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INTERVIEWED BY REBECCA WRIGHT
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The following interview was conducted with Francis E. "Frank" Hughes for the Johnson Space Center Oral History Project on October 29, 2013 in Houston, Texas. The interviewer was Rebecca Wright.

WRIGHT: Did you have more about Skylab and/or ASTP [Apollo-Soyuz Test Project]?

HUGHES: I was thinking about this last night—we can start on [Space] Shuttle today, but kind of as a transition. As we went through, I was discontent with the training process. I loved what we were doing on Apollo, but I was always discontent on what was going on. By the time we got through the 17 Apollos and then the 3 Skylab flights and the 1 ASTP, we had turned the Apollo system into a really good-running, smooth system. Which, of course, that's the NASA way, then (with help from Congress) we shut it down.

The ASTP flight, it was so clean. Almost nothing happened. In fact, it was the most boring flight in the world; it was wonderful. We got them off the ground, got back on the ground, and you could hardly see anything we did except right in the entry phase. What happened is remember I was working as a flight controller in what was called the Flight Control Division, in those days. That was a time, from '72, the end of Skylab, until '75, that's when the Flight Crew Directorate gave away the training.

The training was all reorganized into MOD, and Mission Ops [Operations] Directorate had Gene [Eugene F.] Kranz as the deputy to George [W.S.] Abbey, who was the head of that directorate. That was a disaster walking around waiting to happen because basically, they just broke it up. George took care of all the crew and all the aircraft ops things and Gene took care of the Flight Control Division, and the ops divisions, and that worked. At the end of the ASTP program, I was assigned in the Flight Control Division, so then I was going to work with Don [Donald R.] Puddy as a branch chief, and Ed [Edward L.] Pavelka, who was the section head.

We were going to do the planning for the testing, with the Shuttle testing, which meant that we wanted to buy a 747. Then we had do these other things to visualize what would be needed, and basically write down the plans for what you're going to do—ops plans. There was an ops plan for ALT—ALT is the Approach and Landing Test—and then there was another one for Shuttle ops in the future. I did that one for operations, and I have a copy of it in that bookcase. It was a very unpopular book (when I published it) because when I started working this project, remember, we were going to do 60 flights a year. That's what they were talking about, flying 60 flights a year. At that point, everybody thought that was pretty good, it was doable. We thought that this Shuttle was going to turn around fast. We didn't know the real world was going to happen to us yet.

We could have turned around a lot faster than it ever did. I think that it was our suspenders and belt mentality of NASA [old joke about NASA safety and NASA people, they wore suspenders and a belt to make sure their pants would not fall down.] You know what I mean here, that the KSC [Kennedy Space Center, Florida] engineers were so safe that they took the engines off the vehicle every time, boroscoped out (looked inside it like some laparoscopic test on one of us) and did all kinds of things that just extended the length of the turnaround.

Granted, there had been failures during engine tests. Good people made those good decisions. It was not my bailiwick when all was said and done, they were just being careful and were just looking for problems. But, if it ain't broke, don't fix it.

Anyway, I wrote in this ops plan that if you do 60 flights a year, it means that your flight controller people are going to be on console all the time. During these flights, if you get the Shuttle as good as Apollo used to get, then it's going to be boring. Boring is good in one flight, but it's not your life's work.

If you get some guy that comes in to NASA with straight A's out of Texas A&M [University, College Station] or UT [University of Texas, Austin] or [University of] Notre Dame [Indiana] or Purdue [University, West Lafayette, Indiana], he's not going to work third shift on a boring flight. They will leave for something more interesting. So you're going to have to do some kind of job enrichment, something that will keep them here. I suggested that you would combine the flight control job with flight planning, teach those people so they could be planning a future flight in real time. Meanwhile, if something happens on the flight, you're sitting there in MCC [Mission Control Center] already, working on it. Then you pay full attention to that problem.

I also thought that should be that you don't have to staff a big second or third shift crew, but let them all be a day shift, and if they're at home, find a way to talk to these guys and remote the Mission Control data to their homes. We're talking about 1975-6-7-8, and there was no way to do that, at that time. We didn't have an Internet; just didn't exist yet, literally, we certainly did not have it near the MCC.

No one could imagine being a flight controller outside of the MCC. That was taken like I was making a joke, you know what I mean? Then, when I said, being a flight controller could be boring, that was bad.

Pete [M.P.] Frank [III], who was the Division Chief at the time, decided that I needed to go somewhere else other than his division. They didn't exactly tear off my epaulets and break my sword like you would do in the French Foreign Legion, but I was sent back to the training division. A fellow named Jim [James W.] Bilodeau was running that training division, and it's interesting, his deputy was John [W.] O'Neill. Some really good people were in that staff, and I was happy to get back. It was a very different division than what I had been in before. Now, Deke [Donald K.] Slayton's not the one running the directorate. Before it was very much of a crew-oriented kind of thing then, but now it gets more flight-controller-oriented. In Apollo, we didn't really talk about this, there were two organizations. There was a group inside the FOD [Flight Operations Division], the people running for [Christopher C.] Kraft, and they trained flight controllers, and we trained crew in the FCOD [Flight Crew Operations Division], because it was two different directorates. Now, that's all smushed together into one. There's some effort to work through all this. While we survived through Skylab because that was all still the trainers cared about the crew and the other people cared about flight controllers, now you have to mush it all together. I came back in 1977 and that year was the first time, actually in late '76, they turned on the Shuttle Mission Simulator for the first time.

The Shuttle Mission Simulator had been designed by Link [a division of Singer Corporation], again, and they were working closely with Rockwell to build the Shuttle. It was a pretty good relationship between the two of them. It was the motion base built first, so it was only one base available, then. It was there just to do ALT, Approach and Landing Test. The

visual was just for landing because that's all you did, you flew up on a 747 and then suddenly, you were flying. You had a huge model board—the visual consisted of a physical model where a camera tracked across a big model of Edwards [Air Force Base, California], so you had relief on this [model] and everything else, and all the runways on the lake bed. It was a beautiful thing.

I wish somebody's got a photo of that; I need some photos of some of these things. That'd be a challenge to see if we can find, of this landing scene. Later, when we went to all-digital, that went away and I don't know where it went. That would have been great. It was huge, it was like 20 feet long by 15 feet wide, or something like that. It was a big chunk and it would be great, it would have been wonderful to have it out at Edwards, just if nothing else, to let them put it on the wall somewhere, maybe a Space Center Houston.

