

NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT

EDITED ORAL HISTORY TRANSCRIPT

FRANCIS E. "FRANK" HUGHES
INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: Today is August 29, 2013. This oral history interview with Frank Hughes is being conducted in Houston, Texas, for the NASA Johnson Space Center Oral History Project. Interviewer is Rebecca Wright, assisted by Rebecca Hackler.

We thank you for taking time this morning to sit down and talk with us. We know you spent many years working with NASA, and we'd like for you to start by sharing with us how you first became employed by NASA, and then where you were on those first assignments.

HUGHES: Okay, sounds good. Thank you for coming over, I think this could be fun. How I came to NASA is kind of interesting. I went to a college called St. Mary's College, in [Moraga] California, to get a degree in Physics. I went there because I was going to be an astronomer; that was my thing. My vision was to work at Mount Palomar [Observatory], the biggest optical telescope at the time. The first two years progressed pretty well. The school that I was in (St. Mary's) turned 100 years old in 1963. That was while I was there; I was there from '61 to '65. It had started in 1863.

Somehow, somebody had a lot of sway within the government, because the celebrations for this [anniversary] in the spring of '63, Lyndon [B.] Johnson came to address the crowd at the centennial celebration. It was great; glad I got the chance to see the vice president at that time, and he talked about Apollo. It was just shortly after [President John F.] Kennedy had delivered his famous speech about going to the Moon. The budgets were formed up suddenly, and things

were happening. I was there watching very carefully, along with everybody else, as NASA did the Mercury flights, in '61 and '62. I knew about Gemini, but I still wasn't involved. Suddenly when Johnson stood up on the stage—and it was a beautiful day, it was done outside—and he gave the speech, it just converted me. The astronomy thing just went up in a puff of smoke, and I was up for going to work on Apollo.

I finished the degree in '65, and along the way I applied to go to work for NASA. I applied to [NASA] Ames Research Center [Moffett Field, California]; that was the area of the country I was living in then, around the San Francisco Bay area. They sent a letter back that said, "No, you can't. You're just getting a Bachelor's. To work for us, you need a Master's." That was then, but what it amounted to is that they were a research center, not an operations center. I know that now. So, I went off to the University of Idaho to get a Master's in solid-state physics. I don't know what the hell that (solid state physics) was all about, but I woke up in a bad dream one night and said, "I'm going to do that." I was interested in crystals, lasers and things like that.

While I was there, the first semester, I was miserable. I wanted to go to work, I didn't want to do any more school. I need a break. Of course, I'd gone from mild weather in San Francisco back to—I grew up in Montana—so here I was in Idaho. One particularly terrible day in January—and it was also one of those days where your finals came after the holidays. You took all your books home, looked at them, and felt guilty, but didn't do anything through the holidays. Then went back and tried to take the finals.

I was going to the physics laboratory, but in order to get there—the snow was blowing horizontal, it was about 15 degrees—and I went through the main library. Doing that could take two blocks on my way, out of the weather. I could go inside for a little bit. There was a NASA

recruiting booth sitting there, and it was 4:30 in the afternoon, so they were packing up. I went and stopped them and started talking to them.

A fellow named Art [Arthur J.] Thiberville was there. Art was really a great person, stayed friends with him all the time I was here once I was hired. That was it. I talked to them, and they tell me what they want to do, and I certainly liked that, and they liked what I had to say. I said, "But I just got here. I don't have my Master's."

They said, "You don't need a Master's. You want to work for Johnson Space Center, a Bachelor's is pretty good." In fact, I used to joke about that. You only had to breathe about 10 or 15 times a minute and you're in. "We're going to do this Apollo [Program] and we need people." They handed me half an inch [thick stack] of paper. Literally, it was so many pieces of paper. I skipped the rest of that night, went home and spent the entire time filling out, with my little portable typewriter, all this information required. It literally was like security questions. "How many times have you been out of the country?" I was 21 at this time.

So, I'd be calling back to home to find out. "Well, we'd been to Canada."

"When?"

"I don't know when!"

I made up a bunch of dates, I literally did. They said, "It's about four times (to Canada)." Okay, I made up dates. We just sent it in, I assumed nobody will know.

That was it. About—I did it that night—and about 10 days later, this phone call came, and it's Art. He says, "We'd like to hire you. Come down here to JSC, and work with us."

I said, "Okay, that's good."

He said, "But this is how it works. I've got to send a letter to you, so you'll get that. That's the official offer; you sign it and send it back."

