that there was a really serious problem. So I called the console over there. They have an outside line, and you can call. I called over, and Charley Parker answers the phone. He said, "Why don't you just come on over."

So I came over, and then by that time they had pulled Kranz's shift off, and they were all locked up, starting to debug what they thought happened and figure out—he just created that standalone team that stayed with that, that sort of offline team, throughout the whole mission, for

the rest of the mission timeline. Bales was on that group; John [W.] Aaron; the usual—Kranz's first-line team was already pulled off to do that.

So they took all the flight controllers and put them into the three other operating teams. So you were mixed with people you'd probably never worked on a particular mission with, necessarily, although generally the procedures and all that sort of thing were identical. You knew what to do, and you knew what they were talking about when they talked about this, that, or the other. So it didn't matter. It was just a matter of you'd end up with—I think I ended up with [Milton L.] Windler's team as the Flight Director. We ended up with different phases, each of us working—you're always worried about making sure they stayed on a safe return trajectory. On the trench; that was our worry.

Other people worried about systems problems, things that would run out of resources. You probably read the book or saw all the specifics of how people came up with very creative ways to extend life support systems and that sort of thing. Well, just the way I remember it, I guess maybe I put it in here. People ask me a lot after the *Apollo 13* movie came out, "Well, how close was that to what really happened?"

To me, the movie was really well done, in terms of being factual about things, but I said the only reaction I could have if you asked me that is, "It did a really great job of recreating what really happened on the mission, but in the case of when you're sitting there, we just didn't know how it was going to turn out." Nobody wanted it to go badly, but you just didn't know. You thought, each time you got something fixed, "Ah!" But then something else happened. It was just amazing how many strings of things caused a problem.

But one that didn't show up much in the movie, that I thought was really important, was the fresh water situation. Remember, a couple of the crew got sick. Well, one of the problems

was they had bladder infections, and the doctors were really after them to drink water. Well, it turns out water is also the coolant for the electronics, and when they turned all the electronics off to the bare minimum, where you had one radio that was turned on, but all the rest of it was turned off, so the spacecraft starts cooling down, and it gets colder and colder and colder.

Because the electronics are usually on, and there's' enough electronics going on that it keeps the spacecraft warm. So that was part of it; it was kind of a closed cycle. What happened, they were getting cold, and they couldn't talk. Now that was pretty well done in the movie, I think, but actually, they had to bite their tongue because they couldn't talk. Their teeth would chatter. I could hear [James A.] Lovell. You could just tell he'd just bite his tongue so he could talk without having his teeth chatter. They were down in the low 50 and high 40. They were all really cold. But they refused to drink water. The doctors started saying, "Look, guys."

They were preserving the water, because they knew as soon as they turned the electronics on, they only had so much water. The fuel cells created water, and when the fuel cells were gone, you lost all your water supply on the spacecraft side. On the LM side, it was only designed to handle two people for a shorter period of time. Well, they stretched it out into days of living there. So they knew, Lovell and the crew, knew that as soon as they started turning things on to warm up, they were going to boil off the water, and then they wouldn't have any more water to cool the electronics so then they really needed them. That water normally would have been their water supply to drink and mix food.

Well, they weren't drinking it; they were preserving it. What happened is—that's why I think the movie didn't really pick that up very well—is the doctors got on it. Dr. [Charles A. "Chuck"] Berry, he actually got on the loop and was chewing out Lovell that they had to drink

more, because as soon as you get dehydrated, you start getting delirious, and then you can't do anything. You're really in trouble. So he really had to lean on Lovell to get him to drink water.

They finally agreed to drink more water, and that turned out to be a good thing, but everybody was—they were looking at the water profile. How much water is left, and are they going to have enough to do what they had to do? So that never showed up as much of a big deal, but it was a really big deal. Everybody in the Control Center knew that if that water level kept going down, they were going to be in trouble with the electronics or they were going to be in trouble with delirium or whatever. So water was a real problem, and it didn't show up that much in the movie, I don't think. But everything else was pretty well done.