I got back into the training business again. And the world was really in an uproar, in the sense that how are we going to do all this training? We knew now we had two crews, we're going to have Dick [Richard H.] Truly and Joe [H.] Engle in one crew, and then [C.] Gordon Fullerton and Fred [W.] Haise in the second crew. That's all we had, two crews that are going to fly these flights. They flew unmanned flights for a while, and then they put people in them and they fly it on the 747 without separating.

They just flew around so they'd see how the system behaved and everything. Finally, we did five free flight tests. All the training during this time, we had one team of instructors, and Denny [John D.] Holt was the one that was doing that job as the Team Lead. He and I, we worked neck-and-neck as far as relationships and history, because he had already trained flight controllers and I'd always been in the crew side.

By the way, when we shut down at the end of Apollo, everybody that was in Florida moved back here, if they wanted to. Many did, but many did not, so much of the corporate

memory of that crew training [program] disappeared. It just stayed at KSC [NASA Kennedy Space Center, Florida] and it was used for other things. There was no more crew training down there. That was a blow by itself, when a lot of people who are really good at crew training and procedures like that just disappeared. The instructor people down here were those who did systems crew training. Remember, the early training we discussed, where you did systems training compared to what we would call mission-specific training later in Florida—these guys had to gear up and try to figure out how to do all that training. Skylab was a little bit rough because of that, just the personalities. It wasn't that they were bad; it was a different kind of training they were forced into, just by circumstances. They became really good instructors but it took some time. Others became simulator operators rather than instructors.

There are some people, we always joke about one, Roger [A.] Burke, who was probably one of the smartest people I've ever known, but he was coarse. It was just interesting. We used to say, if Roger worked with you and he's going to make a presentation, you have to have two other people—somebody to go before, to tell what it's going to be like when Roger's there, and then somebody to go afterward to apologize. It was something else. Like I say, he could make the simulator run and do almost anything, but you never knew what the hell he was going to say. I'm bad enough when I talk, but I mean, with Roger, this is way, way outside of scale.

I'm going to put names on some of these, you understand? Roger was a special case and still is. He was a great friend, and if he was here, I'd still tell these stories, but it just goes on like that. He'd leave the room and people would say, "Who was that?" I said, "Never mind. You just learned something; take it, run with it."

There's a lot of notable personalities at NASA. I always think of one that was the head of the software development group, Jim Miller, during Apollo, he was a division chief, and he

would get pissed off at his contractor due to performance. He'd get IBM over to his conference room and (sometimes) he'd walk on the table, up and down. He'd be up on this table, walking up and down, swearing at them about how poor they were doing their job. All these executives with their skinny ties and everything, just putting up with this because he's the NASA guy. Funny stuff.

This mishmash that's going on, and just at this time, in 1977, just beginning of '78, we had to start thinking about training for the flight crews. Now I knew it was going to be John [W.] Young, Bob [Robert L.] Crippen. I know Young forever, I know Cripp because he was the CapCom [Capsule Communicator] that I worked with all through Skylab, so though I didn't know him before, coming in, we got to be really close. Close, like his wife taught my kids how to ride horses, and all this kind of stuff. It was really a lot of things going on, parties and whatever.

At the same time, Jake [Jasper C.] Smith in that division invited a training expert. They got a contract to have somebody come in who's a training development expert. I didn't have any training development expertise. My degrees are in physics, so I don't know training, except I know what I don't know, what I don't like about it. He brought this guy in for a couple of days and the training expert talked about how they would build a training plan. This guy was suddenly preaching to me and [it was] the first time I heard something like a precursors, and then successors. That is, whenever you had a lesson, there had to be something you had to learn beforehand and then there had to be something that came after that one because of the nature of the subject. I just went, whoa, this is the answer to this grief-stricken crowd we have sitting around here. This is the way we should do this Shuttle training.

I think Jake Smith, who brought that person in, should have gotten an award. Actually, he probably got shot down about doing that. The other division people said that training expert wasn't very good, but I got the mail on that one. I said, whoa, this is a really good deal, this is the future. I've always thanked Jake for that, I said, "This is really something important." Somewhere in December of '77, I was in a group, what was going to be ascent/entry training. Just that, it's the dynamic kind of phase of the flight. Not the on-orbit stuff, drilling holes in the sky, but everything else, launching, reentry, landing, etc. There were three groups. Then, there was a systems training, and then there was flight software.

Ascent/entry was training software that I happened to be in because it was always what I was doing before in Apollo. I sat down at the kitchen table one night and I worked to create training flows for ascent, orbit, and entry, just that. It was creating questions like: what would you do first? For example, I'd have a briefing about the software and how it would work so you teach the crew. Then you would plan a lesson of normal operations. This vehicle is a flying computer—we'll get back to that, but that Shuttle is going to be so different than anything that came before. I needed a trainer, something like a small trainer, that would teach the people how to do the procedures. I invented the idea of the Single System Trainer; one of them is in Building 30 in the lobby, now. There were three of those ultimately built and operated on the second floor of Building 4 South.

After you got through with this system, and you'd have to go through each system—you have to go through main engines and electrical and environmental normal operations—then you do malfunctions. You'd have one lesson at least where it's the normal ops, just how to turn things on and turn things off and things like that, then another lesson, at least one, where you'd do malfunctions. When you get through all that, now you'd go to the simulator, the big Shuttle

Mission Simulator that doesn't even exist yet, it's still coming together. You go there and you would say, "Okay, we're going to do launch. Just no malfunctions, see how it looks when it goes to orbit," and do it multiple times. It broke all these things out, and they came into many lessons of about two hours each.

This is two hours in the simulator to do this, and sometimes later, there were four hours. Two hours was a lesson, two hours with the instructor in the single system trainer, and then it was blocks of times like four hours, from 8:00 to 12:00, you'd be in the mission simulator, and then somebody else would get in from 12:00 to 4:00, something like that. This meant we needed two teams. You did a morning team and the afternoon team, and that was all it was, was two teams of about five people, when we put the simulator together.

