NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

FRANCIS E. "FRANK" HUGHES
INTERVIEWED BY REBECCA WRIGHT
HOUSTON, TEXAS – NOVEMBER 18, 2013

The following interview was conducted with Francis E. "Frank" Hughes for the Johnson Space Center Oral History Project on November 18, 2013 in Houston, Texas. The interviewer was Rebecca Wright.

WRIGHT: All right, so, where do you want to start today? Do you want to start with those lessons that you came in through, or do you want to just start on how you trained for missions?

HUGHES: Let's go back, pick it up through there, because the early [Space] Shuttle flights. I came back to training in 1977. Pete [M.P.] Frank threw me out of Flight Control Division after I told him that it just got too damn boring, and we remained friends, but he said, "I don't want you writing my operations plans."

I went back—and that's in '77—and we started putting together plans of what's going on in the training operation.

In '77, Jake Smith [Jasper C. Smith], who was a first line supervisor, a section head at that time, brought in this training expert. I can't remember his name, but they talked about how every training event, you have to know some things before that training, and then there's obviously some subsequent things that go on after that, things that you learn that just naturally follow. They described some of this process, and the idea was, I think Jake had felt the same idea, that there's a lack in what's going on in our training process. All of our training was the

best you could do, but it was always kind of a jumble—now, I'm talking about Apollo and then Skylab and then ASTP [Apollo-Soyuz Test Project]—so, here we are, we're two years after that, planning execution of the early Shuttle flights, the ALT [Approach and Landing Test]. We're going on. They're actually done, but they're so simple.

The biggest thing, all you had to do was get in the airplane, the 747 [Shuttle Carrier Aircraft] would take it off, you'd fly around, and then you'd land. Finally, when we got our guts together, we popped it loose and flew it down to land. It was pretty simple—it's straight in. There's the runway; land. It wasn't fancy at all. They did some things where they would put some control surface things in it, zig-left, zig-right a little bit, and things like that. It was pretty simple. Along the way, though, he brought this fellow in, and I went to this lecture. It was, I think, a two-day program that he gave us, and I thought, "There's something to that." When you go somewhere or you hear something and then a light bulb turns on, or if it was [Robert A.] Heinlein, you'd *grok* this thing—you remember *A Stranger in a Strange Land*—where you just get it, and understand, click, there it is. We went through that way, and the way it started out, then, that's when I went home and sat down at the kitchen table and wrote the draft ascent, orbit, and entry flows.

Then, I assigned people to keep those flows up to date, so it's Michele [A.] Brekke, Bob [Robert J.] Williams, and Dianne [J.] Murphy, who later became Kanipe, Dianne Kanipe. They became the first training supervisors. We'd have them as regular instructors, but then they would have these other jobs, which is to make sure that the specific training flow is right. We added an RMS [Remote Manipulator System], we added in rendezvous, EVA [Extravehicular Activity], gradually, you increased on different things like that. As it put together, every one of those became a unique, functioning entity, and people would treat it that way. They treated it

like you were a really important person, if you were part of an ascent flow, because that meant somebody else had to come to you, like flight planning people or flight procedures people, and work with you to make sure that their training material, their important items, got put into this flow to make sure it was covered.

The training objectives suddenly became a big thing. Every lesson, let's say it's a 2-hour or 4-hour lesson in the simulator, or a 2-hour, 4-hour lesson in a classroom, all these different levels, from books, classroom, single system trainer, to full trainers, mission trainers, you have to have objectives layed out. Those objectives would put together what happened in the classroom. Remember, we developed this rubric, where you would go from standard procedures, normal ops [operations], then you'd go to malfunction operations, and then you'd go to contingency operations.

In the flows, you can see the escalating levels of danger. Standard ops is just: "Here's how you run the fuel cell and how you generate electricity and getting it out there to make it useful." So, you make sure that the reactants are flowing into the fuel cell, that the electricity's coming out of it and distributed successfully. You want to know that the water's going to the potable water tank, (that was the way the Shuttle was built, of course). You made water as a by-product. Once all that material was good, then you'd say, "Now, what is the set of malfunctions you would train on somebody to make sure that they were ready for the events that can happen." That meant you had to have procedures for that malfunction, and the crew would have go through all those steps.

When you get through all of those malfunctions, then you would have a set of contingencies. This is even worse—a contingency would be a cabin leak. The Shuttle architecture was such that if you had a hole in the wall that was a foot across, you're going to

die, but if you're going to have a hole that's a half-an-inch across, the system was designed to feed the leak. That is, it would open up the regulators and start pumping oxygen and nitrogen into the cabin to feed the leak while you had a chance to do something with that leak. If you could find it, you could stuff something in the hole. If you couldn't find it, you'd do whatever. Either way, you're going home right away.

At any given day on orbit, you had contingency de-orbit plans for two or three places around the Earth with a good runway. You could get down without ditching in the ocean. Then if you were really in trouble, you could always turn around and just de-orbit and you could come down, and you lose the Orbiter, you could bail out. Mostly, you'd want to get back with the Orbiter intact, so you knew you could go to Guam or you could go to Hawaii or you could go to CONUS, the [Continental] United States. You could go to Spain, just around the Earth, you could see wherever you are that was within a couple of hours, you could be on back in the atmosphere and on a runway. That was good. All those things were procedures, so they're ready to go. Fortunately, we went through the whole damn thing with the Shuttle Program and never had to use a contingency procedure. It's like life insurance. You bet the insurance company you're going to die and they bet you won't. In the case of this thing, all of those procedures are like those life insurance policy premiums—we didn't use any of them, which was wonderful.

The closest we came was on the second flight, with [Joe H.] Engle and [Richard H.] Truly, they had a fuel cell problem. It was supposed to be a three-day flight and we brought them down the second day, just for that reason. It tripped off a contingency procedure, but it was a non-critical. In other words, the other fuel cells were working enough that we'd say, "We'll land as soon as possible," and they went into Edwards [Air Force Base, California], and it was all good. The procedures were there, it's all put together.

We trained through all of this stuff, and the first four flights were great. I was not a manager, yet, at that time. Talk about the training structure, there's a two-person crew (on these flights) and then we would have four or five people sitting on the console, on the simulator team. That meant there was a team leader and then there was somebody that took care of the computers, somebody who took care of the systems, somebody who took care of communications, and in the case of launch, you'd have somebody took you to main engines or all the propulsion system, it would be a prop guy, propulsion guy, which meant it was main engines if you'd run launch, but then it's also OMS [Orbital Maneuvering System] and RCS [Reaction Control System], those other systems.

When all the stuff went through, those first four flights, I was still very tired, even though I was promoted up out of being a team lead anymore and somebody else took that over, I would go over and sit with the crew. I would actually ride with them, at least once a week. I would sit there and there was a third seat. You had two seats. Remember, you bail out with ejection seats. I would sit in the middle, we had a jump seat, and it was there only in the simulator. It didn't exist in the real world.

After that flight, when we modified to go to the [sixth, STS-6] flight, which was [Space Shuttle] *Challenger*, because they went and took the ejection seats out of [Space Shuttle] *Columbia*, then *Challenger* did [STS-]6, 7, 8, and then *Columbia* showed back up in [STS-]9. Then, when it came, there are two more seats back there, where there's a center seat which is the MS-2 [Mission Specialist-2], or the flight engineer, and an MS-1, which was over on the far right side. There was an instructor chair again, now that we moved the chair over to the far left side, and that's where the simulator instructor could ride. Even now there's four people on the flight deck, you can still be up there.

This seat was only on the motion system, not on the fixed-base. You would actually sit where (in the fixed base) there's an access hole, where you go down to the lower deck, and that's where that seat would be. You could sit there and see around the commander and everything that the pilot does, so you could watch procedures and everything. I had a lot of time up there, and I would make sure other people go ride with them so that they would have that continuity, but also because they were close. You'd be able to talk about things that were important.

A story: The one thing you couldn't do is bring any drinks into the simulator. It's easy to say. It's like on Apollo, where you couldn't bring your shoes in, in SMS, you couldn't bring a drink. On this one, we were okay with shoes, just because you had to walk around everywhere. Cripp [Robert L. Crippen] brings a cup of coffee in one day and sits it on C-3. That's the center console between the two front seats. John [W. Young] is in already, Cripp gets in, and then John does not know this coffee is there, so he proceeds to reach down to key in something in the computer and knocks the coffee over. I'm down on the console at this time—this is early in the training for that day—and of course, there's nothing worse than liquids running through a computer system. The whole simulator just stops, and it's funny, all of the displays stop. Oddly, the way it worked on the flight computers—because we're using real flight computers—all of a sudden, they go X's across every one, which says, "I'm not getting any data from the computer." John says, "What's the matter? What happened?" He didn't know that he did this thing. There was this long silence, as Cripp looks over and sees the white cup laying on its side. More silence. Finally, John says, well I guess that we're finished for today!

Obviously, there was no more training that day because they take it all apart, fix things, clean it out.