I said, "Don't send it here, send it to my home address. I'm out of here." Literally, I put down the phone, I went upstairs and I called—I had told my landlady I was gone—I called my dad, who is a machinist in the mines in Butte, Montana. I said, "I'm going to leave school." He knew I was really miserable at Christmas, but he thought the kind of thing that parents do. I said, "No, I'm taking a job with NASA, and I need to get out of here so I can be ready to do whatever I need to do."

He said, "I just got home." His shift was like mid-week. He said, "Let me get something to eat, and I'll head out." (This is what parents do for kids.)

He's going to drive six hours through the middle of winter—because this January—in Montana and Idaho, and did. I said, "Okay, just meet me in Coeur d'Alene [Idaho], because I'm going to get on a bus here in an hour, and I'll be there, so you'll save some trip time." I did, he did, we grabbed my trunk, threw it in the car, and then I drove the rest of the time. He went to sleep, because we got back into town about 7 o'clock. He got up, took a shower, and went to work.

Anyway, that's the deal. I was ready to go, almost immediately. Then everything slowed down. Security was all heavy-duty at that time, during the Cold War. I started teaching school, substitute teaching. I did that until they finally called, and I was to report on May 2nd, down here at JSC. Then I buy a car—I didn't have a car. I was penniless, a grad [graduate] student. I got a car, and then three weeks before I was supposed to report, Art called me and said, "It's about that job." I thought, "Oh, crap, they read the resume."

They said, "No, no, no, everything's fine." He says, "But we'd like to see if it's okay if we send you to Florida instead of Houston. Still working for us here, but we need a position filled down there real quick."

I said, "Yes, hell yes." Things fly from there (Florida), it couldn't be better.

They said, "Okay, you're going to work for a different branch at JSC." Oh by the way, back at the interview, they said, "It's too bad you came so late that day at the school, but we've made assignments in all of our jobs that we had except one, and it's in flight simulation."

I said, "I'd take it. What is it?" I had a pretty good idea, but still, "I want you to tell me, what you're talking about." So I had jumped from the simulation branch in Houston, run by Stan [Stanley] Faber, and I jumped over and switched over to a guy named Riley [D.] McCafferty, who worked down there. On the second of May, which was a Monday, I came down. I got to Cocoa Beach [Florida] the night before, and reported in the next day. That started it up.

It's kind of interesting, because I got there the same day that the first box of the Apollo simulator was arriving in this big empty building. It was a brand-new building, they just finished building it. That was my home for the next five years (Kennedy Space Center, Building M7-409).

WRIGHT: Tell us what all was going on. You just mentioned that, but '66 was the height of Gemini.

HUGHES: It was absolutely true. In fact, it was interesting because Gemini VIII occurred after I'd been hired, but before I reported, so it was a big deal going on. When I got there, Gemini was full tilt, and it was so interesting because the MCC [Mission Control Center] was there for Gemini—for all of Mercury—and then the first few Gemini, until the MCC [in Houston] came on line. On Gemini I and II, it was controlled down there. [Gemini] III, it was parallel controlled. The MCC in Houston came online, and they watched the one at the Cape [Canaveral,

Florida] do its job. Then on Gemini IV, they swapped, so MCC Houston became prime on that. There were simulators in Houston for Gemini and another one at the Cape. In Mercury, the simulators had been in St. Louis, and one at the Cape. There was no Houston [Center] at that time.

When I got there that first day, there was nothing to do. There was a big empty building. There were four other guys that had been hired before me—and we'll talk about those later—they were really good people, but they all had military background, or something like that. They were coming in from different places, and I was the first one, truly civilian, that hadn't been through any of the military.

We all walked up and looked at this box, what you call the CMS, the Command Module Simulator. It was being built in Binghamton, New York by Link [a division of Singer Corporation], and they came down. There was going to be one in Houston and two of those in Florida. Later, there was one Lunar Module Simulator [LMS] in Houston and two in Florida, although ultimately as they slowed down, they never built the third LMS simulator, so there was only one in each place.

That day, after a couple hours, we walked around and talked. This one guy was my boss, his name is John Mitchell. He walked me around and introduced everybody—he was a great guy. Then he said, "Okay, we're going to have you guys start studying the Apollo systems. Here's the book." They just had one book for all these people, and we're all in one room, one office room. It was just four or five desks.

They said, "Okay, I'll take the guidance system, you take the—" We just broke the book up into chapters and said, "Read it, and then you can come back and tell us about it." Every day, you'd come in and get the same or another section of this one book, one copy. There was only

one small Xerox machine at that time. There was just nothing, no processes. This is in a different building from the one at the Cape. This is on MILA, the Merritt Island Launch Area in the KSC [Kennedy Space Center] industrial complex. The Gemini simulator and the control center were over on the Cape.