The instructor teams started doing this stuff. No one asked the crew what they wanted to do—I mean, there was obviously give and take about that, but you'd say, "This is lesson number X," and gave the names and everything. It said, "We're going to do these objectives." Inside that four-hour block, you're going to see a normal launch, you're going to see an engine out, you're going to see some kind of a cabin leak that means you have to go back home, you have to go back to Kennedy." All this stuff, a page of launch sessions and then another one for orbit, what do you do when you are in orbit? You have to be able to get there, you have to shut down all the engines, you have to be able to align your platform so you see where you are looking. You have to do star trackers. You have to do other things like close the doors, open the doors, things like that, getting ready to go home.

Then, later, you do entry, all these same things, but now there's another page. You just come back with these three pages, and with notes on each block. It was just like a little logic diagram, what you would do. In ascent, there was four different ways to abort. There was Abort

Once Around [AOA] the Earth, abort back to RTLS [Return to Launch Site], Abort to Orbit [ATO]. There was another one, TAL [Transoceanic Abort Landing] across to Africa.

I used a graphic computer logic template for these lesson flows. You got this system and the logic came back, it was kind of linear. Each lesson flowed into another lesson. Then all of a sudden, there'd be four lessons that you can do, any of these four in any order, doesn't matter, But you have to get them all done before you go to this next lesson. Just this block, here. I went back and I gave those lesson flows to three of my guys. Michele [A.] Brekke got to be the ascent person and Bob [Robert J.] Williams—it's funny, there was three Bob Williams around, but this is my Bob Williams, was just the one in the training organization—and then there was Dianne [J.] Murphy, and she became Kanipe later, she married Dave [David B.] Kanipe, but she stayed Murphy, I think, all through her career here. She was the entry person because she had lots of aero in her background.

I said, "Fix these, make them right, add the details." There's a page for each of these blocks that is going to be the details of what we would do inside that lesson, and then we'd have reviews of what's going on. In the first couple of weeks, it became that there was a structure, and it became a catalog similar to what you would find in a college. Later, we added another flow for rendezvous, another flow for RMS [Remote Manipulator System], you had another flow for EVA [Extravehicular Activity], all those training subjects that exist.

In fact, I thought we were going to be meeting near my office and I was going to show you the book, but here's the one that they're living with today. Mine is probably five years out of date, but it's all the Shuttle system flows and lessons It grew to be a couple of inches of paper because inside there, there's a page for each of the lessons, now with all the objectives and the precursors and who has to do it, what kind of instructors you need, which of the crew—because

not everybody goes to every lesson, some of them begin to specialize—and so on. Setting up this process made me feel good; I finally was content with the process that ingested astronauts in one end and turning out flight-ready crews at the other end.

By the time late 1979 came, I was appointed as a first line supervisor, we (Denny and I) were team leads, then. I was a team lead through this whole thing, and there were two teams. After ALT was over, we flew those things successfully, but then Denny was on one team and I was on the other team, and then Denny, when we started doing what became known as integrated training, he became the first Sim Sup [Simulation Supervisor], and another guy named Jerry [W.] Mill became the other team leader. We had two teams, and it wasn't assigned to a crew, it was that you just went out and did everything. You'd have 20 hours this week, you'd do all the morning, whatever assignment came, the crews that came in the morning, you did that. Then, the afternoon, you did somebody else.

That worked for four, five, six months, and then I created a stir, another stir and I wanted to assign a team to a crew. After a lesson, some kid that's a GS-9 [General Schedule] is not going to tell John Young he really made a screwed-up landing. He just wouldn't do it. But if he worked with John every day, like he saw all the good landings, then it would be easier to discuss what happened during that bad landing. We changed that, so then the rest of the time we flew Shuttle, and even now, you'd get a team of instructors that was assigned to a specific crew. Every time that crew was in the simulator, that team [was there], so it made their life a little worse in the sense that they were all over the map in terms of what's going on. But, it meant that they really got close to the crew. They got to be part of the team, so the four or five people that were part of that, you'd have a team lead, you'd have a control person—which was all those guidance and navigation control experts—you'd have a systems person, you'd have a

communications person. You'd have a rendezvous person if they were doing a rendezvous. They had an RMS person, if you're doing that. You also had people that would drop into a team and not drop in it, based on the lesson. It is a continuity thing. Because of this close working relationship with the crew, the teams would be invited to the launch, they would be there at all the parties, and they were just close and it worked. It turned out to be a really, really good deal.

The training started to happen then in 1978. It was interesting because then, we saw we were going to fly in September of '79. Of course, the vehicle got down to the Cape [Canaveral, Florida], and then it didn't go. One problem developed after another problem (mostly Main Propulsion System and Thermal Protection System (Tiles). Those continue to be a problem, which is if you slip the flight, even though you've gone through all of the lessons, you train more. You keep on training. But the meter keeps on running—money is being spent. So delay, by itself, causes a lot of money and a lot of heartache budget wise. In addition, it seemed that the malfunctions we started with in the simulator, our instructors were creative, so they'd create more malfunctions and feed it to crew, and then the flight controllers would be taken aback and surprised by the fact of this possible malfunction, so then they'd have to create a procedure to handle this malfunction. Then we had to train for that malfunction. This went on and on.

The number of procedures went way up and up and up which led to more training for each flight. If anything, when you go back to how you look at training, you have to make sure you keep it down to some level, otherwise, the bill got to be enormous. When we started training for [International] Space Station, a whole different deal, it is an enormous amount of training and time. It takes just 18 months, say, to get ready, but it's more like 36 months if you take all the different countries and all the different vehicles connected together. Pretty soon, I always say that "it's like being sentenced to go fly" because it takes so long to get ready, and then you are

gone for six months or a year, whatever it is. That's another problem that we never solved. That one still goes on today.

That transition, I guess, from Shuttle into Station was a big thing. That is, that finally we added some structure to this training system, which really made me happy with it. I was really satisfied with it. Now, we had to build it, we had to make it work. Just the idea that you came up with something is OK but now you have to go do it.

I never thought about a catalogue until I thought of it after it was created, and I said, "Well, we just did that. We created something like a college catalogue." That's what it was and is.

WRIGHT: If you can, Frank, give us a little additional details because we see things when we create things now, computers and your catalogue, you just search and you pull it up, but everything that you were doing, you were creating by hand.