The training was almost hand-tooled. There were only two crews of trainers, and when you trained, you would train in the morning or you'd train in the afternoon, so you'd do 20 hours a week. As instructors, you took all the mornings and the other team of instructors would take all the afternoons, no matter who came through the door. You'd just train them, and that was good. Then, more crews were getting signed all the time, it got more hectic, and so I had to convince the Division Chief (named Jim [James W.] Bilodeau), and my Branch Chief, which was Bob [Robert K.] Holkan, but they'd say, "We have to do something different."

My answer for that is that we assigned a team to a crew because now, you don't have enough time for them to sit up there and get to know each other and know everybody's kids, and you talk about what the hell the ball game was like last night. That kind of material helps to make it real comfortable. I could do that anyway because I'd known them all forever, but now these new guys were coming in, and they're all just amazed that they're working with John Young. They're blown away, star struck with this stuff. "Last week, I was in Notre Dame and trying to get a date, and now here I'm sitting in this place," or whatever, fill in the school.

If we created this process, when we did, a team would always work with the same crew, then you'd break through all of that stuff. You would realize that they just put their pants on one leg at a time. Because that way, you could come up and at the end of the session, you say, "John, that third landing was just gross, you were really way off on that." You could say it right away, just immediately, and of course they'd say, "Yes, I agree, let's go do it again," and so on. It developed more and more so that it grew until at some point, they were at least eight teams when we got into, '85, '86. There were so many crews in training at different times because it's like an 18-month period, and if you're training six or seven a year, then you've got multiples of flights and simulator teams.

We had 10 different teams at some point, and so the whole organization built up bigger because you just had to do this thing. Then, we had more simulators, where these were just this fixed-base, then there were added gradually two fixed-base and one motion base, so they're all busy all the time, plus you've got people in the single system trainers—there's three of them—and then you still have classroom for new guys coming in, so you'd go through a new procedure on board.

We would take them to the classroom, at least a two-hour brief, and I'd say, "This is how System X works." Then, you'd go on into the single system trainer to see how System X operated. You can see that the SST [Single System Trainer] was just an open machine, it was just busy all the time. Like I say, that in '85, we flew eight times that year. The training system developed into a smooth-running machine, and in a real sense, so did the launching system. Of course, they hit the wall with *Challenger*, but we flew even in early January, and then we were going to launch two weeks after *Challenger* was done. We flew on January [12], and then we're going again on January 28. It was moving that fast.

WRIGHT: Were you like the choreographer in a major musical play? You had to keep all these pieces going.

HUGHES: We had to keep all these people, then I had to get schedulers, one for each crew. I had to gradually put together—they became USA [United Space Alliance] but it was all the different ones—and they became just that. They were a mix of McDonnell, Ford, and Rockwell people that were staffing all these positions as instructors. On top of that, we had another set where there were three or four MCC [Mission Control Center] training teams. Have you ever been to

the SCA, the Sim [Simulation] Control Area? Do you know where we train, behind the old historic Mission Control Center room? There's a training room there and it's a [International Space] Station Control Center room.

WRIGHT: I think I've been in there, yes.

HUGHES: That's the one where we do all the sims. On another floor, there's a room where the instructors sit, and it's called a Simulation Control Area. During these days, you would have a Sim Supervisor and then five or six people, all of them designated to watch over different flight controllers, the idea being they would meter malfunctions in for them, too. The malfunctions would sometime be, put a malfunction over in the simulator and then see how the flight controllers would respond to it over in MCC. Sometimes maybe subtle, you could control how bad a malfunction was or it's a malfunction that the leak is small instead of being large, so then the crew wouldn't notice it right away, but would a good person over in MCC see it?

The flight controllers also had objectives. They had things to do to make sure that they were good enough to sit on that console to get qualified. It's like the guy in front of your airplane, you want to know that he's been through all the right stuff, and the same thing—it's easy to say for astronauts, but we got it to the point where we did the same for flight controllers. Before you could be a flight controller, this is what you did. They went a little bit crazy—over the years, some positions that were there made it worse. It was three years of training to get going, and I said, "That cannot be that you believe that you have to do twice as much training than the astronaut who puts their butt in the sling and goes to do it," but that's still out there. I left with that one still going on, some of those things.

WRIGHT: Were all of the trainers and instructors of trainers, for the most part, at the beginning of this program, were they all federal employees? I know you mentioned that the schedulers seemed like they were more contract personnel.

HUGHES: No, it started out that way, but no. Over time, it just expanded because federal numbers are controlled by Congress. You always get a limited number of people, whatever that number is. That's where we'd turn to the contractor and say, "Okay, I need three more people in this section that cares about systems, so you look for mechanical engineers and electrical engineers." The guys that are controlling the spacecraft, that control propulsion stuff, would get aero-engineers, physicists, people like that. That doesn't mean that we didn't share people up and down the hallway depending on who needed what at a time. That was the kind of thing. Communications tended to get electrical engineers and people like that. We had the computer systems, those we tended to go towards software engineers and computer science, that kind of people who know what it is. We were not telling how the computer worked—we would tell how to work the computer. We're not going to mechanically take it apart and fix anything in there. We'd bring it home, and somebody else would fix it.

WRIGHT: At times, if someone was hiding in a specific area for a specific reason but you knew that wasn't a good match but felt that that person had what you were looking for, was it something that you could do, to switch those people?

HUGHES: We could switch them around, yes. Until we consolidated—we consolidated contract and USA took over, it was about 19[96] or something like that, it was wonderful.

I had a much stronger hand because I could say I need somebody like this, and sometimes they'd have it at McDonnell or Rockwell or Ford, would have somebody like that somewhere, or they are going to hire them. I said, "Okay, hire them," but I'd also say, "How much is it going to cost me?" I'd let them bid against each other so that I could get a better deal, as a government employee. I was able to keep the costs down. When they consolidated, that sounded like you were going to save a lot of money. But actually, it cost you money because then, there's only one source of personnel. You can't argue about the price because I'm not a contracts guy, we can't do that kind of stuff. Before, I was not a contracts guy either, but I can say, "Rockwell, I'll give you this guy if you can give me somebody that can do these things, jump through these hoops, or whatever the hell it is, and keep your price down." They'll keep the price down because they want to out-perform the other two guys.

Consolidation is the worst thing you ever could do, I would say, as far as saving money in the government. Sounds great—yes, you don't have HR [Human Resources] people and all this stuff—that's easy stuff. Where the rubber hits the road, the consolidated contractor just inflated the numbers so high because they could. They had stuff that I never even believed, and then after that, I also could never find out how much it cost me to do anything. I literally would have meetings, the whole thing, they didn't have to tell me—they'd have to tell the contract office, and I would say, "Well, get the damn contracts officer over here."

And he'd say, "We can't do this to these people. They've got to make a profit." Not this much, because they—that contract officer—can't say when they're sandbagging them, when there are more people in play than they need to be. That's here and now, right now, it's going

on. The only thing you could do is have a major layoff and just get rid of everybody, and of course, then you get rid of good ones and bad ones, too. It was always a case where I had a real hand in just getting rid of people, there's two things.

Have you ever had, in your history, bad teachers?

WRIGHT: Sure.

HUGHES: Yes, a bad teacher is easy to find. Good teachers are really a priceless thing. In this business, now you ask people to do three things: to learn enough to be an astronaut or a flight controller, and also become a good teacher. We would have people who had to certify that they understood the systems, then they have to certify that they could teach those systems. I made these mandatory tricks they have to go through, and of course, I had contractors complaining to [Eugene F.] Kranz, they're saying, "He won't accept the people we want to give him." Well, I won't take any bad ones. They come in, I don't know what they are.

I had one guy that got hired, God knows, and he was working for Ford at the time. He was just awestruck to be around astronauts. Everybody goes through a couple of days of that, but pretty soon, you're working with them and so on. This guy would brace the crews for autographs when they'd come out of the simulators, and it was just totally unacceptable —I'm trying to put it in the right phrase—he was a real pain in the ass. That's the simple thing to say, but it was more important than that. It was almost like he was a stalker all the time, within the confines of our areas. I said, "I don't care where the hell you put him, but it's not here. Get him out of here entirely, get him off-site," because with the badge, he would hunt the crews down.

He would go find people, and then he would hunt down the women more than the men, and it was all that kind of stuff. It was just scary.

WRIGHT: A bad situation happening, wasn't it?

HUGHES: Yes, a scary guy, and I said, "I don't want him having my organization's name."

Other ones, they were really good people, and I would say I really think, like, they really got to be good engineers, they understand the system, but they're not good instructors. There's one guy, we got together and I said, "You're not having a good time with this."

He says, "I'm having a little struggle."

I said, "I know. But I like you what you did—," it's main engines, his thing. I call around and I got him a job in safety, but he finished up his career, he went over in safety, and he knew more than anybody in the whole place about the main engines because he studied here, and he was a star, there. He didn't have to deal with astronauts and all this stuff going on, being a trainer, but actually, he was a decent trainer and he taught them a lot over there in Safety. It was just a different environment. He was suddenly, instead of a small fish in a big pond, he was a big fish, and it was great. I did that a number of times. If I thought it was rectifiable, I thought, "We'll work with you to get you smarter, if we can, but if not, let's find you someplace to work where you'll be happy."