One of the big unknowns was why the spacecraft kept changing orbit. It would move, and we'd have to do some simple things. We had them turn on some systems and do a little simple maneuver like this to get them back on the free-return orbit, and it turned out that leaking gases and other things were the problems that they ran into that kept pushing the spacecraft a little bit this way or a little bit that way. It moved the trajectory, so pretty soon they were off that free return again, and in some cases, in fact, several cases, it would raise the point where they would come close to Earth above the atmosphere. They'd just shoot on by, and you'd never see them again. They'd go to a Mars trajectory or something. They'd go into a big, big elliptical orbit around the Earth, and you'd never get them back.

So you always had to do a little maneuver to get the spacecraft slowed down where it would hit the atmosphere right. They had to do two or three of those, which were unplanned. You probably talked to Jay Greene and you probably went through some of that stuff with him, but anyway, the thing that we did last that everybody felt good about was we decided that the

maneuver to get rid of the LM at the end—remember, you're coming back to Earth, and you weren't supposed to have the LM on there; it was supposed to be just the spacecraft.

Well, the spacecraft Service Module, the big engine part, was useless. The "Gumdrop" could only last a few hours, an hour and a half or something. After you turn everything on, it's like a battery; it just runs down. You use up all of everything. So you've got to wait as long as you can to do that. We always had a plan for getting rid of the LM, but they delayed that too late, and everybody was starting to get really nervous that the timeline was really tight. Getting rid of the LM, get everything reconfigured, get rid of the Service Module with the hole in the side of it, and then turn the thing around for reentry. So they decided, well, it's got enough water left in the LM that they said, "Turn the electronics on early."

So they turned it on about an hour and a half earlier than the original timeline was, and the thing starts warming up, and then it was really good, because the procedures—remember I told you procedures, normally you just send the commands and load the computer with everything. Well, the procedures were so non-nominal they had to create, through manual entry, a whole set of software routines that didn't exist on the LM software. So even our commanding wouldn't have done the job. They had to manually enter pages of stuff.

Remember, these guys are hardly able to talk. It was all read up manually to them, and they had to read it back to make sure they got it written down in the right order. You talked to them about keystrokes, and do this, a dozen keystrokes with numbers and then there's a break, and you've got to do this kind of entry. It's like manually loading software, pages of stuff. They just got frustrated halfway through it trying to get it all written down, but they got it all done and then loaded it in.

But the thing that helped was at the end we turned the spacecraft on earlier, and all the electronics started warming up. They start getting to feeling good. Lovell was feeling real good by the time we finally got to the point where they had the computer loaded up. It was a good thing we started early, because it took them a lot longer to configure everything. You had to load the LM computer up, because you had to turn the whole spacecraft around; do a certain maneuver. Then you had to align the Command Module properly, go inside the Command Module.

Now, everybody's in the LM, all cramped up in the LM. They opened up the thing, go into the Gumdrop, reconfigure the spacecraft electronics. That's the one that has the short fuse; it runs out after so long. So they had to align everything with the LM in a certain direction, and the spacecraft's here in a backup procedure. Got everything right, and then the guys in the LM came in. We shut the LM down and closed it up, and you pressurized the gap between the two spacecraft. Then when they pushed the button to separate, it just popped off, because there was pressure in it. They took pictures of that.

Then they looked at the spacecraft when they popped this. You had to now turn around and get rid of the spacecraft, and you're in a different timeline than you normally would. So they turned around then, and they kicked it off, and you saw the big hole in the side. That's the first time they really knew how badly the spacecraft was beat up, the Service Module. Everybody was still wondering, has there been any damage to the heat shield? Are all the systems on the spacecraft going to work? Because the explosion was a pretty big shock. It blew up. And everybody was nervous about spacecraft systems.