HUGHES: By hand, it was all by hand, yes. I literally had pieces of typing paper in the kitchen table one night, the kids were asleep. I raised my kids alone. Along the way here somewhere I divorced, and I raised the kids. They stayed with me most of the time. I'd put them to bed and I'd sit at the table and I'd just take one of these training flows and work on it. One night, I got on a roll and I did three of them in one night, I got their first level done. In those days, we had Federal Electric, a contractor. It was the name of the company which did drawings, procedures, typing and so on. I turned them in and I said, "Make this thing look good."

They literally took stencils and made boxes and then typed the name of the lessons into all this to make this [catalogue] look decent. It looked like a computer flow diagram, with all the

decision blocks if there was a place where you had options to go different ways, things like that. Yes, it was very, very different. We had run with computers in the [Mission] Control Center [MCC], but it was all kinds of a batch job. That is, batch job means you asked for something or you gave them a set of cards, and then they ran it. Somebody ran it, gave the answers back. When I was in grad school, it was hardly any different than that. That was 10, 15 years before that. I didn't see a computer on my desk until 1984. MOD went to computers. Some people had had them, I think, a year or two earlier, but only just. The managers didn't use them at all, at that time. I was a branch chief at that time so I was using it, but a lot of people just didn't.

I remember, in MOD, I was running the training division by then. I stood up and gave a lecture one time, they'd have a Monday morning meeting for all the division chiefs would come together with Kranz, and then later with John O'Neill or somebody, but it was Kranz, and I told them about the Internet. I said, "This is really something. You have to use this. You can't believe what it can do."

They all said, "What are you talking about?"

"It's amazing, you could just ask questions and you'll get answers."

"What's the use of that?"

"It was just amazing," I said, "Hey, I'm going to talk to you in six months and see what you think." It was just there, and I said, "You just climb on and just go to this address on your computer." Because it was by now, it was not just a word processor, it was connected into the Web. I said, "You won't believe it."

WRIGHT: Little did you know.

HUGHES: Little did I know. Now, all those people probably don't work anymore. They are retired and they just screw around on the Web. They don't get anything done all day. <smile>

WRIGHT: Or all the answers are on the Web now.

HUGHES: It's true, it's absolutely true. All of the smart people that work here at Tietronix, and a couple of them, I can just ask them anything and they'll just come up, they know just how to fix my computer, for example. This thing is doing this, how do I fix it? It was a big eye-opening one day, he sat down at my computer and he said, "Oh, yes, I see." He goes to Google and types it in, and he types it in a natural language, and he types like just like I was talking to it myself—how do you get something to la-di-da? It comes back with about 1,700 different ways to do it. I thought, "I could have done that."

WRIGHT: You too were as smart.

HUGHES: Truly, there's no handbook anymore. It's just ask it and it's there somewhere. You pick up the one that you already know, or a new one, possibly, because it'll all come up different ways. It is the most marvelous thing. On the other hand, of course, I always think, there was a short story by somebody, [Robert A.] Heinlein or somebody, about all of the memory. It was like libraries, it was all becoming electronic, and then they found ways to make it smaller because it was just changing electrons around the ring of the thing of it, that's how they did it. They got it down smaller until finally, some subatomic particle has all this stuff, everything that

people know. The whole memory of the world is in something about the size of a six-inch cube. Then, they forgot the password.

WRIGHT: Can't Google that, can you?

HUGHES: There you go, start over. It was just funny. That's what I always think of, that story of everything is just getting it smaller and more portable. Just your phone because it's a conduit out to all that stuff, but you can ask it anything. Now, you can talk to it. In fact, what's funny is when you talk to it, you have to use its pronunciation because if you try to get somebody's name, "Call Rebecca," of course, it'll say, "Which Rebecca?" I don't have any except you and one other in the whole world, but it does that to me all the time. Or it will say, my in-laws' name, it's Czech, Hradecky, but it starts with an H. The name, it comes back, the pronunciation of that word is so strange, so I have to say what it wants me to say, to have someone call Randy *Hecky*, you know?

WRIGHT: You're being trained by a phone?

HUGHES: Exactly. I'm changing my words so I can talk to this.

WRIGHT: Explain to us, because the Shuttle was still being put together and systems had the possibility of being tweaked or switched around, you didn't have any concrete material to work with when you were developing all these, how were you able to get the information that you

needed to start designing the Single System Trainers and that type of information that you needed to train the people who were going to be using it?

HUGHES: It's interesting, there. I was going to double-back on that because once we started with the catalogue, that is, with the flow, that gave a structure to it, but then the hard work started, you had to build all that training for the crew. It's almost funny because you get back to the book—remember on Apollo, we had one book?

WRIGHT: Yes. That everybody got a section of, originally?

HUGHES: Yes, exactly. Now, there was one book but it is the bible for the software in the Shuttle. We had multiple copies of it because now we had Xerox (first one I had ever seen), and so we could crank out more copies than you'd ever know. Dick [Richard A.] Thorson, a hell of a guy, if you know that name, he and Jack [John R.] Garman and people like that worked very hard on the flight software of this Shuttle. As they worked it, they kept good records and they wrote requirements about what the flight software is going to do. The problem is, it's not one machine—it's five machines, and four are going to be all on the same software, that is, at the primary, and then there's going to be a backup. Let's just talk about that.

Of course, all of the material I'm talking about here has to become part of the training. BFS, the Backup Flight Software, using the same algorithms to how to fly home safely but done by different programmers. The idea was, when you built the four in the front end that you're safe from hardware failures. If one of them fails, you still have three others, and so on like that. If you'd had a software problem built into it, well then, they'd all have the same one so they'd all

go down with that failure. That would leave you the backup—hopefully, the people who programmed that didn't use the same code, they would not use the same code, and so you'd get home. We never went to the backup, 135 flights, we just never did that. That's a good fact by itself.

We had to read this book (the software requirements book) and then we had to make sense of it, what they said, because then somebody else wrote back, IBM wrote back, and said, "This is what we're going to build." Then, you had to translate that back to English so you could talk to some astronaut who was going to have to know how to use it. It came down to somebody just spent hours and hours and hours making displays. This is what's going to show up on the screen, and there were several hundred of these displays that were possible in the computer. Where before, in Apollo, it was interesting—we used to talk with little verbs and nouns, verb 6 was display, and verb 16 was the monitor, and you could see over here it was 30, which was the high new angles. [Showing an Apollo cockpit drawing.]