WRIGHT: Let's move your smarts to someplace where it will matter, right?

HUGHES: Yes, exactly, take the smarts that you achieved and go use them somewhere else and NASA will benefit somewhere.

WRIGHT: Two questions: one, how did you know that an instructor was ready to sail on their own, to move into the full classification of now this person's an instructor, whether that instructor was going to instruct other flight controllers or instruct the astronauts, and then how did you know that the astronaut crew was ready to fly?

HUGHES: That's a good question. Let's go back a moment. All of these people, as the instructor, you had to sit in and actually teach a lesson to another instructor for what their assigned subject. In other words, if you want to get qualified for the single system trainer, in order to demonstrate that you know that system, remember this, let's say there were three lessons: normal, malfunction, and contingency lesson for electrical power. Then, you could get qualified for training normal ops on EPS [electrical power system], the only way you could do that is you'd sit down one on one with another instructor in the single system trainer and you would physically give the two-hour lesson, just like you were talking to an astronaut. That person, the student, would ask questions to really plumb the depth of how far you went. That worked really, really well because they went through a trial by fire, basically, and it was really good. They qualified, and we kept records, so that guy is qualified as an astronaut trainer level I. That means normal ops. Then, you'd go through and they'd study up more, and then you'd do malfunctions, so you still have to go through more levels of difficulty.

Everybody that went to a simulator has already been through this material. Before you could be a systems guy, you had to know APU [auxiliary power unit], hydraulics, electrical, and

environmental, at all levels, because now you're in a position where you have to, in the simulator, now you've got normal ops, malfunction ops, contingency ops, all the time. That instructor would have all that depth of knowledge. There would be, like, say 12 lessons they had to certify in before you could get put on a simulator team. Separately, you had to then qualify it as an instructor because you had to go to the simulator with somebody and show that you could operate, actually physically do the things you had to do there. Not knowledgeable about the systems, but knowledge about the simulator system. You think about that, it's its own system. It simulates the spacecraft, but by itself, it's a big computer system, and there's protocol and processes that you have to know.

They did everything—they would talk to the astronauts all the time, but they talked as though they were Houston, so they could do the simulations. Sometimes they wouldn't—they'd say, "We're going through a lesson," so they're just talking between [themselves] like you and I are doing right now. That stuff was going on all the time, and then you could imagine that it would be from 8:00 in the morning until midnight on the heavy days, 4-hour blocks of time, 8:00 to noon, noon to 4:00, 4:00 to 8:00, 8:00 to 12:00. Then, during the night, we'd turn the simulator around, get it ready for the next day. We would perform maintenance and do whatever else was needed. This is happening on three simulators. This is a 24-hour operation.

WRIGHT: For a long time, it was seven days a week. Did your crews work over the weekends?

HUGHES: Near the flight. Generally, we tried to reserve weekends—the system is running, but we'd have people coming in there and they'd be doing hardware maintenance or modifications and updates to the simulator. There you would physically take hardware out and do some

change, wire it if needed, and then to bring it back up, test out the system, and everything like that. Then, any time during the time period, if there was a time the simulator was not going to be busy, like the motion base is not going to be busy from 4:00 to 8:00 today, this afternoon, then the simulator guys would get it, so that they could check out a new software load, qualify a new person or similar things.

For example, we are training for flight 50, but they'd come in with the software needed for 55 because it's got a payload that we need to check out so it's ready to go when training for the 55 crew starts. I had people who just did scheduling. Then, they'd interface with the simulator schedulers, and they had all this work underway, all at the same time. It was a monstrous system and it worked, and it worked very smoothly. Probably too smoothly, and a lot of people didn't know how big a deal it was going on. We had about 150 instructors at the top of it (and almost 300 hardware and software people) keeping it running. That's with full Shuttle training, full [International] Space Station training operations, let's say '98, '99, '01, that time period. It was a big deal.

WRIGHT: Yes, it is, because you mentioned the new loads—especially those first five or six years, the payloads were all new and sometimes they changed and crews changed.

HUGHES: That was going on all the time. I had to rectify some things that needed to be corrected. We were having trouble with crews being overscheduled. It's that kind of thing you're talking about, so I assigned a scheduler for each crew. In other words, it used to always be tough to schedule an astronaut, that you couldn't get him to give you a talk to your group of school kids because they had to check the schedule—actually, that schedule was very different

from the schedule I'm talking about, where they'd be in the simulator from 8:00 to 12:00 tomorrow, and then 12:00 to 4:00 on Thursday. They knew that part of their world, that's an input to their own personal schedules, but this other scheduling now took over the whole crew. Everything that that crew is doing—when they go to Russia, when they go to Japan, all that international travel—all of that had to come together.

When a change, let's say a payload fell out of a flight or was added into a flight, then that's just a big ripple through that whole system, where you'd have to get people learning what it is, and what is it going to do, how much time is it going to take? We had to create objectives for it. Say if somebody comes along that's new, somebody had to think through all that. You get the SMEs, the subject matter people get together, Subject Matter Experts that we dealt with, and that'd be the guy that's the PI [Principle Investigator] for that experiment that would command our attention to make sure we worked his gear. We'd have someone else, the hardware people from whoever, Ball Aerospace or somebody that built the hardware for this device, and talk to them, just find out how long is it going to take to get this training completed. Then, we have a crew rep, somebody that's representing the crew in there. They said, "We think we can do this in 2 hours."

I said, "Really?" You'd wind up in 10, 12 hours because it's just such a big deal.

They'd just say, "Oh, we know all about this." Yes, but they don't—you've got to communicate so much stuff that you already know.

It's that thing we talked about with Judy [Judith A.] Resnik, the kind of thing where it takes a long time to master a subject. But now that you know it, you think, "Well, it's too many hours, we ought to cut this back." You needed all those hours to achieve what you did but now looking back it looks too much. That happened a lot.

From the PI or his team, everybody thinks, "Oh, I can teach this no problem," and then you get them up in the [simulator]. It turns out that that person is a terribly teacher because this person is not ours, they comes from somewhere else. You'd finally say, "Okay, I'm going to take Harry (my guy), and he's going to live with you (figuratively). You're going to teach him everything you know," and then we'll let Harry do this lecture from now on.

That was just another ramification of what you would do. You had to look for what's coming downstream. There's so many different things—different payloads, different vehicle changes, even just coming down to the electronic cockpit. Now, the good thing about it, it was only step one of what was going to be a bigger deal. The ultimate electronic cockpit would have been a major upgrade to the Shuttle capabilities. But, because all the money problems, we got almost nothing out of it. All they did is replicate what the old systems did. We never got to the part where we added new capabilities.

We were going to go to another level installed with a lot more information, which is displayed on those CRTs [Cathode Ray Tubes] if we kept flying. It's like the 10 more Saturn Vs we were ordering that never got to us. They just cut off everything in midstream, we never did finish the rest of the electronic cockpit. All of the money they invested in the electronic cockpit never got to be used because we never got to go to the next step. By the time they got it installed on the vehicles, I think they never even got to one. There was only two of the three installed because we got *Endeavor* done, *Columbia* was done, that's the one we lost, so we quit flying. There was only two out of three that was working for the last few years. All of this work and modifications going on. We flew 135 times, so it's hard to telescope back all the changes that happened. So many people went through the training system, really good people. People who

went to become astronauts. Janice [E.] Voss was one of my best instructors. Jim [James H.] Newman was another. The instructor cadre was superb.

[Interruption]

WRIGHT: That's my philosophy, comment for the world, so it's not anything to do about training, but it is about how people, when you're gone, how they're going to train the next group of folks.

HUGHES: That's true. It's kind of interesting in this, when we started out, *Challenger* [STS-51L accident] came along and that was a big deal. The day it happened, we had just had a launch pad abort, literally, in the flight before it, and that crew in early January had succeeded because they had launched the next day. They turned right around and went. Steve [Steven A.] Hawley was on that flight. Remember that line of his? "I really thought at MECO [Main Engine Cut Off], we'd be higher."

WRIGHT: Yes, at this point we'd be higher.

HUGHES: The crew guys were great, and everything was going on. We had one flight that flew eight people, and that was so bad, that's when we said we'd only do seven max after that. Mostly it was a single crewperson who caused that grief. He was just an interesting guy, and he was the prime on that one. He was so difficult on that flight they were actually talking about taping him to the wall. Gray tape is great in zero gravity because you can tape their hands

together and tape their feet together and put tape over their mouth, and then tape them to the wall and just leave them there. [Grinning]

WRIGHT: Wow. That would have been a story to tell when you got back.

HUGHES: It's like the mutiny, but it's the other way, where you have a sailor that you have to throw in the brig because you need to, and that's our version of it, for space. They got home, and that year was '85, was so much going on, so many flights in process. In May of '86, we were launching from California. Crippen had another flight, his fifth one, and he's going to launch into polar orbit from California, which, if we did it, it would have been so awesome. From that point, so many things changed. The military decided not to use Shuttle anymore. The guy who was the Secretary of the Air Force, I forgot his name, he was supposed to be on that flight, well, it spooked him.

WRIGHT: Pete [Edward C.] Aldridge?

