NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

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INTERVIEWED BY REBECCA WRIGHT
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WRIGHT**:** Today is September 10th, 2013. This oral history interview with Frank Hughes is being conducted in Houston, Texas, for the NASA Johnson Space Center Oral History Project. Interviewer is Rebecca Wright, assisted by Rebecca Hackler, and thanks again for finding time for us again this morning. We were just talking about picking up where we left off from last time, and about how the Apollo 1 fire, and that time after, was such a turning point for the space agency.

HUGHES: It was a turning point. There were a couple of major turning points in that area, if you think about it, but let's concentrate on the simulators themselves. At that point, now, we're talking about 1967, Mercury was designed by McDonnell Douglas, and they put together a simulator, but by today's standards, it's more of like a little, small, part task trainer. There were hardly very many tasks to be done in Mercury, so it was a very simple device. Looked good, it looked like the inside of the spacecraft. The computers that ran that simulator were analog computers and not digital machines.

In Gemini, it got much more sophisticated, that is the computers that ran the system were very good. The instructors who operated on it were much better, too, that is, they really understood the systems because they were a lot more complicated, but there was no training rhythm to it. The crew walked in the door and set the stage of what they wanted to do. There

was no such thing as a lesson plan or objectives or whatever. You trained until you flew, and it just filled up the time. If things delayed, then you trained more, and you just went on like that.

When I got there in May of '66, I jumped in the middle of that, and that's just how life was. As time went on, it'd get more serious. You could just see that there was a problem with it; the drumbeat was only the clock, there weren't any specific objectives. You knew that you wanted the crew ready to go, and they just looked at the timeline, so they just practiced launch, then they practiced landings, and they practiced rendezvous, if that was going on. They just did it over and over again. The simulator, by the time you got to Apollo, had a fairly large set of malfunctions. The people that had worked on designing it had pre-installed a bunch of malfunctions, one for everything you could do. The fuel cells could fail, tanks could leak, all that sort of thing. The design was there, and of course, it was following along with what Link [Division of Singer Corporation] was building for airplane simulators. Somebody sat down and said, "Okay, this is the system, so we're going to have malfunctions X and Y and Z," to put it in without a whole lot of thought about how they'd be used in any kind of a scenario.

Then, we started putting in the scenarios, and this is nothing fancy, it'd be a piece of paper, it'd say, "Okay, tomorrow, they haven't seen any leaks in the environmental control system, or a long time since they've had some," things like that, so people would just write it down and walk in with their spiral notebook and do it. It was okay, it was working, but again, the only thing that you talked to is accumulation of time in the simulator. We talked about, I think when the Apollo crew would fly, it was 300 hours in the simulator. The arithmetic was you had X trainings in the [Northrop] T-38 [Talon], not just flying from Houston to Los Angeles [California] or Houston to the Cape [Canaveral, Florida], but aerobatics and things like that to keep their inner ear ready to go. Gradually, as we got close to landing on the Moon, of course,

you had the LLTV, the Lunar Landing Training Vehicle, (which a lot of people were worried about that trainer). It was an unstable, Rube Goldberg kind of thing. We built four of them and three crashed during the training. The one that's left it's over there in the—

WRIGHT: Teague Auditorium [Johnson Space Center, Houston, Texas]? Yes.

HUGHES: Yes, the lobby of the Teague. We're lucky we've got that one still. Bud [Harold E.] Ream had to bail out of one, Neil [A. Armstrong] bailed out of one, and I can't remember the third one, but I remember we lost them all.

WRIGHT: Was it [Joseph S.] Algranti? Did he bail?

HUGHES: Yes, Algranti, that's exactly who it was, you bet. Yes, in fact, he was almost as bad as Neil in terms of his angle when he finally got out and landed. It was almost like the chute popped and it hit the ground; that was just that close. You're so close anyway; you were never more than a hundred feet up, so it's tough. That's what they used to call a 0-0 ejection. You had no speed forward and no altitude, and so just whatever you got from the seat is what you got. The problem is, you're hoping you go straight up, and if you see Neil, he goes out at less than 45 degrees. He's going across the ground when he comes down because the thing would start swinging back and forth.

We had a couple of other simulators that you may not have heard—in Building 5, there was a Dynamic Crew Procedures Trainer, DCPS, and the whole visual system was actually projected inside of a half-sphere, so it was like a planetarium set on its side, and this Apollo

spacecraft was hung up in there. It was gimbaled so it was mostly good for ejection if you would take the rocket ride on the Launch Escape Tower because it intentionally would go away from the vehicle, and then it would start tumbling, intentionally. This thing would tumble, and then it would eject itself. Then, as the tower would go away, it would be up to the crewmen to stop that tumble and put out the chutes.

Again, you're talking about a 0-0 condition, it's all automatic, but above that, you'd try to get that tumble under control, because you don't want to roll up your chutes around you. We had, in Building 5, we've extended that building, but it used to be there was a simulator side, and then on the south side, there was a big open area, and in there, we had a docking trainer. It started out as an Agena and Gemini [trainer], and then we switched it for a LM [Lunar Module] with a Command Module. It was dark, and it was a big open area, and the Command Module, or the Gemini, as it started, the Command Module was static. It would go up, down, left, right, and the target, which was the LM, would come towards you out of the dark. You steered in there and docked with it. That was their best thing, other than the CMS, the Command Module Simulator [for docking training]. When we put it all together, the visual for that started working pretty good.

The Command Module Simulator and the Lunar Module Simulator [LMS], each one had a model house. I've got pictures of these things—we should probably share photographs and everything else—but if you could imagine, just the Command Module one, that there were two cameras set side by side because there were two forward-looking windows in the Command Module. Then, they'd be looking down a track and coming towards you was a model, a physical model, of the Lunar Module, and it's a full model so it's got legs and everything else, so it looks really, really good. Then, as you came closer, this camera could go up and down and left and

right, and the model just came towards you on a track. And you would line it up so that when you did that, you could see it move, what you did with the hand controllers, you'd hear the noise, you'd hear all the audio of jets firing, and then the visual would get close. This is projected into the windows and behind that image is the stars. Remember, I told you about how good the stars were? You'd actually get a visual of the Earth, too.

The Earth was never very good—but it was the best in the world at the moment. Compared to what we've got today, it's nothing, but then, it was stupendous. People would come and just see it, that kind of thing. The stars were really, really good. When you came in, then, you docked, you physically docked, so with the flags, plop down these little crosshair—they look like barber poles. In fact, that's what you'd say, "Your barber pole," which means that the probe had slid into the drogue and connected.