Now, it was items, that we got to the point where little switch codes, like you have a physical switch here, it'll turn it on or off, but in the computer, you would do an item three execute, and it would do the thing you were asking to do in the software. It was like turning it on. Now, you click on an icon and it does that. All you're doing is setting a flag of something that makes the computer do something different than it was doing otherwise, or you're making a request of how to do it.

At that time, we had to come up with these displays, somebody designed them, and then they were, again, it was no computers yet, so it was all done with people that had to draw all this stuff out and reproduce it and send it out to you and so on. If you wanted any changes, then they had to go back and start over again. Literally tear it apart and do it again; it was not like it got to

be. When we got to Space Station, displays were easy because you could do them just quickly, it was all computerized. If we're just putting together what you have to know as an astronaut now—and that means what you have to know as an instructor, because you have all that going on—it would be that. You had to know how the software works, so here is logic diagrams that you could go through, then here's the displays that would let you talk to all that stuff, and enormous amounts of material behind that, the thinking process of the people who designed it. You have to somehow communicate that to all the students in an organized way.

Then, you go to the simulator, and now, we didn't talk yet about the hardware, but then you'd see that real equipment, which was magic in its own right. Here in your hands is the exact real spacecraft. So now you would put this all together and fly it or at least pretend to fly it. I just wish, time and again, that we had had time to have seen the Shuttle simulators here before they were shipped off. We can go over and look at their Space Station simulators and we can see some of those things. The Shuttle simulator was very, very unique. I'm going to talk about that just a little bit.

Hardware-wise, remember before, in Apollo, we had that interpretively-simulated computer system where you had a computer simulator but you put the flight software into it and it behaved like the flight computer things like that. To simulate the Shuttle flight computers, the computers were fast, as fast as the simulator computers we had at the time. Remember, we're talking about '74, '75-6, that kind of timeframe. There was no computer fast enough that had extra capacity and speed to pretend to be the Shuttle computer. That happened later, but by now, you just used real flight computers in the simulator. It meant that we had actually five real flight computers in the simulator in a cabinet and IBM built this, it's called a SID, it's a Simulation Interface Device. It's job was to fool those five computers into thinking they were in space.

They would do all kinds of things to fake it out. The SID created accelerations and gravity just as it would appear in the real flight. The computers measured gravity, and it would be one G on the pad, go to zero in orbit or it would be under thrust measuring the launch phase. So the SID would tell all the things the computer needed to know. Give it time signals as though it was coming from external sources, but the computers would talk to each other just like they would in the real system and vote against each other and so on.

Then, there was a fifth one, a BFS [Backup Flight System] living in its own little world there. We had to do all this phony simulation data, and we had to fake it into do what it is supposed to do. Then not only fake it to make it work right, then you could put malfunctions in, so you could screw up one. Of course, you couldn't really screw up the computer because it's a real computer so you'd fake it into thinking that it died or something like that. You'd give it a power fail, and you'd make it look like it died, but you'd never actually turn off the computer because you want to restart the next session.

That by itself, that's an enormous accomplishment, to make that thing even happen. It was all satisfactory and was done in the '76 to '81 timeframe. We got it all ready to fly. Enormously good people worked on that, from IBM, NASA, Singer, by then it was Singer, but it was that same group. When they came together, it was the most amazing thing because you'd take off and they'd fly, and it all worked. It was amazing that it ever worked at all. So many people did so much great work to make it all play. That's still true over here, no matter what, because as the spacecraft gets more complicated, then the simulator gets even more complicated than that because you have to do everything the [spacecraft] does plus be able to act as a simulator, which means you can screw things up in a way that looks real.

WRIGHT: How were the two crews that had been named? Were they working with you at this time?

HUGHES: The two ALT crews worked well together. They had procedures. The big thing was it was just entry-oriented. They were going to see if the thing flew—they knew it flew, but then they flew on the back of the 747, and when they got really gutsy, they flew in like a racetrack. I don't know if you know, anything that goes on out there at Edwards is very prescribed because there's other secret areas around it, like north of it is a Navy weapons test lab, and different things like that. You'd get into the air, can I draw something for you?

WRIGHT: Sure.

HUGHES: All this is probably over there at UH [University of Houston-Clear Lake, Texas] because I put all this material away over there in the archives. At Edwards, there's a big dry lake, kind of trains north and south, and up here's China Lake. This is the place where the Navy has some black stuff going on. Then, on the edge of this dry lake, is Edwards, which is buildings and a runway. There's a US Highway that runs by here and there's another highway that comes in here, and there's an Antelope Valley Freeway goes up this way. There's a runway, the big runway. It runs like this, and it's just like that, so it's 0-4, in other words, it's pointing up just 40 degrees off here, and whatever the hell, 04-22. Out here, there's other runways, different ones, in the dirt. They're graded. The nice thing about it is that you can come from anywhere and land on the lake. If you can't make it, or you don't even intend to get to here, because the first

few Shuttle flights landed on the lake. They didn't know what you were going to do, so these things are seven, eight miles long, they're great.

The first one we were going to do, we were going to take this one, and so, way up here on China Lake. We took off in the 747, of course, it took off on the runway, where we'd climb up and up and up until it'd get to when it was about 35,000 feet; most it could do, carrying that big beast on its back. It would be in a racetrack, looked like that, and the airplane would get up to the altitude and that was all it would do. It just went around and around in that way, and when it was time to launch, they'd come down here [near the south end of the racetrack] and then what happened really is that the Shuttle would get very clean [it wants to fly] and the airplane underneath got real dirty, so when they broke them loose, it's like it dropped the 747, almost like a bomb. It fell down and then turned out from underneath it because this sucker (the Shuttle) is going to come down quick through that part of the sky. Then, it would just fly to the runway. That's all it did. It didn't do any fancy maneuvering or anything like that. First one? Let's just see what it's going to do. They wanted to see how all of it went well and everything.