HUGHES: Yes, Pete Aldridge, exactly. I think it spooked him, or it spooked his family, or something else. He never flew, even though he could have still flown on another flight. They chose to walk away from Slick Six in California, SLC-6, and that was like $3,000,000,000 by itself, just that they dug a hole and threw money in it and closed it up. They're using it now, and that's these big Deltas, or Atlas rockets, these huge things that they're throwing payloads into the air out there. I think I still have it; there's an email photo story of these huge rockets going out there, just getting ready to launch, taking the stages out of airplanes and putting it together, it's

just unbelievable. If I can find it, I'll send it to you. I didn't have any responsibilities in the Control Center anymore. We had these operating positions where we would have people in the Control Center, ready to watch out what's going on during each flight that we launched. I was a Branch Chief, and Bob [Robert K.] Holkan by now was the Division [Chief] of the Training Division.

I got to be a branch chief in '84, and so, I was running this Training Branch. I had under me the launch and entry to teams, the systems guys, and the flight computer guys, all in one group. Basically, it's all of the stuff that's not EVA and RMS and those kinds of things. We were sitting in Holkan's office and watched the 51L launch, 3-2-1-0, boom, going up, and then they were gone. It took us about five minutes to figure out who might be on that flight. We were launching so often and there were so many crews in training, and they had these funny number systems. I said, "51L," and I think, "Oh, [Francis R. "Dick"] Scobee. Shit." Then, I said, "Judy." You just go through, trying to mentally bring back who this is. Right away, Christa McAuliffe, because that's all they were talking about. Poor old "the other guy."

Finally, [Ellison S.] Onizuka, which was the last one I thought of. It was like, "Shit." I knew that I just had a problem because Mike, my son, was really close to Onizuka. He came over, we had lunch one day, I don't know why but my son was out for holidays and we had lunch together. He talked to him all the time because he was just about to be 10. People came and went around the house a lot, but some are better than others, that kind of thing. El was really, really good, treated Mike good, and I said, "Oh, shit, get home tonight and I'm going to have to talk about that one." I'm having my own troubles, and then I realize that this one, some of the others working for me have different ramifications.

It was funny, I talked about Judy, that I had a scheduled meeting for her two weeks after the flight. This is the one we were talking about. She was MS-2 [Mission Specialist] on that flight and did a real good job. Ellison was MS-1, she was MS-2, so she was sitting between the two.

Then you go through that whole thing with [President Ronald] Reagan coming down—were you here then? People never come to visit us when things are good and then there all over us when things go bad.

WRIGHT: I wasn't on site, but I was here, in the area.

HUGHES: Then we had to go through the Rogers [Presidential] Commission. It was interesting because I had to testify for them as the head of training, at the time. I was not the Division Chief, but Holkan says, "You take this," and he'd rather have somebody else go do that duty.

I did talk to them and they said, "Did Christa McAuliffe know that this was a dangerous business, and did she really understand that?"

I said, "Well, the short answer is yes, we had lessons about emergencies, we talked to her, we talked about all the ways to get out of the spacecraft in an emergency and all that sort of thing. But, if you could take her out to the launch pad, ride 350 feet up in the air in an elevator, all the way along the way you're passing the fuel tank, which is enormous, and two solid motors, full of solid fuel, obviously dangerous, and then you get into the spacecraft, load her in," like we did for CDDT, Count Down Demonstration Test, "and then everybody around there got the hell three miles away. If she didn't figure out by herself that this was dangerous, there was not a damn thing I was going to be able to tell her in a classroom that would have made a difference."

It's this awe-inspiring vehicle and you realize it's pointing straight up the air, it's the size of a Navy destroyer, and it's full of fuel. Anybody with half a brain is way far away, leaving you alone out there. Yes, it's dangerous. That was it, that was the conversation.

Now, everything happened different, the whole system ground to a halt. When we lost the crew in Apollo, NASA did the review. We put it together, they named a guy [Floyd L. Thompson] from Langley [Research Center, Hampton, Virginia], and he was the head of the [investigation]. He was named to that position within that evening of the accident. Frank Borman was on that board, all these people, knew what the hell was going on, they knew the business, and then they immediately start tearing the thing apart. Nothing was sacred. No contract was sacred, no people were sacred, everything got looked at. On this flight [*Challenger*], immediately, they put this big-ass [investigation] together. Of course, mostly because Reagan had no clue what the hell this was all about. Then we had to start teaching the investigators how the vehicle worked. The people who were running this investigation, who make this big thing, didn't know anything, except for Sally [K. Ride], who was on the [commission], and seems like there was another astronaut.

WRIGHT: [Neil A.] Armstrong was there.

HUGHES: Yes, thank you, but he didn't know this vehicle. Neil's great, but that's right, and Neil, we had a great time when I was talking to him about this thing, and he would agree. He said, "You just climb up and ride an elevator up the side of a Saturn V, you're going to figure out this is not really the standard 737 you're going to take today to go to Toledo." It all went to hell in a hand basket, and it took forever to get through to the Rogers Commission. That was the

only time I had anything to do with it, other than watch and follow along, but things had to happen.

Somewhere in August, 1986, Carl [B.] Shelley approached me and said, "We'd like you to help us with a Space Station Operations Task Force [SSOTF]." So in the fall, we met every other week in Washington [DC] for four months, like September, October, November, and December, that's three and a half months, and then in Florida, in one of the hangars down there, we met there up until April, to put out a report. There's a really good report on how you're going to operate the Space Station. Of course, when we through the Russians into the mix, this plan went out the window.

Meanwhile, back in Houston, we have all this training horsepower waiting around with nothing else to do. Training is going on, but that's almost an automatic system, now. It's running really well, but the crews are just peddling on a stationary bike, they're not going anywhere.

I went off and did that SSOTF, and I was running the training part of this whole SSOTF thing. It was one thing good because of it, as I learned a lot of really good people in Marshall [Space Flight Center, Huntsville, Alabama], forged a lot of good information and good contacts over there. The worst thing is that back in Houston, because they kept training, all the crews stayed together as though they were going to fly right away.

Some crews' families said, "I don't want you to do that anymore," and so they left. There was a lot of people that did leave, but along the way, there is too much creativity.

Because I was not around, the crew knew everything that we could do on this simulator. They knew all the objectives, so my guys would invent new malfunctions, something that the simulator could do that it couldn't do before, they'd just modify the simulator.

Then they'd have a sim with the control centers, and they'd throw this new malfunction. The flight controllers and crew would be surprised and didn't have a procedure, so they'd make up a procedure to handle this malfunction. That would create an objective, so you had to make sure every crew sees this malfunction, and so, pretty soon, where before, like, there are three cooling loops in the system, pretty soon we're having two failures, simultaneous failures. All those procedures ballooned up a lot, and when I came back, I was able to get rid of some of these procedures, but by then, I was working on this thing until all of '87, and then they turned the Shuttle over to someone else and I was asked to become the Space Station training guy. We put together the Space Station training organization. We were over in actually where the HEB [grocery store] is now, remember, there was an Eagle building for a while, but it was originally the Alpha and Beta were the buildings earlier?

WRIGHT: Zeta Building, yes.

HUGHES: Right. I think it's right on the beer aisle, is where my desk was. We were there until they built [Building] 4 South, and then we moved back onsite at JSC. Along the way in that, John A. Wegener, a good guy, was Deputy Division Chief when I left. Now, he was the Shuttle Division Chief and then I had the Space Station Training Division for this other organization. Later, when I came back on site, they put it all together and it became Space Flight Training Division; it covered all of Shuttle to Station. We operated that way until I retired in '99.

WRIGHT: At what point in there did the astronaut candidates begin to be trained, or had their own couple of years of program. Was that always from the beginning?

HUGHES: That was right in 1978. I'm glad you brought that up. Remember back in'77, '76 where we did the objectives, and start training the crew? Well, then I used Kathy Abotteen to put it together. I said, "Okay, what are we going to do to get new candidates?" The TFNG guys, the Thirty Five New Guys—but that's not words that were used for that acronym. So then, she put together what we should do, and we'd beat that around a lot. It became an ASCAN [astronaut candidate] Training Plan, and it meant you did a lot of classroom lessons. You did all of the classroom [training] that you would do as though you were going to fly, so you got it done early. Then you did all the Single System Trainer. Then, you would do some simulator lessons. However the ASCAN simulator opportunities usually were at odd times. It is like, 8:00 p.m. to midnight, when nobody else wants that simulator time. They would get to that SMS training time at those odd hours. From '78 on, all the ASCANs came in through that system, they all did that. The ASSCAN training got better—that is, we honed it more closely and got it to be more effective.

By the time of the second ASCAN crew group arrived in 1980, they had it better. The system worked pretty well, but the idea was that you would pre-arrange so that before you got in it, the first crews going through, they had to go through the classroom training for Shuttle systems, then they would get in the SST, then you would go to the simulator. Now, if you got assigned to a flight, you'd go straight to the single system trainer because you had done most everything, and that's like a warm-up. You've already been through some of training, and all the classroom time. That is unless your payload requires it, then you didn't have any classroom at all. It's like any kind of training that you do on a new job, OJT [on the job training], you come in here and you learn how to do whatever it is we do here, you go through classroom [training],

and whatever small amount of training we provided to the ASCANS, but you didn't get to do any flight training. So ASCAN training is all generic training. It's all generic training. They learned, "This is how systems work," not, "This is how your system's going to work with this payload on this day of your flight."