I went to lunch, went across the street to this place, found out where the cafeterias are and all that sort of thing in the MSO [Manned Space Operations] building out at KSC. Then Larry Thompson, another guy who's there, another new guy, he said, "I got to go across to the Cape to the GMS [Gemini Mission Simulator]—." He was there long enough, he had trained on Gemini some, but he had been moved over to Apollo. He's somebody with a modicum of experience, and now he's going to go over to this other building.

It was kind of exciting. They said, "Do you want to go along and see the Gemini simulator?" Well, hell yes, there's nothing else to do. Literally nothing assigned, except read this damn book.

We jumped into his car and drove over, and it was all wondrous. Here's MCC—it's not being used now. By then, it's just dark. It was the hot spot of everything going on, and a year later it's not being used at all. Larry went to do his thing, but they turned me over to somebody else, and they took me in and showed me the GMS, they called it; Gemini Mission Simulator. As they went through it, it was really great. They said, "Want to get in?"

Yes, of course, throw me in the briar patch. They put me in it. It was interesting. You climbed in, so I was in the commander's seat of a Gemini, and then they would close the door. Then they would put the visual over it, so you could actually look out the window. It was very, very simple; all you could do is see an Agena spacecraft, if you had done the right maneuvers

and rendezvoused with it. The visual was just a little TV, and you'd see this Agena sitting out there.

I get in and start farting around with it, and I was just having a good time. They launched me, and I was in orbit. They said, "Now, if you turn on this computer—" They had little Gemini computer that was only a 4k machine, 4,000 words of memory, and you could do these computations. The instructor is very literal; you just tell me how to do this rendezvous, because we're all excited about how it was done.

(By the way, we're doing a rendezvous to the International Space Station now in four revs [revolutions], after launch [M=4]. We did it in one orbit. It was M equals one [M=1]. You would launch, and you would rendezvous, poof, you're right there. We got so conservative on the Shuttle. I kept saying, "Why are we doing this? You're wasting days and days of fuel." Anyway, that's a whole different story.)

I was in there buried in this simulator and Larry comes over the headset—now I'm hearing him on the headset. He says, "Frank, let's go. I want to go back. Are you done?"

I was going to say, "Okay," but somebody pipes up and says, "Gus is still here and he's going back over in about an hour."

I said—I don't know who the hell Gus is, but "If it's okay, I'll get a ride."

Somebody (another voice) says, "Oh yes, he can get a ride."

I get through; they take me through all these maneuvers. I get out of the simulator, and meet Gus [Virgil I.] Grissom. First day out, that's my first real dyed-in-the-wool astronaut there. He is cool, Gus is just Gus. He was such a great guy always. He immediately says, "Oh, you're the new guy, huh?" Because they're all assembling, new people are just flown in every week. "There's the new guy," or something like that all the time.

"Yes, I'm me," and that's it.

He says, "Where you from?"

"Montana."

"Oh hell, I go hunting in Montana all the time." Those kinds of coincidences happen a lot, things start connecting up. He says, "Okay, are you ready to go?"

I said, "Now I am." He walks out, and he's got a new blue Corvette. One of the Jim Rathmann's [owner of a local Corvette dealership] things, there's a whole story about that.

He says, "You ready?" I'm am trying to strap in, because there was hardly any seatbelts in cars at that time.

I said, "Where's the [seatbelt]?" (I had one in my car, but I had to install it though.)

He said, "No seatbelts." He puts it in gear and roars off. The geography down there is there's a long freeway, and it goes up and down the length of the Cape. Then off of it are all these two-lane roads that would go to each of the pads along the way. Of course, this was Mercury Control Center, so it was the control for three different pads that fired Atlas rockets. You would come off this freeway, turn down half a mile, and then make a turn into the smaller area, which is where the Control Center was. That was gravel; this is not big-city. We're still out in the Florida scrub country.

He puts it into gear, and he just floors it, and we go racing up this half-mile gravel road, and he's going about 85 miles an hour. When he turns onto the two-lane road, without any slowdown or stop, now he's got it up to about 120, going toward the freeway. He looks at me with a big grin and said, "Are you having a good time?" Just like one of those things where your hair's going back like this [streaming back in the wind].

"Oh yes."