If you could see these things, when it'd drop them, it didn't even fly a minute, of course, you come down so fast in the Shuttle. It's 12,000 feet a minute, so I guess it might be more than a minute. Seemed like they were going pretty fast. You'd go down, and so we did five of these, none of which land on the runway. They all landed on the lake. You saw John Young landing all the time, coming down with two chase planes and everything, and there are chase on all these tests. He came in on this one, he came down on an extension of this one, but came down this way, so it landed very, very slowly and touched it down. He was heading this way (west), but that's only because in the morning, the wind is coming in your face, it's coming up off the ocean and coming this way. That was a big thing, depending on which way the wind [was blowing],

you went to different places. If the wind was screwy, first, we wouldn't go if it was too bad. We wanted to come from here down on the longest runway on these early flights. We're literally talking about 10 miles, or something like that, so you could land any part of it and still be doing okay.

WRIGHT: Were you out there during the testing?

HUGHES: Never. I was always in the Control Center. Never saw one in person. The only place that'd have a good seat is somebody in the chase. If they offered me that seat, I'd have been there, but no. It was on to the MCC.

WRIGHT: Based on the ALT program, you were able to take information and include it?

HUGHES: Yes, so '76 and '77, we took the only simulator we had, the motion-base, and put into it all the dynamics that we knew about the airplane, all the systems that we're flying, but there was no environmental control system. We were just breathing air. They had oxygen because you were going up 35,000 feet, but there was nothing fancy about it. No more than you would get a regular passenger airplane. The five flights, the only one we had any trouble really was, I think it was two, when we came off the airplane; first, third, and fifth was [Fullerton and Haise], and then the second and fourth was [Engle and Truly].

When they came off, they got some turbulence, and so they got into a PIO [Pilot-Induced Oscillation]—that is, that you tend to get into like a porpoising kind of thing. The most important thing that Gordon contributed, Lord love him, (he just passed away this year), said,

"Get off the stick." In other words, just don't touch it, and it settled out. It just landed. It was just because you start over-controlling it, and everybody had to learn how to handle this thing because it was a control stick that allowed you change a rate, you were asking for a different rate as opposed to a position.

Very different from what airplanes normally do. I sat up in the simulator so many times with Cripp and Young, and he would sit there and he'd have the hand controller and he didn't even hold it. He would literally have it between his first finger and thumb, and he would literally just nudge it. He'd just let it fly, and it was so great to watch it because he's a great stick-man, anyway. He would be able to make this thing do whatever he wanted to do without thinking about it. It's almost like that, he'd just nudge it a little bit, never over-controlling it, and then he would put it down right on the concrete. No matter what we gave him, and then, of course, we had tire failures, blow-outs, all kinds of stuff, bounce on the runway and everything. Then, he just acts like a normal airplane pilot—in other words, if it veers off to the right because you blow a tire, he just gives him some rudder and brings it back.

WRIGHT: Tell us about being in the Control Center during this program. You had some folks that were still there from Apollo, that had been trained through Apollo. Were there also new faces in there, and how did this mix work well together?

HUGHES: Yes, there was a whole set of new things and new people coming on. The training, we went through that, for the very first time, we did integrated sim lessons also; pre-script, ahead of time, and we had objectives for the flight controllers. So, it was not just the crew for that. Denny did the work on that; I asked him to put it together, and they went through the objectives

to see what we have to do to get the environmental control system guy trained, or the electrical part guys, or different people. So, you could target the things going on.

There's a real concern on that stuff, is that you make sure everybody gets up to speed at the same time. You don't want to over-train—we did on the first flight because we couldn't fly; it went on and on and on forever. We started training in '77 and by '79, we're ready to fly, but the vehicle wasn't ready to go, so it all went on and on. As we went through that, we gradually started training those flight controller teams, and there were teams, so then you had to work with each team and make sure that everybody was certified within a team. It was easy when everybody needed to be trained at the same time. Later, when you get replacements come in, then you have to kind of zeroing in on get this guy up to speed. So, the Sim Sup would talk with the Flight Director and say, "Okay, I've got a new ECLSS [Environmental Control Life Support System] guy so I need to get him up to speed," or her up to speed, because now the "hers" were arriving in big numbers.

WRIGHT: How was that received?

HUGHES: Different people had different reactions. In my group, I hired almost every woman I could find. If they were offered to me, you'd bring them in and talk to them and pick them up. I got so many good people—Janice [E.] Voss worked for me as a co-op and then as an instructor before she got to be an astronaut. Jim [James H.] Newman came in, went through, a lot of them, George used me as a staging point. If he found somebody that he didn't go hire as an astronaut this year, suddenly I'd get a call and say, "I've got a guy for you."

WRIGHT: You knew your purpose, huh?

HUGHES: Exactly. It was funny because slots on some service are controlled by the Congress, we don't get to just do whatever. I said, "Well, what do you want to do with them?" In those days, I had McDonnell, Ford, and Rockwell slots, instructors working for me, as it came together.

He said, "I've talked to McDonnell and they'll give him a job, or her a job." Okay! No problem with me, I get a new good person here, and so I put them to work. You know that two years later, or every year, they were applying to become astronauts. Suddenly, get them the word, and they said they're going. You're just happy to have them as long as you could, and they did good work on the way. Janice was great. Newman, I say those two names because I was close to them. In fact, I was single at that time, and I would go on vacations, and I hired them to stay at my house. My kids always talk about [how] some of their babysitters were astronauts.

WRIGHT: They were raised by the best, huh?

HUGHES: Exactly. Not a bad deal.

WRIGHT: Not for anybody, yes.

HUGHES: Quality people, you didn't have to worry about some 13-year-old kid down the street burning down the house; I'd have some 26-year-old Ph.D. quasi-astronaut

WRIGHT: Had different concerns, yes. You controlled their future though because I'm sure that the right word from you helped a long way.

HUGHES: I gave them the right words for sure. It was an interesting time because I've always had a big open house kind of thing in my place, I always go through and say, like, right now I'm saying around here, "Who's available for Thanksgiving dinner?" Some of these kids are from all over the world, and they can maybe go home for Christmas, but they're not going home Thanksgiving, too. I said, "Come on over if you want." I used to joke about it, my kids never quite know who the hell was coming for Thanksgiving. It was always interesting, though.

WRIGHT: That's right, it's life not dull, that's for sure.

HUGHES: That's it, that's it.

WRIGHT: Finally, STS-1 was ready to go.