But everything seemed to be working fine, and I was on the shift where they got it down to reentry. Then they turned it around, and they did the reentry maneuver. They separated it,

and they're coming in like nominal now; everything seems to be working right. And the thing goes into blackout, because the heat shield just generates all this ionospheric plasma, it cuts off communication so you can't hear anything. So they come in, and all of a sudden, again, it's like going behind the Moon. You figure out when they're going to the blackout and when they're coming out of blackout.

Well, they went into blackout about right, but when they were supposed to come out of blackout, it was easily a minute, and I think the record probably shows it was probably like a minute and a half, and the CapCom had been calling and calling and calling, and never heard anything. So people were really shook up.

Then all of a sudden [imitates sound]. About the same time everybody saw all the chutes, they called in and said, "Hey, we're fine. Everything's fine." And you saw on the camera right there in the Control Center, you could see the chutes coming down, so it was a good time for everybody. Everybody felt really good about it.

People said, "Well, why didn't NASA make more of a big deal of it at the time?"

Well, I told them probably because it was a screw-up way back at the Cape that never should have happened. The probe that came loose and fell down into the tank, they thought it was a sensor that had failed, and they just waived it in the Cape tests. They knew it happened. In all the diagnostics, when they went back and analyzed what happened, it turned out that a probe that senses, when it senses the temperature changes and all that, actually is sort of pushed up and sort of press-fit into a fitting, well, it came loose and just fell down into the tank. And there's a little sensor thing that's kind of a transducer that gives you the telemetry information you need to tell you what's working and what the temperature is.

They thought the transducer failed, so they just waived it. And what happened is it really had fallen off, and so when the pressure built up, there was nothing telling you there was any problem, and it just blew up. So the goof was in waiving that kind of sensor problem. You always have problems, and you're waiving all kinds of things, but just using good engineering judgment, you try to decide whether that's the right thing to do or not, and you'll be okay. Well, that was one that it wasn't right to do.

So NASA felt like—internally, I just feel like they felt that it wasn't a good engineering decision, so it was our fault; it shouldn't ever have happened. So you never got a good sense from anybody that you really want to talk a lot about it. But when you look at the way Kranz and everybody behaved and how the whole team pulled together and pulled it off, that was a good story to tell, and when *Apollo 13* came out, I think it kind of reawakened everybody to what really happened and how hard it was to pull it off. We're very fortunate that those guys came back at all.

WRIGHT: All that you were doing in those years from '64 till, actually, Apollo 13, there was a lot going on in the country as well. How much were you aware?

PAULES: Well, more than a lot of people, because I was still in the Navy Reserve. I stayed in the Navy Reserve and retired as a Captain with 30 years. But during that period I'd had these monthly weekend drills, and we would know. We were kept pretty much up to date on how serious things were getting over there.

We had guys that were in the Air Force. The Air Force had put them in for training. One of the guys that got divorced in that Christmas break, his tour at NASA had ended. He'd worked

some of the unmanned missions with me; he was a guidance guy. Then he goes off to fly [deHavilland C-7] Caribou in Vietnam for two years, and he comes back a really different guy. He's back about three or four months, and it's clear that things just went south on both of them. So he announced the day that the party started—I guess it was a New Year's party when this all came out. We combined Christmas and New Year's parties into kind of a break in between. He announced that they just couldn't reconcile anything. He was so thin. He lost a lot of weight.

It affected people in ways that you—we had our head down, and you didn't even know things were going on. Most of the guys didn't have a full appreciation of anything going on over in Vietnam, but we had had things like the submarines, when the submarines got lost, and they were lots of—the Cold War was still going on with Russia, and there was just a lot of stuff in the background that most of the flight control team probably never paid any attention to. I would hear about it and be involved in some of the stuff where we had to react on the Navy side.