WRIGHT: Staying on the subject for just a second, at some point did Duane [L.] Ross inherit that training?

HUGHES: Duane was drafted in when they started selecting people. After 1975, we did ASTP, and we had the dysfunctional MOD [Mission Operations Directorate] with George [W. S. Abbey] as the head of it, and Kranz as the deputy. Then, in '77 or so, we split it into two, so FCOD [Flight Crew Operations Directorate] got reconstituted, George took that one, and then Kranz took MOD. The training now is part of MOD, so the training mandate is to do both flight crew and flight controller training, so that separated that out. In '77, when they decided to do more astronauts, then he [Ross] got tapped—Duane was in HR and knew the hiring process. So he just stepped in when George got him to do it. [Christopher C.] Kraft was still the Center Director, in '78. George said, "I need somebody from HR to run all of this astronaut interviews." Duane was it.

When we said we were going to do 35 guys, they must have got 6,000, 7,000 applications. There were big numbers that we flew in to interview, probably several hundred. It was a big thing to just plow through all those applications. So George, of course, uses a bunch of astronauts and puts them to work, reading resumes and picking out the interviewees. Of course, they're all picking out their buddies that they flew with. Typical, of course. The scientist types

are getting their buddies out of academia. It was great. It got done and the group was selected. Working through all of this, Duane just became the ASCAN guy. Gradually, as it got going through the years, there was nobody else but Duane working at any time, except when the interviews are going. Everything, the flood of applications comes in all the time. I think they had a couple of people up in the astronauts office who were working to take care of the paperwork, it just happened, it's like topsy. It just happens because nobody expected you to get 6,000 or 7,000 applications, and when they go through, it's interesting because when you get that big a crowd coming in, the 35, well, they have their own set of problems. They had to have babysitters up in the Astronaut Office to just schedule them and get everything organized. This is before I got my organization geared up to handle that kind of thing.

Later, the new astronauts would come in—let's say there were 8 to 10 of them—then we would know what they were going to do with ASCAN training because we had written it by then. We had honed it down to a fine art. When they went through, it would be a piece of cake to absorb some people in, and they would know exactly from the day they came in. I would talk to them, the new crowd, I would be one of the first ones to talk to us, this is what's going to happen, here's Kathy Abotteen and she's going to be the training supervisor for the ASCAN flow—that's that whole thing—then this is what it's going to look like, and you're going to go from A to B to C to D, and they were perfectly content because they just came out of the military and that's how it was built. Yadda, yadda, yadda, and just go through, it was okay. It was all how much time you'd spend on T-38s, how much time you'd get pre-qualified. They would re-qualify on the airplane because many of them, if they've been through the military, they've seen the T-38 before in part of their history, so they'd have to re-qualify in that one if they're pilots.

The MSs, they had to learn how to do anything in a T-38, so there was ground school for them. They'd go to Ellington [Air Force Base, Houston], and it was everything about how to jump, the ejection seat, they don't know anything. It was always a big thing about their boots, they'd have to get their flight boots, and then they'd have the flight boots, they'd have to go over and take a mold of the boot because the leather part of the boot is the only thing that survives a fire, so you can tell which person this was. That's always an eye-opener. Then, the first time you finally put yourself together and you're in the back seat and you're heading down the runway. You are riding in something that's 20 feet long and about 2 feet wide and you're in it. Now you're scooting along and go straight up in the air still over the runway, then you're start thinking about insurance and all kinds of things that you didn't think about before you applied. As a transition to get from being a skilled scientist to a not-so-skilled backseat operator, we taught them how to run the radios, navigation aids, things like that. After they got good at it, they would do the air traffic back and forth between FAA [Federal Aviation Administration] when they'd go cross-country with some pilot astronaut in front. The Aircraft Operations Division guys did that training for the ASCANS.

WRIGHT: Prior, during the Apollo Program, they had to fly, didn't they?

HUGHES: They learned to fly. Yes, at that time, the six astronauts we had then, the scientist astronauts, they actually went to flight school. Nobody else went to flight school after that. Some of the guys came in, they'd already had some qualifications in the past, so they would get to fly—if somebody in the front seat would let them. Nobody was ever transitioned to pilot in command, at least in my watch during that time. They didn't take an airplane out by themselves,

but they would always angle around to go with somebody else. "I'll go with anybody," they'll say, "throw me in the backseat, I'm going."

WRIGHT: They had so many hours they had to be in the air.

HUGHES: Yes, 10 hours a month.

WRIGHT: Which doesn't seem like much, except that they had pretty full schedules, didn't they?

HUGHES: Yes, they had really full schedules. Once they got assigned to a flight, it was easy, though, because then the airplanes became available to them. It's a pecking order, and if you're an ASCAN that's not assigned, even if you've graduated, it's hard to get a seat in there, so they'd just always hunching around. Two hours is a 2-hour flight, but you just did touch-and-goes, that is, when you go and fly around again and you land and take off. That was all good because you were getting your hours.

WRIGHT: Let me go back, too, because I don't know if we're really finished with *Challenger*, what impacts did you have, and how your job changed when the Return to Flight was up and going?

HUGHES: Yes, let's go back and just finish. There was two parts of it. Me, personally, which was that I went through this year and we were trying to figure out what the hell happened. There were so many things—it was a month after the *Challenger* before I ever heard of an O-ring, so I

was really pissed in the sense that we had this problem that we should have been talking about, and it was covered up, as far as I'm concerned. There were people at JSC who knew about blow-by and all these words and everything—"Oh, I knew that". But, it's not like I'm living in a hole. We should have been talking about this, and of course, if I had heard about it, I'd say, "Why the hell are we flying?" If this is true, is this serious, or is this just kind of a fluff, whatever. Of course, it all came together that morning when the O-ring didn't seal up.

This is so much like the Apollo. I was so pissed, in a way, because the Apollo crew was killed because you couldn't open the hatch. The reason they couldn't open the hatch is because Gus's hatch blew loose (on his Mercury flight), and so they over-engineered to make sure this hatch is not opened accidently. Then, in Block II, they were going to have a hatch that you could activate and open it, it had a nitrogen cylinder that you pumped up that would pop the hatch open. It was secure as possible, but three activations of this handle and the locks would have popped off. They still would have been damaged from the fire, maybe only the middle guy would have got out, who knows. The fact is, is that we were that far away, why the hell weren't they moving that thing, that new hatch, forward? It was safe enough to fly twice—they were going to fly two of those spacecraft, 12 and 14, and then, of course, 12 was destroyed and 14 was just shelved, we didn't do anything—and the next time we flew, with Apollo 7, was with Block II, with all the right hatch control design.

Here we are, the new design for the new tang and groove, the interface between the two SRB [Solid Rocket Booster] field joints, are already designed and they're moving through the system, but we're going to fly all these other vehicles before we put the fixes into the system. I think it was like three more Shuttle flights before we'd have got that new design. We are bulletproof, right? We kept flying. I was really angry about that for a long time, just angry. I

didn't even know who to feel angry at; it's just one of those things where it's like, these are all friends, these are people that come over to the house and drink beer, or we go to their house. Greg [Gregory] Jarvis and Christa, they were really good people. Not as close as some. I was closer to Christa's backup, the other teacher.

WRIGHT: Barbara [R.] Morgan.

HUGHES: Barbara Morgan, yes. Somehow, we just connected up more. I would walk out of my office and they're (the crew) standing in the hallway, talking to a couple of my instructors who they just did a session with. Those people are just all around. We were close. What the hell are we doing flying a system that is so broken? If it's not right, and it would be so easy to say, "We're going to stop flying for three months while we get this other damn thing, take these things out back and light them on fire and burn the fuel out of them," so you could make the modification. Of course, somebody counted the pennies and dollars, or whatever the hell, and said, "We'll just fly them because we flew the others and they're okay." That's that.

My guys—they were hurting. I had been through this once (Apollo 1), but it didn't mean it was easier. But my instructors were really devastated, especially the ones that worked on this crew. I had to help some of them weather that storm. That took a lot of talking to some of them.

This is a job where sometimes they spent more time with the crew than with their mates, and they're with them all day, they're in the simulator all day, then they go talk about it in meetings, and then sometimes after work, they'd have a couple of beers or whatever, that kind of stuff. They probably, in those last crew hours, were just constant companions. There were seven or eight of them, and they were really, really devastated.

This accident had another effect. For some reason, I've always been close to the wives. This flight was really closer than usual. Scobee's wife, June, she was real close. She was getting a Ph.D. in education up at [Texas] A&M [University, College Station] at the time. So she would bring student groups down and I'd put them in the simulator. We just developed this other kind of relationship, as professional teachers. She and all of the wives were really hurting. (We ultimately worked with the families to build a simulator used in the *Challenger* Center organization still doing educational activities.)