HUGHES: Before the STS-1 came, we worked through a lot of problems. We had engine problems out in the real world. So then we really, really worked the engine model to make it a better model than it would have been otherwise, so we could simulate some of the problems they're seeing in the engine. We didn't do much on tiles because the vehicles, either it flew or didn't fly. We made drag, we could fix it up so there was some tiles gone, or so you get drag on one side. Never as bad as [Space Shuttle] *Columbia* [STS-107 accident], where the whole wing

came off. It didn't make any sense—you don't have to train for that. That's such a bad day no matter how you get to that situation. You don't have to practice how to die.

It was really, really important that they understood and knew what to do almost instantly. You could just see what was coming along, and an engine fail, you never had an engine fail without some other problems. We just always simulated as though there was shrapnel flying around back there. As a matter of fact, the engine failures that we had on real fights were great, they were all self-contained. We didn't get any damage from anything else back in the back end, but we'd always give them at least one hydraulics leak or something with it, just to say, "Well, this engine is down, but it might have come apart back there." You can't tell—you're 120 feet away from it, up here. You would throw something in to make sure that they knew that it could be a worse day than just an engine out.

Immediately, we put in an all-over timeline of where to go if an engine failed. We put it in early, then you had to go back to Florida. If you put it in later, you can go to Africa. If you put it in later than that, you're going to abort into orbit. You can still use the two engines that are left and burn further, longer, and get there. They'd go through all that training and think about it, so it became part of it. They just knew what it was doing. It's interesting because the communications, while we were developing the simulator, would become calls that would be used in the Control Center. What the crew wanted to know is can I get to orbit yet? Can I get there with two engines left? Can I get there with one engine? Which is actually possible, in some of the scenarios.

Ron [Ronald C.] Epps, who became one of my first flight supervisors, later when I was Division [Chief], he and some guys developed this ARD, it's the Abort Region Determinator. It was a piece of software in the Control Center. It's based on your altitude and your speed and

how much fuel you've got left. It would decide, are you RTLS, are you ATO, are you AOA, and all these different things. Those things were hammered out. Then, we had to communicate to that crew, really in a very terse way, so that's all those calls that you'd hear were always developed in the simulator, then we would make sure everybody used them down in the Control Center, so that they would know just what was going on.

The CapComs, who were, of course, part of the team, would come over and work with the crew about what do you have to say to make sure you're not going to be screwed up, not going to be confused about what's going on, situation. Down underneath it, it's like the old thing of a duck looks calm on the top but underneath, it's paddling like hell. In that ARD world, it would be that way, because the FDO [Flight Dynamics Officer] would be watching all these measurements and parameters and the people working at the potential problems. They'd watch and see exactly what it is. They'd have an indicator that says "No RTLS anymore," in other words, you're too fast, you don't have enough fuel to return to KSC. You're not coming back to KSC. That was a great call on each flight because I never believed we could survive an RTLS. It was just one of those things that haunted me.

That's a whole different thing, and I get into physics and why I didn't like it, and I used to talk to a lot of people about that all the time. The problem is, if you had a problem, I thought you should go back immediately because you're already one engine bad—why the hell do you think these two others are going to burn for longer now? We had a separation concern. Once you shut down the engines, what will all the fuel do inside that tank? Will it stay stable? So with all the dynamics associated with these question, the dynamics people decided that we should just separate with an empty tank.

Nobody was sure what it was like if you separated from a full tank, or half-full. When you shut down the engine, then the fuel would roll forward or bouncing around in there. I remember we talked about all the engine stuff in the Saturn V, well the same thing would be in the big orange tank. They were worried about if you separated there, it might come up and hit you again because the fuel is bouncing around in there. They convinced themselves anyway to burn it down to 30 percent, then you'd separate because you knew the answers, 30 percent, it wasn't going to do that because there's nothing in it, pretty much, at all.

We did all those things, anyway, so that we'd get to orbit, then they'd run through the procedures to safe the engines, and everything shut down. It's interesting if you think about it, this thing is so big, it's just enormous. I talk like it's still alive, and of course, it's all history now, but there was about nine tons of fuel still in just the pipes between the tank and the engine. You would vent all that out as much as possible because when you said zero, you'd close valves on the tank side and close down the Shuttle side, and then finally, you would separate, but there was still a lot of fuel laying around and you want to get rid of it somehow.

If nothing else, for just weight, later, and CG control—that is, the center of gravity—because if you got rid of it then that CG would move forward and that's better for flying, the quality when you're coming to entry. Some of it wasn't that way when you started, and we would find things and say, "This thing is really droopy coming in."

They'd say, "Well, it's your models."

I said, "Okay." Then, we'd go check it further and I said, "I don't think it's the model." All that fuel's sitting back in the back end still, can we get rid of it? I said, "Will you vent it?" Some procedures were changed and things got better. We flew some flights—it was not like we knew all the answers on the first one—sometimes, we got further ahead.

WRIGHT: How confident were you that the crew was ready to go on the STS-1?

HUGHES: I was really confident. I was confident in 1980. The simulator got better, the crew got extremely better. It was interesting, it's the only time anybody's done that, to launch somebody straight off, but you had to believe that the models were good. They weren't perfect, they weren't really perfect, the thermal models were terrible and they took four flights, I think, before we figured out what was really going on outside with the temperature, coming home. That's where you got those spots, I think we talked about before, the black spots on the OMS [Orbital Maneuvering System] Pods, where we did not know that they were being impinged there.

I'm not an aero guy, but I know it's like a blowtorch, if that shockwave comes up over the wing and that's where it landed. They thought everything would go over the OMS Pod and just be gone, but it didn't. It wound up impinged on that, and the first two flights, I think, they actually had damage that they had to repair on *Columbia*, in that area, and that's when they decided to put the black tiles there, so it just handled the higher temperature than they thought they were going to get. It's funny, nobody would think anything about it except why do they have those funny black tiles in that area? Everything else with these laminated, it's like blankets that they just put over it, because it was thought it would be cool, and they were cool relative. Only 1,000 degrees, not 2,500, it's funny when you talk of these temperatures. It was really great. Funny story—do you remember the Steak and Egg [restaurant], does that even mean anything, there is a Mediterranean place there now.

WRIGHT: Yes.