One of these times, we may walk over to Space Center Houston, then I could fill in for you guys with some of this [information], so you could see the hardware and I can tell you what some of that means. If you will, on this whole thing, there's a drogue, it's called, it's a big funnel-shaped thing on the top of the LM. In the bottom of it, there's a hole, and so, when you came in, even if you didn't do very well, you'd slide down this funnel. Then, this probe of yours—it's kind of like the male/female pieces of this thing—this probe would go through this hole in the bottom, and then it had little latches that would snap out, and they'd hold you there. It's called a soft dock, so the vehicle could still move around, compared to that. Then, you would throw a switch and it would drag itself back in, so it'd pull the LM back.

When it did, there were two O-rings around this tunnel, so now you just pulled them together electrically. You could check the air pressure inside that tunnel. If it's good, then you would open a hatch on the Command Module side. You'd go inside and connect a cable that

would connect the Command Module to the Lunar Module now, so that is, you could talk to it. On top of that, there were 12 latches around that tunnel that you're in, and by connecting those up, you have physically now made it a solid vehicle. Now it's one animal so that when you steer in the Command Module, there's nothing movable or loose and flopping around. That was a pretty good deal.

A side story: everybody came in the Cape to see what's going on, and here, too, but Gene Roddenberry [creator of *Star Trek* television series] and William Shatner [actor] came by. They were down doing some local scenes down there for some program. I remember that they had inset on a Centaur V launch because I think they went back in time [for the *Star Trek* episode] to try to save us [Earth]. They were doing that, but they came by with, I think, Pete [Charles] Conrad [Jr.]. Pete was always bringing people by, "Isn't this amazing?" He's so gregarious.

They showed up and it was great, everybody was excited about them. So, we put them in the simulator, the Command Module simulator. It's Pete in the left seat, and then the two other people in the other two seats, and we launched them, which is a roar. No vibration—this is not a motion system and anything like this—but visually-induced motion. You get up there and pop, there's the stars and everything. It's really good. Pete would say, "Okay, now we'll turn around and dock with the LM," because it was supposed to be like an Earth orbit, like Apollo 9, so they're getting ready to do this. They turn around. Unbeknownst [to them], a fellow named Gary Probst was our visual guy, and instead of the Lunar Module, he had built a Revell model kit of the [USS (Starship)] *Enterprise* [from *Star Trek* television series]. He had that mounted in the model house, so when they turned around and looked back at the LM, there was the Enterprise against the stars. Pete and everybody went crazy.

Here this sucker was just hanging against the stars, and we were just amazed at how good it looked. They had to crawl over each other because there are only two windows, they had to crawl around so they could look out there and see what was going on out there. He says, "Let's go see it," and so, Pete took the control, and he literally, they flew down the left side of the *Enterprise* and around and back up the right side, like you were going to dock with it—it was so good. Then, they went on; he was showing them other things and how to navigate and how you take pictures of the marks on the Moon. It was pretty good.

I was sitting there, I was looking, and this is old style TV, so there's real bright lights on this thing. I looked up, I'm just on the simulator console, running the thing, and I said, "Oh, Pete, check, there must be some problem with the space up there," and they all looked back, and the *Enterprise* was melting. The front end was just kind of drooping down. I called Gary on another line, I said, "Gary, get your model." I turned off the lights quick, and of course, the plastic would freeze up again. We couldn't stop where we were at on the tour. The guys, they came out and they signed it, Shatner and Rodenberry signed across the *Enterprise*. Somewhere in the world, Gary has a nice memento.

WRIGHT: A great, fun story, yes.

HUGHES: Yes. There were so many things like that. Well, came time a couple of years after that—they did the first [Star Trek movie] about "*Veeger*." It's just called *Star Trek: [the Motion Picture]*, but the first one was about the Voyager. They ran into Voyager, but it had developed intelligence, and it was trying to find its way home. When they first saw the *Enterprise*, by now, the *Enterprise* was a really high-class model, CGI [computer-generated imagery] was not even

used. If you go sometime and look at the movie, they had launched on a shuttle or something like that and they're in orbit, and the *Enterprise* is in dry dock, and all of a sudden, Shatner says, "Let's take a ride around it." They did, they recreated that whole thing. They flew down the left side and backup the right side. Now the *Enterprise* is cool and it's got lights outside, and windows with lights on inside. I said, "I've seen that before! I know where they got that idea!"

WRIGHT: You lived it, yes.

HUGHES: Yes, I know where you got that idea. It was so cool.

WRIGHT: The simulators, though, the pieces, these five different training areas, but specifically, the simulators, were these built by the manufacturers?

HUGHES: No. For both Apollo, the Command Module was done by North American Aviation, and Grumman did the LM. Both of them contracted with Link to do the simulators, so that worked well because then within Link, they worked to get these two simulators working great so they talked to each other and generated local telemetry.

I want to talk about that for a minute. As the simulator came together, if you think, there's the physical thing, the crew station, we would call it, that's the cockpit, and for the LM, too. It was perfect. The communication between the manufacturers in to them was great. They got panels; they got stencils that they used so that the images, the panels looked like the real world. The switches felt the same. We did everything we could to make it feel good and look good. Hand controllers were the same hand controllers they used in the vehicle; they weren't

rated at the same way, they didn't cost the same amount, but they were the same hand controllers.

In fact, there was a hand controller repair shop down here in Houston, and many times, if I had done a trip from Florida to Houston, I would carry my suitcase and another suitcase that had a broken hand controller in it. It would come back here and get fixed and go back on another day. To save shipping, we'd just carry it down by hand, and I'd get another one on the way back. They'd have another one ready for me when I would have two or three days in Houston, and I'd take a new one back there that would be installed in one of the three simulators that were down there.

Remember, we had one of each [simulators] here, and then we had two Command Module [Simulator] and one LM down there [at KSC]. It was supposed to be two LMs down there also, and they cut what was LMS-3 because of funding, by that time, as we were slowing down. There's the crew station, then you have a host machine that has all of the software so that the environmental control and the electrical power and the communications, every system that's separately simulated, and then they talk to each other. It's a mission simulator, where if you fail the electrical power over here, then it's going to show up some parts in the environmental control, some of the GNC [Guidance, Navigation and Control] all the way down through the other systems. That was important, I mean, that was really important to do.

On top of that, you had the visual system. We've talked about that just peripherally, but we can spend some time on it. Those are some things I could show you some pictures, like I said. Then, you had a network simulation—that is, we had something where the simulator actually generated telemetry, then we had software that made it look like it was coming from Hawaii or Guam or something where you were in the Earth. Later, when you're at the lunar

distances, there were just three stations: Goldstone [California], Madrid [Spain], and Canberra [Australia], Honeysuckle Creek down there that had big antennas so you could look as far away as we were. We had to simulate that network system.