WRIGHT: Yes, you know them all, don't you?

HUGHES: Yes, I know them all and there's a lot of talking to my instructors for months after that accident. The whole summer, from January to August or something like that.

And then when they offered me this opportunity [SSOTF] to go to Washington and work, I took it. I took it almost as an R&R [rest and relaxation] period. Carl Shelley, you know Carl, a super guy. He's one of my favorites in the whole business here, but he was in this SSOTF too. He and I were the only two from JSC on the training or operations because it's an operations kind of deal.

I was still with my kids (they were preteens), so I would go there for a week and then be back in Houston for a week, and gone a week, and back, all the way through the fall, and then switch it over. In the spring, it was the same thing, except that we were in Florida, on the Cape [Canaveral], in a hangar. They just had an office building built into it. We did all this stuff. About May, the SSOTF was all done. We wrote a great report that you can find somewhere. Of course, it did not get used in the way we wrote it. We'll get to that later.

Now, back in the job. When I came back, of course, the hole had filled up because I had to appoint other people to run everything in my Branch. That's when they said, "Well, we're going to create this new MOD job and so it's going to be a Space Station training office."

My organization evolved into two training division in, like, '89 or '90, something like that, in '91, when we got into the new Bldg. 4 South, they just combined the two divisions. There was a Shuttle Training Division and a Space Station Training Division, and they gave me the whole thing until I retired in 1999. Along the way, I've been through the same thing now with *Columbia* [STS-107], later. Again, this crew to instructor interface is so strong that even though I was not there part of it, I had to still talk to a lot of those people afterward, and help them get through the problem. It's an incredibly successful flight and then we lost the crew coming home. I even had difficulties over here in Tietronix. Michel Izygon was totally friends with Ilan [Ramon], they would go to temple together. Ilan was here all the time, after work. He and his family, his kids and his wife, would be around here for some reason. I'm going through it again, helping people to cope. I thought, "Holy crap, I am in some Ann Landers kind of thing."

WRIGHT: What do you tell them, Frank? After all these years of people and watching people become so close together and although they may not be here together, with the distance of traveling, but you know that those relationships are there, but then now these are final. How do you get these people through this and keep them going, where they'll still want to work in this program, knowing that this can happen to them again and again?

HUGHES: What do you do at a wake, a funeral? You tell stories, you laugh about the funny things, you cry a little bit, you go through all that stuff. I talk about what we did in the olden times, when this happened before. You try to say, "You'll get through this. I've done it twice before." Here I am, I'm standing in Arlington [National Cemetery, Virginia] with a group of people who are seeing Arlington the first time, and I said, "I've been here too many times; this is not one of my favorite places. For as beautiful as it is, it's not one of my favorite places." There are no good answers. I don't know what the hell I told them.

WRIGHT: Did you have people leave within your organization that just didn't want to go through this again?

HUGHES: Yes. Not many, they're pretty resilient, but I had some, yes. Some astronauts, same deal, again. Some people, the families say, "No way, I cannot do that." It's always been a problem. I used to talk about this with Jane Brandenstein all the time. She did put together a group that was formed to help the astronaut mates, wives actually then. There was nothing worse for each family than doing it again. The worst flight I remember is [STS-]49, Dan [Daniel C. Brandenstein] is the commander, and that's when we went outside (EVA) with three guys outside to wrestle that satellite. Along the way, he had flown three times already, this was his fourth. Every time was worse because the family, if you think about this, your husband is going to fly in the Shuttle, on anything, so you're just terrified. You know it's dangerous.

Before *Challenger*, the mates could get by with it, you wouldn't visualize it. Suddenly, you've got the visual, now, so you'd see this thing. That means your kids have it, so they're upset, they're crazy. You've got to stabilize the flyer's mother and father, who are going crazy,

slowly. They are coming to Florida or not, depending what it is. Then, because of all that stuff, a lot of people come to Florida but they expect you to pay, so you have a big expense from that, then there are schedules for everyone, that you can see what happens, it just gets going, layers and layers and layers of people. All kinds of people are coming together. The friends all want to be there, you invite them, then there are attacks on your time because they're frantic. You have parties, you laugh and everything down there, but if you were in the pre-launch, you've been through some of that. If you look at the commander's wife—or husband, now—you're getting both sides of this experience.

WRIGHT: Yes, the spouses go through a lot of stress.

HUGHES: The spouse goes through a hell of a lot, yes. Generally, it cost a minimum of $5,000 to fly, $5,000 to $10,000, between airline tickets, parties, and jewelry. Sometimes they'd buy something special and then they'd carry it with them and get it engraved, give it back to the spouse, stuff like that. That's not getting compensated, you don't get that from NASA. But it is important for the milestones in their lives.

WRIGHT: Right, but you really can't train for those things, can you, because it's what they experience in themselves.

HUGHES: They don't think about it. Now, I made sure that professionals did to talk to them about that, this is really important. Crazy. That's the paper I just wrote and gave in September, this 100-year Space Ship Conference, this is just going to be important. Imagine, you're never

going to come back, now how the hell do you say goodbye to your parents when you never come back? Of course, my answer was, "Take them." Make whole family units go, and take them off, and train them to do something. Or they're picked to be able to do something, and then you bring the kids because they're going to be the future crewmen, and you go from that point.

As people die, hopefully they're going to put together new crewmembers, but then, how many? Even if you say 1,000, pretty soon you're going to have crossbreeding, you're going to have some weaknesses, so is it 5,000? How the hell many? Or there are people who say you can make love but you can't have children with this person because you're so damn genetically close to your family. It's some interesting things about that.

WRIGHT: Lots, lots, lots of details, wherever you go.

HUGHES: Exactly. How many people would you take with you (on a 100 year trip), and then, do you put them to sleep or do you keep them alive, and then what if they don't wake up? What if they're damaged when they wake up?

WRIGHT: What changes did you make, if any, in your training protocols after *Challenger*? There was new systems and change in suits?

HUGHES: Yes. There was a whole bunch of things. We had the firemen's pole, the bail-out deal, so all that had to be added to the training. The whole procedure, that the commander would go down with the ship, it's theoretically you would have somebody up there control it. If it's controllable, by the time you get to 10,000 feet, everybody starts jumping out. You know that

process. Then, you have all the emergency training on the ground, what's going on, because that suit, that's why it had 150, 160 pounds of equipment. It's got a lifeboat, it's got a Mae West, it's got your parachute. That suit has water, food, lights, dye markers, anti-shark stuff, and all the things that are ready to be used. Then, we'd put them in the water tank over there and they'd go through these processes and make sure that they knew how to use everything, again and again and again. Of course, it'd be, here's the commander who's been trained multiple times—because he was in three or four flights—and then they would go through, so they could watch over the behavior of the newbies that are coming through the first time. Make sure you do that.

WRIGHT: Your already extended training instruction that was compacted in a small amount of time just got loaded again with more?

HUGHES: Bigger, yes. Then, we changed how we launched the flight, then we changed what they would do at certain phases, they changed when you're flying in to land in Africa, the abort once-around would be changed. Every abort mode was different. The suits, physically, were changed, but that's updates. Flight rules were changed, so you had to go through everything that was different on all those abort modes, what was going to happen, which meant that you changed lessons, which lessons were finished and not touched for years and years; now the upheaval.

That's kind of a one thing through the summer, but we didn't fly for almost two years. Then, you keep doing it again, it's that same thing, if you can't keep training then you get into that kind of thing. Of course, I talked about that, where the number of malfunctions increased because they could do it and they were bored and they figured out more creative ways to screw up flight controllers, which would then create another procedure, which would then go

through—so, you inflated that stuff. I got rid of them, some of them, later, but it was just really difficult. Any of that stuff, it's like taxes, once you put the procedure in there, who's the first guy to say, "You're never going to use this."

WRIGHT: Among your instructors, did you have different teams that wanted to do their own philosophy even though you had a lot of pieces? How much leeway, I guess, did you give to your instructors with their team to do with what they did with the astronauts?

HUGHES: Quite a bit. There's a lot of different ways because you had to believe that the commander and that team lead were going to work together to get the best thing done for that crew. Every crew is different. If I have somebody on a crew that has a scientist, then it's going to be different than one that has an Ellison Onizuka. Ellison was good at everything he touched; somebody else is not. You get in situations like that. There was one person that was slow with the arm, and they're assigned to the flight, you can't say, "Un-assign them, take them away," because first of all, by the time you know this, sometimes it's just difficult.

The procedure for that flight was to take the arm, raise it up like this, and set the breaks. Then, the commander would fly the vehicle until the spacecraft was right here, the target. Then, release the breaks, and go—that was it. Basically, you just made an extension of the spacecraft, and then he flew the spacecraft exactly to the target, and then you had to go two feet, snap it, go through the mission, successful. That Commander would never assign that crewperson to do that kind of job in a flight again. My guys worked on that with each commander, it's like, "Let's do this." Somebody, they had a meeting one day, and that's what they did. It's good, everybody's

happy. The person probably knew they were not so swift on this job but because they were happy to be on the flight, they didn't want to screw it up, and then they get successful.