HUGHES: We were so excited. I had no role in the Control Center—I had my people in there, but I was in Building 4, watching. Of course, the first day it didn't go, then two days later, they got it into orbit. We were so excited, there was about 10 of us, we went over to Steak and Egg to have breakfast after the launch. We were so excited and so much and so loudly (talk about hyper). I mean we were just like little kids. These were 35-year-old people—they threw us out. They asked us to leave. We ordered and we're just disturbing everybody in the damn place, it's like, we were still talking. We ate, but they said, "Can you guys take it home, take it out of here?" They didn't know what the hell to do. They were just trying to serve eggs and we were there rehashing the mission, as far as it had gone so far, and telling stories, and just being ridiculous and loud and noisy, yes, and loud.

WRIGHT: The crew was a little bit different in the sense that you had a seasoned veteran, with John Young, but Bob Crippen had enjoyed computers and took a great interest in learning how software had worked. Did that make a difference in the training?

HUGHES: History repeats itself. When we flew the first guys, they came out of an age where airplanes were just no computer on it. You pointed it and it went where you wanted to go. When Gus [Virgil I. Grissom] flew with John [Young], now, the computer on the Gemini was really small, but it was on John's side. Gus says, "You're the guy." When we went to Apollo, he was the guy, because they were coming out of the world of F-4s, which is a fairly computerized machine and A-6s, if they're Navy guys. All of a sudden, the older guy would just say, "You got it." It's funny, then, [Shuttle], Young says to Crippen, "You got it," because now

Crippen came out of the F-14s and flying computers, F-16s if it was Air Force, so that's all they had, was computers. The new guy got all the stuff to learn the computer, and so Young was pretty good at it, but Cripp was the one to be the computer guy on board.

That's what, again, he and I worked forever to make sure we understood how that computer worked. Not just how to work it, but how it worked, because that was the deal. You were always wondering about what it would do different than you thought it was. The good thing about it, again, on the simulator, this one now, when we're not flying the flight software but you had the same box, so that was good. You know that the timing was right, and all those things that we had problems with earlier, didn't get there. We still had to make sure we fooled it into believing it was in space and doing all the things that you do.

WRIGHT: Did you make a lot of changes? I know you learned a lot during those first four flights, but did you end up making lots of changes to get ready for supposedly the remainder of the ones that would move into the 60 flights a year?

HUGHES: We did. When we came back, every crew, the debriefing was great, and that first four was really interesting because the unique personalities. The first two crews were probably like the same, then it was Engle and Truly, again, they'd already flown the ALT and they moved straight into this flight, [STS-]2. They had the one that had fuel cell problems, so they came back a couple days early, but they were ready to go. All of those four, I'd say, with the fourth one being a little stranger, and that was [Thomas K.] Mattingly, but it worked, and we did change a lot. Personalities changed how it is, you know, just how it is.

Crippen and Young, we had more fun with them. With the first two crews, it was like a laugh a minute, and every time the crews would come along, you could see that it's the personality of the commander details what's going to happen on a crowd. If you've ever been to a party somewhere and there's a laugh-a-minute kind of person, then the party is just buzzing because everybody's laughing about what he said next and last and all this stuff. That goes on even to this moment today. Different crews go to orbit different ways.

I always say Apollo 10 was the best crew in Apollo because it was that same trio of clowns, [Thomas P.] Stafford and John Young and Gene [Eugene A.] Cernan. When they get to be commanders, then, it was not so much. It was funny still, but now they're the commander, so they have to reign in the horses and keep these guys in line, and it's a different thing. When they were the unbridled stallions that were running around, they were going crazy.

The first four flights, we learned a lot about fuel cells, environmental control, where we actually had to make changes in the simulator models just to match up with what was going on. Then, there were real funny things, like the fuel cells, they had gas in the water that it made, and it's a hydrogen gas, and of course, that was not dangerous because we just got rid of it, but if you drank it, then it bloated you, so it was that kind of problem, and it didn't taste good. We had similar problems on Apollo, but not so much as this one. They solved it later—it was a membrane change in the fuel cells, or something they did. Too much stuff gas would get through and get into the water while on the wrong side.

There was something in there about landing. A big thing is you've seen this happen all the time, but when you come in, this is like a very strange thing to fly because you come in, you're Mach 6, Mach 5, and slowing down. It's a very sporty flying airplane, and then as you

get down lower and slower, after you go around the HAC, the Heading Alignment Cone, let me try to do this.

The fact is, it's getting slower. It's getting slower and lower, it means that it's less responsive, so the computer changed the gains, so like a little, tiny nudge on the stick would make a little, tiny change on the surface that's outside because you're going so fast. By the time you get down toward landing. A little tiny nudge on the stick, well, the control surfaces needed to move a lot to make that same effect happen. You're losing energy it all the time. They found when they came down to touch down that everybody did a good job.

It's just down, except I think STS-[3], we had one pretty good bounce on 3. Then, you had almost no control of how hard you smacked down. If you land on a commercial airplane that you fly in, you feel this thud as the main gear touches down. Then you feel lesser thud as the nose gear touches down. In the Shuttle, because the speed is bleeding off and the elevons have less authority to keep it up, as the nose wheel is coming down. The problem is because now the elevons [Shuttle control surfaces] are all the way up but they still couldn't control how fast the nose slapped down. That's why we added the [drag] chute.

The chute wasn't to help slowing down, although it does a little bit, but it was to hold the nose up until the pilot let it down. Flight after flight, we just couldn't do it, we couldn't control it. And you can't go around pranging the nose down time after time. There's a 10 foot per second vertical speed limit on that, you could bend something. You just couldn't do it, so they were up in the 7, 8, 9 a lot, in those early flights. That's why we added the chute [on STS-49, 1992]. The idea was just to put it out quick, it's going to slow you down a little bit, but that's not what it's about. That would be nice if you're landing in Africa or somewhere where the runways are short, because it relieves some of the stress on your brakes. But mostly, it's once you get it

out, it holds the nose up in the air, then you can lower. You actually help to push it down, which is just right, and once it's down, that way, they don't leave it on, all the rest of the way. Once it's on the wheels and ground, then you see it pop the [chute] loose. If you'd landed in Africa, and they do have a short runway, you would have had that chute all the way to the last moment. That's probably good.

WRIGHT: We're about 11 o'clock, do you want to stop right here and then we can give you a break?

HUGHES: Yes, let's do that.

WRIGHT: Okay, let's do that.

[End of Interview]