But guys like John Llewellyn, Llewellyn was a Marine in Korea, and I think everybody in his platoon was lost but him in Korea over the offensive up north where they really pushed hard to beat them back, and then he never had much—[Douglas] MacArthur wanted to go forward, and [Harry S.] Truman wouldn't let him do it, and so he had to back off. Llewellyn never forgave him for that. [Laughs] Llewellyn would stay real close to it, and he paid real attention to everything going on over there. He's the old ex-Marine. He'd come in, wave the flag, and stir up all kinds of trouble about what was going on this week.

But generally, most guys I would say were pretty sheltered from that, mostly by their commitment in what they were doing. They didn't have time to look around much. So that was my observation of it.

A lot of other things were going on. Everybody was getting anti-Vietnam by that time, so there were all kinds of flag-burning things going on then. Again, guys like John Llewellyn would go out and stomp on the flag burners. [Laughs] There are a lot of Llewellyn stories. I hope you have somebody collecting Llewellyn stories.

WRIGHT: I don't know if we have that much tape.

PAULES: Yes, that's right. There are lots of Llewellyn stories. Yes, really funny stories.

WRIGHT: Well, after [Apollo] 13 did you go back primarily to working on Skylab?

PAULES: I had made my decision to move over to the Department of Transportation [DOT] in [19]'71, and [Apollo] 14 was launching before I left, so I went in and supported the launch of 14, and that was pretty much my last involvement with that. It was interesting; I followed it for a while. I was very involved when I was doing this research group I was with up in Cambridge [Massachusetts], so I didn't get to follow the space program as closely as I probably normally would have.

But, you know, it was my goal as a kid to go to the Moon, and I'd gotten there, as close as I'm going to get. I'd never be an astronaut or anything. You never know; you try to figure out why would you change, why would leave, why would you do stuff like that, but I had sort of met the goal that I had set to do. I could see Skylab being so much calmer and more tranquil and less exciting, say, than Apollo was, that it was probably a good time to change.

One thing about being a flight controller, you cannot let your guard down. You can't get complacent about anything, and we always all talked to one another about that. When you get to the point where you're feeling complacent about anything, it's time to move on. You really don't want to be putting anything in jeopardy by not being really attentive all the way through everything from design to execution.

That didn't particularly enter my mind, but when I talked with Lunney, other times later, Kranz. They marched me through the list of guys to go up and talk to, Kraft and so on, about why I was leaving. "You've got all this experience. It's time to stay. We're going into new programs," and so on. And I agreed with all that, but I wanted to get into new research at that point and work on these real high-tech, kind of Buck Rogers-y transportation systems. I have all those pictures, too, all these ephemeral kinds of guideways that carry people, move us all around. It's sort of hypothetical stuff.

I went to work at DOT working on these really advanced systems, and that was exciting. I enjoyed doing that for years.

WRIGHT: You followed one of your mentors, is that correct?

PAULES: Yes, John Hodge talked me into coming up there, because he had left. Cal [Calvin H.] Perrine [Jr.], who was in engineering, I didn't know Cal—I knew Cal because of guidance system work. He worked the systems side, and we worked the software and the protocols and procedures and everything; but I didn't work closely with Cal. But I worked directly for him when I went to Cambridge, and Hodge, we spent a lot of time. We'd get together. Everybody played bridge. We all played duplicate bridge, and so guys like Harold [G.] Miller—he and

[Carl B.] Shelley were—Harold Miller ran the simulation facility, all the computer software. He worked at [NASA] Langley [Research Center, Hampton, Virginia]. He was there as soon as they started up Mercury. So he's got a lot of history, and he retired after a certain stretch in Space Station. He came back. He went away and came back to the Space Station with Hodge when Hodge came here.

So I followed. Hodge was one notch above Lunney all through Apollo, and then he moved up into the Advanced Programs area, and Kranz took over. So effectively, it was working for Lunney and then Kranz for the end of my time in Apollo. Then I went up and worked for Hodge, with Perrine in the middle, for three years, and then the work I was doing for the Department of Transportation in urbanized transportation, the guy that ran that R&D [research and development] program here at [NASA] Headquarters [Washington, D.C.] kept trying to talk me into coming to Headquarters.