WRIGHT: Do you ever have a time where you thought you're going to have to tell the crew they weren't going to fly because they weren't ready, that it just didn't come together?

HUGHES: We even did that on Apollo 11.

WRIGHT: I do remember you telling about that, yes.

HUGHES: We were saying, "It's one more month! Deke [Donald K. Slayton], please!" I told you about the one where I had some trouble. I'd go back through this document, but I had several times, I strip out names for a lot of these things.

A female employee who, once became an astronaut, felt that she was just above everyone else, she was really special. So she would come into the lessons—now, we're talking about single system trainer lessons where you had to read something, then you come in class ready to work. We'd do this normal training thing, and she wouldn't do the reading, so the guys would try to give lessons and she didn't know the basics. She was asking questions that were demonstrating that she didn't know what the hell it was. Then, she'd get pissy at them because they should be telling her this stuff, which, if she had read the prerequisite [material], she'd be ready for that. They assumed that, and then you go—it's just like any lesson. It was really a problem, so I got into this, and it was more than one instructor is hitting this kind of thing. I get

them together and I said, "Okay, I understand, let me see what I can do." I went up to the commander—she was assigned to a flight—and said, "I'm having this trouble with so-and-so."

He says, "Join the club."

I said, "Well, okay, let me try this," and I outlined what I'm going to do.

He said, "Go for it."

I go back down and I tell my instructors. I said, "For so-and-so, there's three lessons coming up next week. If you have any trouble, any trouble at all, and she demonstrates that she's not prepared to get in that class, you just very politely shut down the session, close up your books, and say, 'I'm sorry, but we'll have to reschedule this lesson because I can't do this anymore,' and you walk out. You don't stand there for any kind of arguing or anything like that, walk out, and go to my office. If I'm not in in my office, you find out from my secretary where I am and go find me and tell me." Everybody's good.

It was about Tuesday of the next week, all of a sudden, one of my instructors shows up at my door and he says, "I had to walk out of this lesson, a systems lesson."

I said, "Okay, you're off the hook. Disappear, go to your office." I walked down, slide into the single system trainer in the commander's seat because she was in the other seat—it was like an electrical lesson—and she's pissing around, putting stuff together and everything, and I said, "We got to talk for a minute. My guys are really professional. They work really hard to get this stuff right. It's really important that we get you the best training we possibly can, and they're dedicated to do that. But your side of that is you have to be ready; you have to read the prerequisite material, do all the things you have to do." She's giving me the interruptions in between. I said, "No, no, my turn. Now, I'm passing the word to my guys. If we start another lesson and you're as bad off as you were today, in terms of preparation, they're going to do the

same thing. We've had a couple of bad lessons, including this one today. If we have another one, then I'm going to go to George (Abbey) and tell him that you should get taken off the flight."

Her eyes got like this big. She says, "You can't do that, you can't do that, I'll talk to so-and-so, the commander."

I said, "I already did. He's totally in agreement about this. He could do without you. We'll get somebody else. There's lots of people up there who would kill to get this assignment, so you have another lesson scheduled three, four days from now," whatever it was at the time, I knew this schedule, "another lesson coming. We've had a lot of trouble here and I'm not going to waste my guys' time, so it's up to you." Then, I stood up and left. They said she was pretty good the next time and got better. It was like that, and I don't know who she talked to after that. I said, "I'll get you off this flight. I have no problem with that." You have to. People will do crazy things and that's one of the worst. You endanger everybody else if you don't know the damn stuff—we're not going to let you go on and screw up a flight.

WRIGHT: I was going to ask you, what are some of the most important basic lessons of pulling a crew as a cohesive working group, to be able to do what they need to do, take care of each other, once they launch?

HUGHES: Different things happen. If you think about it, there's a three-person [team], in the commander and pilot and the MS-2 that get you to orbit. Nobody else has anything they need to do with that, so the interaction between those three is critical. The third person is interesting because the MS provides an instrument scan that watches for other things—everybody always is

looking, but there, they have this view. We should maybe go over in Building 30 because that's where the SST, the single system trainers there, we could just talk about some of this stuff. When you're in the seat and strapped in, then your helmet, you can't look back. You can't look up like this because you can look up inside the hat, but the visor's right here. In other words, you can't see switches back here. They had a swizzle stick, literally, that it's right here, but when they launch, they have it, so the MS could reach up and throw a switch. You could actually turn it on or turn it off with this thing, and they did, sometimes, when they had a malfunction or something like that caused them to do that.

The interactions, like you're a third switch-thrower in that cockpit, the other side of it is at different times—I'm trying to answer your question, that's one—going home, you got that same thing going, see what I mean? Once you're in orbit, though, then it gets to be a bigger group because everybody's got jobs to do. Some are just doing photography, some are doing navigation, they're doing rendezvous, somebody's doing pilot activities, and that's a ballet going on in there. That's a different kind of thing. It's very slow because we don't do things fast when it comes in to docking, but far out, there's somebody taking distance measurements. They have a laser range finder kind of thing. Separately, we have a radar system that tells how far out you are. All this information is being put into the computer so that it gets updated, what's going on. People on the ground, somebody else is talking to the ground and getting information that they write down and then key it in, or it's been sent from the ground up into the computer system. This is all linked, and then there's a phase, when you're 20 miles out, it looks like this way, but if you're 100 feet out, it's very different.

Now, the commander is totally in charge of what's going on; everybody else is reading these because now you've got these two big vehicles starting to come together in space. It's like

you're docking an ocean liner in a port, so that's why there's a pilot involved who does that all the time for that port. We don't have that, but you get the idea, the roles change to get that to happen. Then, the person who's running the arm, that becomes really important, let's say it's a Hubble [Space Telescope] mission. Now, the commander gets you up—the arm is only 50 feet long, which means then the guy's going to fly so you're within 30, 35 feet, so you can reach out and snag the thing—and then, when you snag it by itself, then you set the brakes here and hold it, and then you stop doing anything and let all the vibrations damp out.

Then, you can turn everything back on and start bringing that thing down because it's action-reaction. This Hubble weighs 40,000 pounds, this Shuttle weighs 200,000, but they interact with each other. That kind of stuff has to be taught, first of all, and then practiced and practiced and practiced. They know what is going on, and that dependence, where you can say something and you know the other person is going to know what you meant and do it, inherently, you don't have to say, "Oh, I meant to do this," so they even practice how they say it, so that you know exactly what you mean and get the exact reactions out of it.

The one I've talked about before, about this thing where you just—where they couldn't get that confidence, so then there wasn't anything you do with that person. It's not damaging enough to toss them over the side of the ship; you would just say, "Okay, here's what I'm going to do, here's our procedure on this flight. I like it this way." You don't have to say "Because you're a dumb cluck," or whatever else, you just say, "Here it is." Hundreds of feet out, this thing is already parked. It just means it's an extension of the vehicle, and now I, as the commander, am going to fly up, like that's the end of my probe. Mentally, that's the thing I'm flying toward, and then you get close enough, stop, settle everything out, and it's like two stationary things. This is only two feet away, and then you go straight forward, and just grab it.

WRIGHT: Make it sound easy.

HUGHES: Yes, because the pilots could do it all the time. It's like a union, where they said the RMS was going to give it to the Mission Specialist Union, so they had to have something useful to do during this ops space, and it worked. Many, many of them were very good, some weren't and they got better, and others just didn't get very good.

WRIGHT: I imagine you had different challenges based on whether or not they were scientists or physicians or engineers.

HUGHES: Yes, but it's almost across, many of the doctors were really good pilots. Joe [Joseph P.] Kerwin, he was one of the ones who went off and learned how to fly. He was a good pilot, so you could give him a job and it didn't matter that he's an MD. He was a good pilot, too, so you'd give him a stick and he could fly around. Just different people are just different. I'll give you all the names when they're really good at something; I don't give you those other names.

WRIGHT: That's okay. If you don't mind, we can finish the session, just talk for a few seconds about the challenges of—or maybe we'll put a start for the next one—challenging for specific, intricate missions like you mentioned the Hubble, and then also, when you trained people for Shuttle-Mir because you were starting that international interaction in the work that you started doing with the Russian crews, as well as getting your crews ready to deal with the Russians.

HUGHES: I know, it was interesting because the two are so different and yet similar, they'll come together. Let's just do Hubble, first, and maybe we'll pick up Mir the next time because Mir opens up the whole Russian thing. Hubble is the first time we started using virtual reality. [R.] Bowen Loftin, who's now the president of Texas A&M, and I go back a long way, but we're back to when Building 12, they had a laboratory over there, doing virtual environment stuff. In fact, Michel and Victor, here at Tietronix, were part of that operation over there. They were working for different contractors. They were doing these virtual reality environments.

Hubble by itself was a big challenge. It's heavy, it had to go to a high orbit, so there was all kinds of things we did mechanically to make sure we could carry this thing up there. We launched with less fuel than normal, in some sense, but we had to use all the fuel we had to get up higher altitude. The way the Shuttle would work when you launched, to have to go back a notch, is that it would launch into an orbit that was like, 150 by 30 or so, and then you'd dump the tank. The reason was you would do that, you wanted the tank to fall into the ocean, it would reenter. Then you would perform an OMS burn, where you'd light that off, and then add enough velocity. Now, you're in 150/150 or circular, or something like that. This beast (the Hubble)—and we used the big engines—and we put it up 350 miles (like 350 by 60 miles), way high up, got rid of the tank , and then we had to use all the fuel we had to make that, just more OMS fuel, to make the orbit circular (350/350).