I want to go back just for a minute and talk about that; today, I want to get into it. When we did Mercury, the sophistication was very low. We were always pushing the edge, it was the best you could do, but when you look back on it, even by the time we were doing Apollo, what they had done in Mercury was really old-style. The magic and the simulation guys, they would make up tapes, big 12-inch tape reels, and they'd send it with a guy who physically would carry it out to Australia, and then they'd have a timeline. Here comes the spacecraft overhead, they would play this tape back through a phone line back to Houston, so it looked like the spacecraft went by and it was okay, things were going along. There'd be another guy sitting in Hawaii, waiting, if that's where it was going up, so it'd be heading northeast across the Pacific, and they'd play another tape that was synchronized. "Now, here comes the spacecraft over the hill, you see it for five minutes, and then it's gone. They would send a simulator guy and a CapCom [Capsule Communicator] out there, one of the astronauts.

When they did a simulation of the network, that's what it was called, the network simulation. That term is important right now because you were doing a simulation of the network. There were no spacecraft flying, but you didn't have a simulation except the network, so you played these simulated, phony tapes through the system, and the real system looked like there was a vehicle that went by.

When Gemini came along, they had developed enough computer capacity to begin to simulate the network, so now you didn't have to send people all over the world to do this. On top of that, with the new MCC [Mission Control Center] that was being built in Houston, the

data could be sent back here, so you didn't have to have CapComs out there either. Do you remember the time in the early flights, where you'd hear these beeps with every conversation? They'd say "beep," and then you'd get a CapCom saying, "Gemini, this is Houston," and then he'd un-key, and you'd hear a beep. The beep actually was a trigger signal, so that way out at Hawaii, there's a mission going on, but it would be a signal going out, and the big amplifiers out there at the site would turn on so that whatever voice came down that line just like a telephone line, but it would be sent out to space. Those are called Quindar [tones], they were big switches, and when the guy got beeped, talk, talk, talk, beep, the things would turn off. That was how you sent it. The crew didn't hear that beep; they just heard somebody talk. It turned on, whatever you said through there, and then it'd turn off.

That's what that signal did, so that was this time where they were able to sit in Houston and talk to them. The only two people that had that ability were the flight director or the CapCom. What would happen is now we would have simulator sessions, the crew would get in the simulator, people would get in the Control Center, and we'd do a simulated network simulation. It's still a net-sim, right, everybody's getting trained who are up and down the line, but the data's always coming from the simulator, and the CapCom sits in Houston, in the Control Center. That became a Sim-Net-Sim. "We're going to have a Sim-Net-Sim today."

As you went through Mercury and then right into Apollo, we would do that, sim-net-sim, but on top of that, you not only have the instructors running the simulator, now, you'd have a couple guys come from Houston that would sit on this network console. They would put in malfunctions on the network. "Hawaii's antenna is stuck, it won't move, so they're not going to get any data from Hawaii." All kinds of stuff like that. You could see that now we're practicing all of the people, and not just the main flight controllers in the room, but the people we called the

ground controllers—these are people who run MCC, that is, how to make it run. And even today, if you look at the [International] Space Station consoles, on the back row, far on the right side, it's called GC, Ground Control, that's those people that make sure that the MCC supports what the flight controllers want to do.

That's an honorable position, those are people that are really good at what they do and they always have been. They own the building. They can field backup computers, they could bring another one online. Sometimes in the tapes of the real flights, you'll hear the flight director say, "We're going to get into this rendezvous," or, "We're going to landing." He'll say, "GC, let's bring up the backup computer." They'd have a running backup computer; they could switch over to it without even thinking about it. That was going on, and yet, they were unsung heroes. A lot went on and they didn't get all the big attention of what's going on during the missions.

In our simulator world, it was the same thing. They would come down and work on the network, but the problem is, they had a very circumspect kind of thing because if they put on a failure that killed the communications between the Earth and the spacecraft, then what the hell is the simulation doing? You know what I mean? Everything stops because until you fix the communications, nothing else is going to happen.

We always had a session problem like that, where the first thing you'd want to do with those guys is let's mess up downlink at Hawaii, or in Africa, or wherever the heck, in Spain, and then we say to them, "Well, if you do that, I can't do my other malfunction that I want to do over here because FDO [Flight Dynamics Officer] wants to see that down in Houston.". It was going on, but those people managed to make it work, and they got it done every flight.

We never had a problem where we didn't have data from all those crazy computer connections that they had to do, and the people were awesome. They really continue to be. It's just different now because everything's out of Houston, you're sending it to satellites; the only piece on the ground is at White Sands [New Mexico] because the TDRSS [Tracking and Data Relay Satellite System] satellites, and that's where the TDRSS control center is at. That's a very interesting place, if you go and talk to some people up there, that would be something fine.

WRIGHT: When you were first talking about Mercury, the training was built on accumulation of what the timeline was going to be, they'd launch, they'd do this. At what point did there become more of a choreography of how to build a training schedule to get them ready through all these simulators with such limited time to get them ready for the flight.

HUGHES: It really didn't happen until Shuttle.

WRIGHT: Wow.

HUGHES: Shuttle, it really was. It got a little better for Skylab because I got involved with that, so we can hold on to that. Along the way, it bugged me, too. In other words, I just was only a year or two out of college, and college had a catalogue and it had precursor stuff. You wanted to get a physics degree, this is what you have to go through, and you know how many hours it's going to be, and so on. If it's a chemistry degree, you know it's a whole different set. Some the same, but many different, like that. In this training system, you just got in and farted around for a long time, and then you flew. It just bugged the hell out of me, gradually. It just was one of

those things where you'd go with because you'd think that's how things are, but then you realized, we flew some people that were just dangerous. I don't want to get into the names here until a few more of them die, but I mean, it's really bad.

I'll tell you, on Apollo 11, we asked Deke [Donald K. Slayton], we begged him to keep them on the ground one more month because it went so fast, went from [Apollo] 8 to 9 to 10 and 11, it was so fast. We said, "Just let that Moon go around one more time and we'll be so much more ready." Of course, it was way out of anybody's hand because by then, you'd announced it, and it's a political thing. It had nothing to do with whether they knew what they're doing or not. Obviously, they did a great job. [Apollo] 12 was much better because now we'd head in to November. Everything we learned about 10 got put in, whatever we learned about 11 was more of it, so 12, that was probably the best, ready-to-go flight at that time.

It got better and better as we got on because we knew how to train them, too. We knew what was important. We made the simulator better because every flight was a test of the software, so that made it [better], we'd go back and say, "Well, it wasn't quite like this, it's like this," and so, then we made the simulator do that, whatever it is. That went on and on and on.

[Apollo] 13, Jim [James A. Lovell, Jr.] was really good. I worked with him on Apollo 8, just on navigation because it was the first time he got into what we called cislunar navigation, navigation that's away from the Earth. If you think about it, all navigation we talk about, you always have the Earth underneath you, and GPS [Global Positioning System] does it even the same, where you still think about altitude and you think about latitude and longitude. What if you're 150,000 miles out away from the primary planet and you're getting close to the secondary planet, or it's going to become the primary planet? It's a whole different thing. That one, you'd get into things where you measure star angles.