So I did, and so we moved here in [19]'74. Then I was working here for 10 years, and you'd hear things about people moving around, and the Space Station Program was starting. They were starting studies. Then I heard the big announcement in I guess it was January; [President Ronald W.] Reagan made the announcement in January of [19]'84. Then in about September of '84, Miller has gone back to work for Hodge. Miller comes over and says, "Hodge wants you to bring all that analytical experience on cost-effective, life cycle costing, and all this back over here and come to work with Space Station."

So I did, and I stayed with NASA right up till a couple of months ago. I worked Space Station from [19]'85 all the way up to [19]'94, and then I switched over to be the Chief Technologist for the Earth Science Program at Headquarters. I was at Headquarters all that time, from '85 all the way. Very different world from being out in a Center. [Laughs]

WRIGHT: We look forward to hearing about that. And before we close today, as our time is getting close to the end, I have two questions I think I want to ask you. One is that all the years that you sat at Mission Control for launch, I understand you actually got to see a launch.

PAULES: Yes.

WRIGHT: Tell us about Apollo 17.

PAULES: Well, gee, you did do your homework. I had left NASA by that time. [Apollo] 17 was the last mission, and it was a night launch. I'd never seen any launch, Apollo launch. I'd been out to see the vehicles being crawled out to the launch pad and went up in the VAB [Vehicle Assembly Building, NASA Kennedy Space Center, Florida] in the very top, and got to look in the spacecraft after it's been all assembled and everything, but I'd never actually seen a launch.

So I said, "All right, I'm retired." Let's see, our daughter was born in [19]'71, so it was December of [19]'72, I guess it was. So we all went, and I took the family. We were going to go down and watch the launch. Well, we had it all set up, and remember, it slipped a couple of days, and our flight and everything was all set up; we had to go back. But on the last day with the last minute of the last hour or something, they finally got the thing off, and I have all these movies of it. I took still 35mm shots while my wife was taking movies of it.

It was really exciting, because it's kind of a great way to end your career and that particular notch in your career, because you got to see the thing really happen. There's nothing

like being at a launch, even though you're not really close to it. The launch vehicle looked about this high [gestures] out at arm's length, probably.

But when you see it lighted and the engine light at night—you're not expecting the shock wave actually to get all the way over to where the viewing areas were, but all of a sudden you can see all these birds take off. Flocks of birds take off, these seabirds between you and the launch vehicle, as this shock wave comes rolling toward you. You can see that the brush and the trees all wiggle. You're still not expecting this thing, and it all of a sudden [imitates noise]. It's really very, very exciting. It just rumbles, and it's a really deep rumble.

I went to a [Space] Shuttle launch later when I went back to work for Space Station, and the Shuttle, I compare them in the Navy to like a 16-inch gun firing—which is a real deep [imitates sound], and the whole ship shakes and everything—to a 5-inch gun. This is the size of the bullet, 16 inches across versus 5 inches across. The 5-inch sounds like a really sharp crack. It's just a crack [imitates sound], really different, and the Shuttle sounds the same way. It crackles when it takes off. The Saturn V would just kind of—you could feel it in your bones. It [imitates sound] all the way through, even where we were standing. [Laughs]

So our son—we didn't talk about that, but our son was growing up during this period, and one of the things I'll always remember, he could draw all the orbits, all the trajectories, and the stuff about how these things would fly out around the Moon and make the loops, and all the various key sequences that occur. We've still got all this cartoons he drew when he was six, seven, eight, during that period. He remembers it really well.

He got into model rocket building. We went out and launched all our model rockets all through that period. We got into a club that built model rockets. So he was very involved, our son was. My wife, like I said, she would teach school at the high school, and the kids, almost all

the kids around there went to that high school, so all the astronauts' kids, Schirra's, and a whole bunch of them would go up through the teaching process with her in Spanish. She taught Spanish.