That was a whole thing on the front end, just to get this beast to the right altitude where it had to be. The right altitude is as high as we could get it, because two things: one, it would stay in orbit longer, and there's less air and therefore, less drag. It actually went up higher than the Space Station is, now. (We'd love the Space Station to be up that high, too, because then we wouldn't have to worry about drag.) Then, when we took it out of the bay—the delivery flight,

that was actually Charlie [Charles F.] Bolden [Pilot for STS-31] delivered that one with his crew, and it was perfect. They just put it out and everything worked. They backed away and the telescope turned on and they said, "We're good." They were prepared to go grab it again and put it back in the bay and bring it home if something didn't work. They left. It's only when they started checking out the telescope that we knew that the mirror was bad, it was ground incorrectly. Then, that made the second flight a big deal. They had to go back to this altitude, find it, and rendezvous, pick it up, which is straightforward.

It just doesn't matter what altitude you are when you do a rendezvous. You go through the same steps. When you got it, it was so delicate, the delicate processors and instruments inside made it difficult. We didn't use the virtual reality to launch the thing, that was pretty easy, but it's this thing about getting the doors on the Hubble open. They're all nailed shut with all these fasteners and everything, and we had to have the right tools to get in there. A lot of these pieces were not built to be changed out. The telescope was built to be serviced. But not everything that we needed to do for this mirror problem was made to be serviced. The crew had to do a lot of things that were completely new and had to be invented during the preparations and training.

They were doing four different EVA days, different guys, we had two sets of EVA crews so two guys would go out, and then the other two would go out the next day, because the wear and tear on your body on an EVA is awesome. I don't know if you know—you come back in and the gloves are so tough that your fingernails are all black and blue, just the effect of squeezing down, and your forearms hurt. The space suit is like a balloon, so all the fingers stretch straight out. To do this is just really difficult. That's why if you look at a hammer that

we use, the diameter of the handle is huge. The circle is about this big, the handle is large, because then you can grab it without making a tight fist.

All of these kinds of things go on all the time. This is routine we know now, after years of doing this, and then the power drills that they use, they had to make sure you have enough power packs to interchange things like that. They got the Hubble all open, really tore into it. Actually, we did the training on it virtually and we did it in the water, both. It was really crude virtual stuff relative to today, but it helped them a lot to just be able to see these things and how it all fits together. Of course, it helped us to make the technology better, too. We're talking 1991, '92, '93, this kind of time. I think we launched in '90, and then it was December 1993 when we came back to try to do the repair. Then, for the other repair missions, after that, it got only better. That is that the virtual stuff got better. If you've ever been over to Building 9 when there was a virtual lab over there, and actually go through this virtual simulator, it just got exquisitely good.

WRIGHT: Were you in the discussions to decide whether or not the astronauts could go in there and repair those, and/or if they could be trained to do it?

HUGHES: We were, but actually, by that time, I would let my team lead go and represent the commander and that person, they would do that. As far as safety, like earlier, no. Somebody else did that. I don't know anything about the Hubble in terms of sharp edges. That's somebody else that had to make that call, but the astronauts were part of that discussion. If they said they could do it, then we'd train them to do it. If they agreed it was doable, that's good, because that's their call. If they'd say it's too damn dangerous to do, well, I'm not going to talk them

into it. That whole thing, I'm very proud of what they did with that first one. After that, everybody knew a lot more about Hubble, you could go back, we tore it apart.

Just sliding that first big-ass spectrometer in there with the new lens on it, it made a whole difference. Different cameras added, it was great. I was so impressed with these guys. Tom [Thomas D.] Jones and all the different people kept going up there all the time, and what is this guy's name, the one that's in Washington as the Chief Scientist?

WRIGHT: Currently?

HUGHES: Yes, he was up there twice.

WRIGHT: John [M. Grunsfeld].

HUGHES: Yes, Grunsfeld. Too many names, hundreds of names, if you think about it. He was up, he was an astronomer, he was trained as an astronomer, not trained as a mechanic. John is a super guy and I am so glad he is not here to see that I could not come up with his name.

WRIGHT: Mechanical astronomer—it starts a new field now, mechanical astronomy.

HUGHES: Yes, I know, he said, "This is really different than the career I thought I was going to have."

WRIGHT: You mentioned Hubble and you also mentioned the time that the three astronauts went out, and Kraft. Are there others that stick in your mind from all those Shuttle missions that there more difficulty in training in those missions, or were just the missions difficult so it needed additional training?

HUGHES: Both. There was something wrong with every flight almost. It's very rarely they would come back home, that we didn't have to go in the simulator and practice something, or in the water tank, or in one of the other training venues. When you got to that situation, when you got in orbit, the biggest problem was not the things you trained for; it was something you didn't train for, it's something that was missed, something that turned out to be more difficult, going back all the way to Gemini, where the guys, they got out, and this is a piece of cake, there's no gravity, and they didn't have an adequate place to grab on, they couldn't control their orientation of their body. We learned a lot so that by the time it got to [Gemini] 12, [Buzz] Aldrin went out and just did a hell of a job, but we also hardly learned anything from that flight (because we used everything from the earlier flights.) Mike [Michael] Collins did a hell of a job on Gemini 10,—he actually went to another vehicle (the Agena from Gemini 8,) they brought it back in and got an experiment package from it. Then they docked with their own GT-10 Agena and John Young and Mike drove themselves up to 400 miles (a new human record). Then Pete [Charles Conrad] on [Gemini] 11 drove the spacecraft up to 800 miles above the Earth (another record).

They did all these things. During Gemini, EVA kept falling on its butt, though. Mike Collins and John Young on [Gemini] 10, they launched and did everything they wanted. They lost a camera, they lost a glove, there's some stuff like that, but small potatoes relatively. What they couldn't do is get the damn hatch closed. When they came back in, the Russians almost lost

Alexey Leonov because they had a fabric airlock kind of thing, and his suit had ballooned up, so he had to actually let pressure out of the suit in order to get back inside. Ours was kind of like that—when they got it all down, heat expansion or whatever else, but then the Gemini, they actually had a pry bar that they took with them. That bar helped them to close it with a lever because they couldn't just grab the door and pull it closed because the expansion of the gaskets, it was hard to get enough to latch it down tight. They brought something along, kind of an unauthorized [tool], and then it just found its way into the cockpit.

WRIGHT: To work.

HUGHES: Yes, and it worked. They would not have made it back without it. Things like that.

WRIGHT: I guess that part of your lessons that were embedded was to teach them to have the confidence in knowing what was on their spacecraft, to be able to make things like a fly-swatter or how to pull those latches down.

HUGHES: Yes, all of that stuff. Dale [A.] Gardner going out on that [EVA] that they did because they tried one day and they couldn't snag that satellite, and then they went back the next day, they farted around some, invented some, then went back out and did it. Yes, the fly-swatter where they turned on the switch on that [satellite]. It's not just the crew—this is with the ground, it's [Jack A.] Kinzler, the guy with the [parasol] on Skylab.

Individual guys are superstars, and then they just have to convince somebody else. I had the same [experience] with how to fix it so you could roll the spacecraft and let the crew go to

sleep, just individual things that they did all the time, which was just astounding to see. Somebody would have this, "Oh, let's do this." That whole thing of putting three guys in an airlock by itself was a big thing for STS-49. Yet, without doing that, we'd have never been able to get that done and save that satellite. Nobody would try to do that on regular procedures, and they said, "Can you fit all three in there?" The guys look at each other and said, "Well, hell, yes!"

WRIGHT: Made it work.

HUGHES: Made it work. It's just stuffing a phone booth, right? Then, getting back in, same deal, you'd pack in. Who's got a hand loose to close the hatch? It's an amazing thing, that some people thought we followed the flight all the time, that the simulators would just be there and running along minute by minute, everything the crew did, that's if somebody in space—we didn't do that. The only time that happened is [Apollo] 13, I told you about that, when we just rebuilt the damn simulator overnight and made it like that real vehicle. Other than that, we got on with the next flight. They're graduated, they're out the door, turn them over to those guys in Houston and we just keep on going, in MCC versus the simulator. Immediately turn around say, "Zap, you're back out there, right on line," and it doesn't matter. You could throw out anybody on the simulator, walk in the door, and say, "I need the simulator because I need to do something for the crew." This guy that you were training now becomes your test guy. They immediately say, "What do you need to do?"

WRIGHT: "While I'm here."

HUGHES: The astronaut would say, "I'm here, I'd be happy to do it." When they're in orbit, they want somebody else to say the same thing.

WRIGHT: That may be a good place to stop, and then we pick up the international, how it started.

HUGHES: Yes, let's pick it up from Mir and how that began to develop.

WRIGHT: Sounds good.

[End of interview]