You actually find a star that you know and you measure the angle between the star and either the edge of the Moon or the edge of the Earth, and that angle, if you think about it, the star's not going to go anywhere, so you could take that angle and you could rotate it. You could make like there's a cone, and you know the only place on that angle could be if you're somewhere on the surface of that cone. Then, you take a second one, a different star, and then you'll measure it, and measure it to the Moon, the edge of the Moon. Then, you get a second cone. If you can imagine those two cones being put together, there's only two places you're going to be, and it's on the two lines where the two cones intersect. If you do a third one, you get a point.

There's only one point where all three of those cones get put together, but we only did just two because in the computer, it also had an idea of where it was to begin with. It's projecting a state vector, it's called, which is three numbers of position and three of velocity and time, so there's seven components of this state vector. There's a guy up at MIT [Massachusetts Institute of Technology, Cambridge, Massachusetts], he created a thing called a Kalman filter, and you took all these things and you mixed it together. What it would do is say, "This is where we thought you were before, this is the two possible places you could be, so it must be this one because it makes sense." You'd correct your position based on that.

WRIGHT: Your astronomy background.

HUGHES: Yes, it was right in the middle of that. We had a grand time making it work, but then we fed back to the guys at MIT all the time to say, "Well, what if this happens?" It's that million monkey thing, when you get astronauts involved and they're not going to do exactly what you

thought they were going to do because of misunderstanding or whatever, and they find some error or weakness in the software, and so we'd give feedback and they'd get it fixed.

WRIGHT: MIT and the whole cooperation or coordination, let's see how you describe how that was an ongoing evolution.

HUGHES: When you build software for a spacecraft, you verify it. That's a big part of the cost, is how to verify that the software works. There are a lot of things, like in Shuttle, they had that SAIL [Shuttle Avionics Integration Laboratory] that was what it was for, the avionics integration, testing, testing, testing. Astronauts were over there all the time. In the SMS [Shuttle Mission Simulator], and before it, in the Command Module Simulators, Lunar Module Simulator, we never had that. That's not our job, to test—it was to train—but inherently, you tested it every time you turned it on because we were doing some things about it. That's what occurred. Very rapidly, the guys in the software world at Houston and the guys at MIT realized what a benefit they get out of making sure that they knew exactly what was going on all the time, so what we did is we created a—I can't remember the name of it—but it was a software coordination group. [Interpretive Simulated Apollo Guidance Computer (ISAGC) Coordination Group]

Jack [John R.] Garman and guys like that were down in Houston, here, and so, Clair [D.] Nelson—I mentioned him before—and I co-chaired this software group within the simulator to make sure that the simulators got the latest and greatest software all the time. Anything we saw wrong with the software was fed back to MIT and back to Houston, across the duck pond, that the guys on the east side or the simulators over there in Building 30, are the builders of the

software. It's funny, sometimes that could be as far away as from here to Dallas, it just depends on the organization.

We just really worked hard to make sure we were in each other's pocket all the time. It worked very well, and it came to the point where we knew what was going on intimately all the time, even though I was a GS-9 or GS-11, Clair was, I think, one step higher than me, just because he'd been here two years and did a little bit of work on our Gemini, but everybody was 24, 25 years old. When it came down to it, we also knew inherently that the crew was ready to go, or not, that they had gaps in their knowledge base.

During this time period, there was a place in Mission Control called the Simulator Support. It was a room right across where the door is now for the MOCR on the third floor, it was called the Flight Director's SSR, Staff Support Room. In there were people like Jack Garman and John [W.] Jurgensen, who were the software weenies, and they talked to the software guys out on the main console, and then there would be one each of our guys. I would come down here with a Command Module guy, so we'd work 12 hours, and there'd be two Lunar Module guys come down. I did lunar, too, but not as much. I concentrated on Command Module.

There'd be two of us, one representing each simulator, there, and we worked for the flight director, directly. I could punch up the buttons in flight—we did, routinely—somebody would say, "Okay, CapCom reads this procedure to the crew," and they wrote down whatever it was. Then I got to punch up that loop and say, "Flight, you should have CapCom do that again because I can tell from the way he [astronaut X] said it, he's not paying attention. It's like if you know your husband and you say something, but he's watching TV, and you get one of those 'Oh, okay.' You know that he did not hear whatever you said. It's that kind of thing.

The guy would say something like that, you'd just know that he was half-listening or he was sleepy or whatever, but he didn't get it. The CapCom would just say, "Let me go over that one time. So, they'd always do it, they never said, "No, you dummy," but somebody would say, "Okay, somebody down here didn't hear what I had to say; I want to say it again to you to make sure." That generally is enough to snap them up and make sure that they listen, too. That was a position that we were there through all those missions, through the whole Apollo thing. That's different. They didn't have that in Mercury or Gemini. The people were close enough because it was just across the hall, you could get that kind of help, easily.

The coordination with MIT was interesting because there were about four of us who really almost lived in Cambridge, there, because we went often enough. There were always meetings. Any software, there's new versions of software; it comes out on a routine basis. They got to the point where they got a rhythm, where there was a new one for each flight. They got cute names, like they were the software, C was for Command Module, so it'd be Colossus and Columbus and different things like that. The Ls for the Lunar Module was Luminary, and other things. I can't remember some, but they had these code names. It's like today; you hear Microsoft or Apple do things like that, just because you have to have a way to talk about the next versions coming, because number 62.5, it doesn't have the same romantic appeal. People say, "Wow, this is really cool, this is good."

As we went along, we got to the point where there was almost like a triangle between Houston software, KSC [Kennedy Space Center, Florida] software, and MIT. We were just going at it all the time, so it was routinely, just pick up a phone call and say, "What's going on?" It's funny, as a second dotted line out to Downey [California], where they had been the top dog for early—because they came up and had all the money to get something going right—we were always

slower and behind it, but once the simulators matured and came together, no crewman would ever go out to Downey anymore because they could get everything they wanted with sitting at home. "At home," relatively, at the Cape. It was amazing what would happen, and it would just go on like that, to the point where the Apollo wives had to come down to see their husband down there. They moved into the Cape. When they went, they didn't ever go back home. It was the last 60 days, or something like that, they just stayed there. And the wives and kids would come down to see them and then either stay for the launch or leave and go back home, depending on how they wanted to do it.

There's a whole other thing—we don't talk about it—how much pressure there is on a family. I always talk about I want to write a book on the pressures on the wives, then. The pressure on the mates came because then you get how many tickets you have to buy. It costs you about, I figure, to fly on a Shuttle, it costs you something like $5,000 to $7,000 because you had to buy tickets for all the family members that couldn't afford to come to see you launch, and it's a one of a kind [event]. You'd have the problem where your mother, is going crazy and the wife has got to take care of her, and she's got her own problems of thinking about fears, but you've got to maintain some composure and settle down the other members of the family that are going batshit. It's just wild things going on every day.