So one of the things that happened is when Armstrong had flown [Gemini] 8, and they were doing a world tour after that was over, and they went down to South America. They wanted to get a little familiarity with some key Spanish phrases they could take with them, and so Schirra's son mentioned, "Well, get Mrs. Paules. She can teach you all that stuff."

So Armstrong and Dick [Richard F.] Gordon [Jr.], they came over to the house two or three times, and they'd sit in the evenings, and Dinah would teach them key phrases in Spanish they could do. Armstrong took off. He just learned it all, flat out, and when he got down there, he had learned a number of dialects for like Ecuador and some of the others so he could tailor what he was saying when he would speak to the crowd. All this was kind of—he just real-timed it. He was really a sharp guy. A very analytical guy, but bright, bright, bright.

So she got very involved in the space program, and the one thing that you always remember, I was in the Navy, and we were in the Navy together. The Navy is very close-knit. Your ship goes to sea for six months or eight months, and the families all take care of one another. The officers' wives all congregate. They do a lot of things socially together, and the kids, they kind of take care of one another for everything.

So we got really used to that kind of environment where everybody was close that you work with, and it was the same when you went to the space program. We did everything together, almost all the socializing with people you worked with, and the wives knew other wives. Everybody knew everybody, and you did a lot of stuff together.

That was the biggest shock, although we knew it would happen, when we left NASA and you went away, there's never an environment quite like that that's so closely knit as the flight control groups. That was the biggest thing we missed, and still miss that. We get together for all the reunions, whenever they have those things, and stay in touch, but it's not like you live together almost for years at a time.

It was important, because the wives, they went through a lot of trauma in the process. They were out of synch with daytime; your schedules were all screwed up, but they supported one another very well. The kids all grew up together, and it was a really good experience from a personal lifestyle thing for everybody, even though it was hard on some people.

WRIGHT: One other thing I wanted to ask you, too, while we're still on the Apollo era, you mentioned a few minutes ago that in '84 President Reagan announced about the Space Station. Well, in 2004 President [George W.] Bush said that Americans are going to return to the Moon and then go beyond. If you had some lessons learned or some advice to pass on from one lunar landing era to the next, how would you suggest that the people that are now creating this program, Constellation, that's going to take us back to the Moon—what lessons learned could you offer, based on your experiences, that would help them get there?

PAULES: Well, it's like we talked about kind of at the beginning. The thing that's important in flight operations is really knowing the systems well, know how they behave, what works well, what doesn't work well, how they interact with one another, and the human interface for those systems, either the crew or the ground. The only way you really have a way of mastering that and having some influence is to have your flight control and flight operations teams sort of a

concept of operations built into the management of the design and development of the whole program. So you've got flight operations very heavily influencing—not just the ground crew, but the flight crew—very heavily influencing the design as it moves forward through the development phases.

You can't just go off to—like tends to happen sometimes, especially in the unmanned programs and military programs. You spend a lot of time designing things, and you hand it over to an industry guy. They build it and then hand it back to you when it's all built. With these kinds of systems, where you've got human lives always on the line and long-term quality control and viability, where, really, mission success depends on these things lasting for long, long periods of time, being maintainable, and all that sort of thing, the only way to do that is have the operations people, people with experience in operations, very involved in the design right from the get-go. That's the biggest advice I can give them, because that was so valuable to us when we were doing Gemini and Apollo.

They tried to do that with Shuttle, but they're trying to make Shuttle, I think, probably—and I think everybody agrees with that—is they tried to be too many things for too many people. Tried to solve DoD [Department of Defense] problems, and a lot of things for one vehicle. It makes Shuttle really complicated.

WRIGHT: Do you have anything else you wanted to add today about your Apollo times or looking back over this?

PAULES: No. It was a wonderful experience. It's just something you can't ever recreate. There will never be another first landing on the Moon.

WRIGHT: Thank you for today, and we'll come back and talk more about Station and beyond.

PAULES: Okay.

[End of interview]