WRIGHT: You were part of that coordination team, and so, did you have instances where the three pieces of this triangle didn't necessarily agree on what was coming through on that software?

HUGHES: Oh, yes, yes. Not terrible agreements—we talked all the time—but they'd put out a brand-new piece of software. I'll just give you one example, they do the best they could, they send it down to us, and it was a piece of crap. Something that used to work doesn't work anymore, things like that. We came in to one and it was very interesting because remember I told you we had this ISAGC, this Interpretive Simulated Apollo Guidance Computer? It was living inside this simulation computer down here. We found out that there was a computer problem. We went up there and I went to Boston, and we did a rendezvous. When you did a rendezvous, there were three or four maneuvers. If you do a rendezvous, you have to do three things. You have to do a maneuver to make sure you're coplanar, that is, the orbit of your plane and the other one is coincident, and if it's a little bit out, you fix that first. That's very expensive, in terms of energy.

Hopefully, you launched into that same orbit, but then, after that, you make it coelliptic, that is that—I'm going to draw a picture—just that with an exaggeration, let's say here's the planet down here. You get so that you're always at the same delta, it's like if you can imagine somebody drawing another ellipse, but it's exactly the same, 1-inch all the way around. That's being coelliptic. You'd finally do the last thing, you would maneuver from that orbit up to the next orbit, so you only go up 10 miles, or something like that, because by being down and behind it, it means you were catching up. If you're a mile down, or let's say 10 miles down, then you're catching up at 20 feet per second around the Earth. It's just how it works out. You would get these very simple things, so then you knew that every second, you were getting 20 feet closer to where you want to be. It's two feet per second per mile lower in orbit, it's just around the Earth, but it's a little bit different around the Moon, but I'll just give you an idea because we've been

doing so much around the Earth for the last forty years. Then, you go coplanar, coelliptic, and then coincident, that is, coorbital.

You go up and make two maneuvers, one that makes you accelerate, so you actually drift upward that 10 miles, and then when you get there, you add more energy to stay at that orbit. That really is called braking, because you're going up and you get closer and you fire jets, but you're actually firing in the direction you're going, so it makes you go faster to keep up with them. Relatively, it looks like you're just holding position. In Cambridge, we did this maneuver and I checked. It's a little computer, so when you'd ask it to compute the next maneuver, let's say, to do a constant delta height, this is to make it that coelliptic, then it would take 30 seconds, literally. It came on and there was a little light that came on and it said, "computing," and it would be working its little heart out, and then you're done. It's good.

Next week, I'm back in the Cape, we've got that same computer software there, ran it and everything, and hit the button, and, boom, got an answer. I said, "That's cool." Then, I realized, wait, how did it get that answer that fast? We just saw this other one struggling with it up there, and this is the same software and it's the same problem to give it. It turns out that the simulator computer was running too fast. That's just giving you an idea. We found this and we could fix the thing, so we intentionally slowed the simulator computer down so it'd match what a real Apollo Guidance Computer would do. It's like if you had a Pentium, and suddenly, you wanted it to go twice as fast, that would be great in a lot of ways but if you're trying to simulate the first one, you want to make sure the guy doesn't think it's broken now because it's taking forever in the real flight to get the thing to the right answer. That just gives you one idea.

There were errors, just simple errors or screw-up, the typos show up, things like that, where they had to get it fixed. Once we get it fixed, it would work just right. There was always

constant feedback going back and forth. It was interesting, that intimacy. At that point, I would have to go to the Flight Readiness Review [FRR] in Houston, and North American would get up and say, "The spacecraft's ready, Joe."

LM, Grumman people would stand up and say, "They're ready to go."

MIT would say, "The software's ready to go."

Then, Chris [Christopher C. Kraft, Jr.] would turn to me and say, "What are you doing, Frank?"

I said, "Yes, crew's ready to go, Chris." I look around me, and Deke, I'm sitting next to Deke, but I'm the one talking because he doesn't know what the hell is going on. He's delegated down four levels, or something.

[Interruption]

WRIGHT: I think you were talking about going to an FRR, and going through the list.

HUGHES: Yes, the FRR is a big deal, and of course, it was the place where NASA would say, "This crew is ready to fly," and so the crew would come, or a representative of the crew, and that rep was Deke. At that time, I worked for him. In other words, we were working not for Mission Operations [Directorate], but for Flight Crew Operations [Directorate]. It was Flight Operations Division and it was the Directorate, and then it was Flight Crew Operations, in those days. Deke was running that one, so he'd come, and instead of my boss, and my boss's boss, and all those things like that, they'd send Frank because when they started out, they couldn't answer all the

questions, and so, pretty soon they said, "You just go and tell them what's going on," and that's how it worked out. It worked out pretty well for everybody.

It was very strange at first because Chris would come down through the Control Center, call us, and all these other people, my peers at the time—because we're all just working dudes—suddenly, here comes Chris Kraft and Gene [Eugene F.] Kranz, and all these people who knew me because I'd been doing this kind of work. It was an interesting time, but when you got past that, the fact is that we would pass the word along that the crew is ready to go, but it wasn't just that. You'd say, "Okay, we've done X, Y, and Z, we've done this many rendezvous, we've done these kinds of things, and the crew has seen all of the new updated procedures." When we're ready to go, somebody would put a stamp on them and say, "That's it, time to go." Even then, because of them, I was close to saying this is not right. But I know the crews and I knew when they were ready to go.

It set the bit again that we just aren't doing this right. They're ready to go because I know them intimately, but they didn't have to go through 19 rendezvous; they just went through whatever number fit in to the time we had. I know that they're all good, and if they weren't good, we worked on them more. We would just work hard on those areas until they were good. It's like one person on the crew was always good with whatever we're talking about, and different people had different jobs to do. If you did it right, you could have two who really understand like that.

WRIGHT: Which brings a point, you mentioned that the crew had been updated on all the new procedures, and so you're going through the checklist, telling the FRR people that yes, they're

ready, but can you talk some about that coordination of where you got the information of knowing what you needed to have them trained on and how that came to be so updated?

HUGHES: Sure. First of all, going back to that, there's other people than just trainers that we're talking about. When we were going through this, talking about software, but now, John [W.] O'Neill and all his people, he was a branch chief in Houston and they worked on their flight plans in one part, and then their flight procedures, the checklists. There was another division up there, Jim [James W.] Bilodeau is the guy that ran that division at this time, and Tommy [W.] Holloway was one branch chief, and John O'Neill was another one. One was the Flight Planning Group, and they got all that stuff going, and then another group, Doc [Dr. Donald] Stulken, he was doing EVA [Extravehicular Activity] procedures. Marvin [E.] Dement is one of the people, but they did the systems checklists. In the simulator, everything fit into it, that you would get copies of all the checklists and updates. You got updates, pen and ink, that you would do every day.

It got to be voluminous enough that Link actually hired young ladies to do these pen and ink changes. They didn't do anything else, they just kept the checklists up to date. It was very simple pen and ink, but they wanted to make sure that every approved change was in the simulator checklist right away. It might be that a reprinted checklist will show up in another two or three weeks that would have that change in it, but for now, the crew, they'd be lined out and a new thing written in right beside it, saying, "Do this, not that." That process came to be. It was nascent when it was in Gemini, and by the time of Apollo, it got to be very specific. Down to the point, though, I remember with John O'Neill, I was out on the pad, and before Apollo 9, I guess it was, and they were putting checklist changes into the flight books. Part of it was because the

vehicles changed, because the software changed, because whatever, but they were changes, just errors, simple errors, they'd get fixed. They were out there putting these changes in the night before they launched, and stored these books back into where they'd be during the flight.

That was an amazing thing. We tested them, those changes, we'd test them in the simulator before they went up to the pad and wrote them into the flight books. That was going on. The same thing was happening with the flight plan. The flight plan was a minute-to-minute thing. It's not like today, on the ISS, where it's very relaxed, in a relative sense, unless you have something like a rendezvous where everything has to be on time. Like, today we do an EVA even, well, they get to change it until tomorrow, they don't have to do it today. Once you're into it, it's a time-related thing, but rendezvous, you're going to launch down here. Once you start that rendezvous, everything's going to happen in a time-ordered sequence, and you'd have to do it on the right time. Or, you have to recover from it some other way. In this case, everything on Apollo was just the clocks controlled it all, and it had to be done, and it was so important to get it right. The books had to be right, the flight plan had to be right, and it all had to be consistent, internally.

Then, we'd have to verify it, so that meant we'd have, in the Apollo crew, a prime crew, and then there was a backup crew, and then there was a support crew. There were nine people that you'd have to deal with, and the support crew were the gofers. They'd have to run around and just do whatever had to be done. The backup crew was literally getting the same training as the prime, and that was good up until the last few weeks before flight. Pretty soon, they took a step back because the prime crew got more and more time, and the backup crew was just barely able to stay into it. That produced the kind of problem like we got with Jack [John L.] Swigert

[Jr.] stepping in for Ken [Thomas K.] Mattingly [II]. That's a whole story of itself, too, because Ken didn't get sick.

WRIGHT: That is interesting because you're talking about the planning and the consistency and the verification, but everything you're talking about happened within two years.

HUGHES: Oh, yes. Oh, yes.

WRIGHT: Where we started today, or stopped last time, was about the [Apollo 1] fire and how that became such a turning point.

HUGHES: It was happening then. Part of what you could feel is the acceleration. Even though that fire happened and there was a restart, a reset, all the momentum we'd gathered up was still there, in terms of what was happening in the simulators, what was happening on the vehicles, big changes happened in the meeting. Somebody said, "Okay, we're never going to fly 014, the second in that Block I system, and 101 is the first one. It's just like, oh, okay, so we just trash all of these books that we had talked about, and we had to go now, the only thing is a Block II. Everybody would say, "As soon as I know anything about Block II environmental control system." By then, we knew people and we'd say, "Somebody come down from Houston and tell us what's different about this new hatch," or we'd go across the street and we'd panhandle, we'd find somebody at KSC that worked for Rockwell or Grumman and say, "Come on over."

If they had time, they'd love to come over because they hadn't seen the simulators, either. They just got books or paper or whatever, so when they got a chance to get close to the crew, and

then close to the hardware, they'd never seen our hardware, which even it was not real, but it looked really good. People loved to come over and try to share their brain load to us. Coin of the realm was rides in the simulator. If you guys help us, we can—that's aside for young ladies, who got the tour too—but it was pretty amazing that people would do anything for you to come over and help out the astronauts. We thought that it's always crew, because it's always the clock, and it's always Kennedy, and you only got so much left of this decade and so on, so you had to get it done. That was just everywhere; it was just part of the deal, and nobody talked about it inherently, it was just there, that you always knew the clock. Every time a year turned over, it was like, that was a big thing.

WRIGHT: I would have to think that missions, too, because once Apollo 7 occurred, that put man back in space, it certainly accelerated then. Can you share too, how that impacted what you were doing?

HUGHES: Yes, it was interesting because Apollo 7 was a really good flight. Wally [Walter M. Schirra], Walt [R. Walter Cunningham], and Donn [F. Eisele], the three on that [mission], Schirra, Cunningham, and Eisele. When they went through the [training], they beat the hell out of the simulator. They really, really did. They were the backup crew for the crew that was killed, so they were moved forward, stepped into the prime seat. They moved to this new spacecraft, new Block II. They worked with us to get all the mods [modifications] into the simulator, because now it was out of configuration, the vehicle was going to be different than the one that was going to fly. That meant that they had things moving through the simulators called mod kits—they were modification kits that would be installed in the simulator to make it now

look like the next vehicle—somebody had to build a fire under people back in Downey to get these mod kits moving forward and coming from Link, if they were coming from there, whatever the source of them. Along the way, there's another concern, the LM is not making it, it's not running right. The LM simulator was limping along, waiting for things to get better, but meanwhile, when we came up to Apollo 7, it was October 11th of that year.

It was interesting because I'm still single. I got there and never got married, and so, they would call me and I would break dates, I would do whatever the hell else I needed to do, I would go to Houston, or I'm going to North Carolina, or I'm going to Downey, or whatever. I was married to the job. It was Labor Day of 1968, and I was down at the pool. It's Florida, it's Saturday morning, looking forward to the three-day weekend, and it was great. I had a lot of plans, but I walked back in to get Coke or a beer, whatever I was drinking, because it was a warm day, it was about 11 o'clock. The phone's ringing, I pick it up. It's my boss, Branch Chief Riley [D.] McCafferty, who says, "What are you doing?"

I said, "I was sitting around the pool."

He says, "Can you meet me in Melbourne at two o'clock? We're going to Houston."

I said, "Okay." I said, "Why?"

He says, "They're sending [Apollo] 8 to the Moon." This is Labor Day, and we're going on December 21st. So we went down to Houston and we got in Building 30 on the office side of it that afternoon, and we spent the whole weekend there, in our meeting. They decided in August, I guess, and then for us, that's the first day I heard of it, so the first three days of the month of September. It was like I came down, and here's the crew that's going to go, and their backup crew, and all the flight controllers starting from Chris, [Glynn S.] Lunney and Kranz and all the guys, and then on our side, it's Deke and his cadre, Riley and me, going through this stuff.

This is what the vehicle's going to be, this is what we're going to do, 10 revs [revolutions] around the Moon, everything. Nobody's ridden the Saturn V, nobody's seen this vehicle, the new Block II spacecraft yet, all these things going on. We're still a month before Wally and the guys go. It comes down to that, and he says, "MCC, are you going to be ready?"

They said, "We will be ready, yes."

"Crew, you guys?"

And crew says, "We'll be ready, yes."

"Frank, simulators?"

"We'll be ready." I had no clue what the hell I was doing—how we were going to get all that done.

WRIGHT: But that's the answer, right?

HUGHES: That's the answer. I said, "Hell, yes, we're going." We had enough momentum, you knew that you could get most things going, but there were so many new things that hadn't been tested yet. We had a simulator, and we had a mode of flying, it's called the Saturn Stick, that if you really screwed up and the spacecraft computer lost its brain, you could throw a switch and take over, and you would physically hand-fly the Saturn into orbit. Saturn Stick, you've probably never heard about that.

WRIGHT: No.

HUGHES: We knew it was coming, and something we had to make work in the simulator, and we haven't even designed it yet. Along the way, it's all this other stuff. I knew that we were going to have a simulator, because the Block II stuff was coming together for Apollo 7, so now the question is can we build a fire under anybody and bring it forward [on the schedule]. It was really interesting because Jim Lovell and I had known each other a long time anyway, and when we got it all going, we just became blood brothers. It was just like his job was to navigate them out there and back. I remember back, we'd said, with Apollo 1, that crew, you couldn't even align the platforms. You couldn't do things that were really, really important to do, and now it's working good, the simulator was working good. We had stuff for even the escapades up in Cambridge, across the river, all the techs, the telescopes, everybody's working, so you get these big things happening. Everybody said, "Yes, we're ready to go, let's do it. Every day, we started doing simulations now of the Apollo 8 flight.

The first one, here's poor old Wally, still trying to get his [Saturn] 1-B off the ground on this thing, and suddenly, this thing is overshadowing his world, and these other newcomers are taking over the facility. We'd have to keep his ego under control, and again, he and I worked very well together, so we'd say, "This is what we've got to do, and we can put you in tonight from 4:00 to 8:00."

He said, "We'll do it, we'll take it."

I've got the simulator to do something, we've got to put a mod in, I'm taking it down, we're not training tomorrow because I've got to put this thing in, the Saturn Stick, or whatever it is, the different things were going on. Everybody played along. They went up and flew a flawless flight. They had 11 days of flight, nothing happened—which is the most boring thing in the world—but boring flights have always been my favorites.

WRIGHT: Yes, yes.

HUGHES: When they get going, yes, their only problem, the poor guys, is they get sick on the way. They had terrible, terrible colds, and of course, I don't know who had it first, but they spread it around because you can't get away from it. Then, the whole thing about wanting to keep their faceplates up on the way home so they could clear their nose, so they could do the Valsalva [maneuver]. The only problem is he said it. He could have just been quiet, and nobody would know. There you go.

Eisele was a great guy to work [with]. He was the one I had worked on the navigation on that job, so, whatever we learned or dis-learned from him, it helped Lovell even better, going through that training. You had to find the stars, you had to make these alignments, they call them, in case, to align your platform just by shooting stars by themselves, and there was a button. You'd steer until the telescope was right on the star, and then look to the sextant, and you have it nailed. Then you'd hit a button and the computer recorded all the angles of all the things, what's going on. Then, it would compute. You'd do two stars, and that told you where the platform was, just relative to the universe.

There's other ones, the navigation things you would have to do separately. The P-51, Program 51, was the alignment of the platform, and the P-52 was the one where you began to start doing navigation. The whole design of this computer, by the way, was very simple. It talked to you or you talked to it, with verbs and nouns. There was a display system and you'd put in "verb 06 and noun 30." I don't know how I remember all this stuff. So it showed you the

three angles, the roll, pitch, and yaw that you have right now. You could put that up, and then you could control the vehicle, doing that.

06, though, was display. If you do "verb 16, noun 30," it would monitor. So, it would change them every 1 second, so you could see a changing display, but it's just 3 registers, that's it, with about 7 characters across it. It was fancy at that time. You had that world going through all the time. I have an Apollo Lunar Handbook, I'll bring that in next time, so I can show you some of the stuff I'm talking about. Some of these things, like you say, it's easier if you attach a picture.

WRIGHT: We will, we can do that.

HUGHES: You get to this point, and the crew is going on so fast, [Apollo] 7 came and went, probably that was the 11th of October, something. That got done, and now, you're really hot to trot to go to Apollo 8. Frank Borman was nervous about that. He's a good pilot, good everything, but this thing was so big, and it's just taking over your life. It's interesting that the three women [wives] came down to them—they didn't go home—they came down to see them, no kids, and when it came time, I went to the Control Center.

On the 19th of December, I flew from Florida to here to be in the Control Center with another guy named Joe [Joseph E.] Sundra. He was another Command Module guy. There's no LM guys because there's only the Command Module on this flight. Along the way, on April 4th of that year, the Saturn V—I'm talking about things happening, that was a big thing. We lost the crew, but now, a year later, here, suddenly, we fired the Saturn and it works great. Everything is perfect because they drove it up high in the sky, and then drove this Command Module down at

near-lunar entry speeds, and that all worked. Then, they did Apollo 6, which is the other Saturn trial, but the problem is, that one, they had trouble with it, pogo was a major thing. You understand what that was about, where you get the oxygen feeds through the fuel tank. If you want, we can go over by the Saturn sometime and you could add some of this to some of the real world problems, like the Apollo 13 incident where the crew bashed their heads against the console.

[Apollo] 6 was another step along the way, I think that was in [April]. Then, Apollo 7 came in October, so now it's just leading up to Apollo 8. I'm giving a paper in two weeks—Mae Jemison has a study called 100 Year [Star]ship [study]—and I'm talking about psychosocial problems of crew because the human element has always become my thing. I'm a hardware guy in one sense, but how to get people navigating, how to get home. It came down to they realized they're leaving Earth, that's it.

It got to be interesting, every time in the simulator, you'd start the Saturn here in orbit, and then you'd start the engine, and you'd say, "Go." Then, the TLI, Translunar Injection, so now, you'll always see everything in the simulator, and it's just routine to see something that's going 25,000 feet a second. It's just so fast, but we live with it. They light off this engine and it's going 26,000, 27,000, 28,000, and you think, this is amazing, and yet, it was routine because the simulator software is just cranking it out, just like it should. And suddenly, you're at 36,000-odd feet, and you shut it down, and you're on the way—not to the Moon—you're on the way to a really, really high elliptical orbit.

If you did nothing, it would go way the hell up there and come back down. The only thing is the Moon is going to come in the way and capture you along the way. If you did everything right, you lead the "duck" three days out, (like you are leading a bird to shoot it). By

the time you get close enough, then you are captured and you'll start orbiting around the opposite way, into the orbit. Jim was okay, and Bill [William A.] Anders was okay, but I think Frank started thinking about this a lot. It's like, this is his last flight, then there's a part of it you just don't want to screw up. Everybody who did that flight said, "Dear Lord, don't let me screw up in orbit." It was so solemn that Bill Anders asked me—his wife came down to see him off and everything, and I happened to be going back on the same flight that she's going back. He says, "Will you make sure she gets to Houston for me?" It was like you're making these last will and testament kind of moves. Of course, I did, and I got a Rent-a-Car and drove her down to Clear Lake, and turned her over to [Alan B.] Shepard [Jr.]'s wife and some other people. It was always that kind of stuff going on, so it was very solemn.

When we got in the Control Center, then it's all business, now, we got all that taken care of and we had a ball. Three days out, 20 hours around the Moon, and then send them back. But along the way, I had a couple of things where Cliff [Clifford E.] Charlesworth was the Flight Director at that time, and Cliff was a great, great guy. Between Joe and I, we made a couple of really good calls. That kind of thing, say the crew didn't [pay attention. We would] say it again to them, or pulse them again on that subject because they always screwed up on this procedure. He was one of the first flight directors to come back and say, "Way to go, guys, that was a good deal."

It was like such a tense situation until they fired the engine to get out of orbit. It was jocular going into orbit. You have to think about this. You fire yourself off from the Earth. Now, when you're going into orbit, you go behind the Moon, so you can't see the Earth anymore, so calm is gone. But you haven't fired the engine yet to stay there because you've got to go all the way around back. If you imagine a line from the center of the Earth to the center of

the Moon and out the other side, that's where you start the engines. You did that, and of course, you're 60 miles above the surface. We used to joke about that 61-mile mountain back there because nobody knew much about the back side of the Moon. There was one ratty picture that the Russians had done, and you couldn't tell anything.

Got them into orbit, everything worked great, they're there, so they're doing things, and then the last couple orbits, they do the Genesis [reading], and that was really, really important. Then, back to work, and until the countdown came and you fired off that sucker—which we couldn't see, again—and then you had to wait, and if they didn't fire it, they're going to come out at this time, if they did fire it, they're going to come out sooner because they're moving faster, now, that posigrade maneuver to get out of there.

Of course, they came around there and everybody was very cool. We all relaxed. I don't know why the hell we relaxed because you still had three days of all things that hell could break loose coming down. But on every flight, it was like, "Oh, now we're on our way home." You knew that there were still problems you had, there were problems where sometimes we had an out-gassing on the spacecraft and it was changing where you thought it had been, and so we'd have to make maneuvers, coming back home. When they came down here, the crew had to fly, physically fly, and I don't know if you knew that, but when they came down, they would dip into the atmosphere and give away 10,000 feet per second, and actually climb back out for a time, to cool off, and then fall back in. That's where they could skip away. If they were coming too shallow, they could actually skip away and miss the Earth, so you'd come down to the right angle, come back out, and then come back in, in that second time. It's almost like a standard entry out of a 200-mile orbit. This little piss-ant computer was doing all this guidance for you and doing the right things. It was great.

WRIGHT: And working well, that was the good news.

HUGHES: Worked well all the time, did it every time, did every time, yes. Then, we had an EMS, an Entry Monitor System. It was a new system then. It had paper on it, and then a stylus that scraped some gunk off it so you could see a trace of what you were doing. It measured the Gs [gravity] you were versus velocity, and so they would physically, you had to tilt over 180 degrees and dive in the atmosphere, then some back around and come back up. You actually flew this thing, if the primary computer—or flew it anyway, I mean, you always had it running so you would know where you were at—they were able to take over automatically and do all this stuff. Nobody did, fortunately. They did it in the simulator all the time, so we could do a successful entry using this EMS. Which, of course, the simulator had a problem because every flight, every reset, you had to take this paper thing out and put a new cartridge in, and then go like that. It was a marvelous kind of thing.

Apollo 8, it was interesting, Frank had trouble. He was the first person that got sick from space adaptation syndrome, we knew now. Nobody was ready for that. That was a different experience because in Mercury and in Gemini, you wore the damn thing. The spacecraft allowed to go nowhere except how you would sit in the simulator. Then, when you get there, Wally, Walt, and Donn had the same thing, but it just didn't bother them. It's like 60 percent of people get it. None of those three did, they didn't have any problems.

Frank is the only one on this flight, and it was very embarrassing at the time because he had been there before, he had flown good flights. There was no way to say, "Don't worry about it, everybody's going to get this." You don't know most people will get this all the rest of the

time. It's because you have somewhere to be, somewhere else, and so, we knew later, even on those flights, if you stay in the simulator position for the first three days, so you're oriented in gravity, then you get better. If first thing you do is tip over and go down and get something out from underneath the chairs, then you're lost. You're losing your orientation and get nauseated.

WRIGHT: Miserable feeling.

HUGHES: Crazy.

WRIGHT: That's it, yes.

HUGHES: Yes. Always crazy. That flight, coming back home, was really great. That was one of those flights. By the way, the last day of the flight, the flight lands, everybody's happy. Deke comes by and says, "Are you going back to the Cape tonight?"

I said, "Tomorrow…"

He says, "I've got this Corvette."

So this guy, Joe, another young guy, says, "Okay, you going back to—" then he realized what Deke is offering. Yeah, no problem."

Deke says, "But there is a problem."

Joe said, "What's the problem?"

"Somebody broke into my car and they cut the top," of the convertible, so he's going to go back and get it fixed or trade it in or whatever. He had this gray tape over the slice in the convertible roof. So we get in the car, and now we're going 90 miles an hour down Interstate 10

to go back home. Periodically, this gray tape would come loose, and it's right over the driver's side, so, [imitating noise], this terrible noise, sounds like a machine gun over your head. "God damn, Deke." We'd stop and tape it back up again, tape it on the inside, do whatever you can to keep it together, and hit it again. Did we just drive at 60? No, hell no. It was December, so the gray tape would get cold, and then it wouldn't hold together again. It was crazy. We were just young.

WRIGHT: Yes, it was fun.

HUGHES: We were doing [Apollo] 9. By then, the LM was alive, and you could go over now and look at it across the street, here's the first LM, and it was awesome. I never thought about it as being tinnier at all, the things that people said about it. I said, "Well, I wouldn't drop the screwdriver in the Command Module either."

WRIGHT: Now, it's about 11 o'clock, you want to stop here and pick up about the LM?

HUGHES: Okay, that's good. Let's stop, yes, picking up LM and Apollo 9.