He was going to check out the new guy to see how he'd do. Then he turned onto that freeway going north, to get back to the Merritt Island side. He was about 140 miles an hour, going north. All these guys, they were just bulletproof, literally. They just played all the time. They would get a new car every six months, as soon as the ashtrays were full or whatever then that was it, they would turn them in. Then Rathmann would sell them saying, "Gus Grissom used to drive this car." And it was only about \$500 a year or something like that, a leased arrangement.

WRIGHT: Yes. Good deal.

HUGHES: They hardly paid anything. It was an awesome deal. I used to drive Corvettes back and forth from the Cape to Houston. I came down a lot, and if they wanted to get rid of one, it was time to turn it in and it was in Houston, then they would say, "Here's my gas card. Will you drive it back?"

"Oh yes." Stop by Tallahassee, and Gainesville, and all the women's schools along the way. I'm 22, and then get back to work down there.

Or they'd have the other way. "Will you take my car to Houston? When are you going?"

"I'm leaving Thursday."

"Okay, here's the gas card."

"Okay." I said, "But I was going to stop over in Nashville."

"That's okay. Just use the gas card."

WRIGHT: Good deal.

HUGHES: It was a good deal. Fell into that briar patch and it was awesome.

WRIGHT: As you were reading those chapters of the book, getting up on the Apollo simulators, how did that all transpire? Were you part of what set up down there for that training?

HUGHES: Yes, when I came in, the first CMS 1 was being built here in Houston at the same time as CMS 2. It was just like CMS 1 was about three months ahead as the pieces were coming together. You have to imagine, the simulator was constructed. There was a "crew station" inside of it. It was built to replicate the Command Module. You had a place where three people sit. There's no service module, that's all virtual, because you just did it in software. CMS had this extensive visual system that wrapped around it, and I can show you pictures of it sometime. What it amounts to is that you would be in this situation and you'd look out the forward windows if you were doing rendezvous, or if you're in orbit you could look down and you could see the Earth going by.

It was an amazing neat visual system. It was done by a company that contracted from Link called Farrand Optical [Company]. They were in the Bronx, New York. They don't exist anymore, and I stayed in touch with many, many of the people over the years. They were optics experts. They did a lot of work, like refueling simulators for the Air Force, over the years.

They did the simulation for this CMS simulator. The first thing that came was a piece of the visual system. The structure [for the visual] had to be put up, then the Command Module piece came, and it just rolled in underneath all this structure. Then they had to do this optical alignment. There were 10 of us [instructors] there that were for this first delivery—there were 8

of us, I guess, it was. A couple of leaders—the CMS 2, it was called. CMS 1 was Houston, 2 and then 3 were down there, Command Module Simulator 2.

This guy came with it, and they were going to assemble this simulator. They were coming down from New York, coming to Florida. They were all excited about being there. Some were going to just come down for the assembly; some were coming down to live because they were going to support this simulator over time. There's a lot of really, really good people that came along. When it started, it was just an assemblage of boxes of gear

I've got to stop for a minute. My degree was in Physics, remember, that's what I did. What I began to realize, that everybody was else was an engineer, except one guy. We got to be very good friends, the two of us [Pleddie Baker].

Those engineers knew so much more about their subject area, if they were aerospace guys, or if they're electrical engineering guys, or if they're mechanical engineering guys. An analogy is like the icicles on the side of a house. They were like one of those icicles. They would go all the way down, they knew so much deep into the subject. They had studied it all so much more than I, but they didn't know anything about anything else. The electrical guys didn't know any mechanical; the electrical or mechanical guys didn't know any orbital mechanics, only the aero guys.

In physics, I had studied all those subjects. My education was a broad brush across all of these disciplines. Physics is a study of how things work. All things, so I knew optics, I knew orbital mechanics, I knew electronics, I knew mechanical engineering at my level. I could speak to these guys building this simulator. Everybody else could come out, and if it was one of their subjects they'd get interested in it, but if it's some other system, they just didn't seem to warm up to it.

Pretty soon, I knew these simulator experts all of the time. Literally, they started calling me out when they had a question. I became the interface to the NASA cadre there. "They need 400 cycle, 160 volt AC power supply," because they need to do this test. Then their gear crumped, or it didn't get delivered, or they never thought of bringing it, or whatever the hell happened.

Pretty soon, I was just going back and forth, like I had done in school. I was always a lab assistant; we just did stuff like that. Suddenly I'm doing it with them, but inherently I'm learning more about how this simulator works. I didn't design it; I didn't have anything to do with that, because I wasn't there yet, but I sure as hell got to know how it worked. What is it supposed to do? Not everything that it did every time; it didn't deliver, sometimes, what they said, but it delivered a lot. Over time period, it just started to be better and better. It was a good simulator.

At first, we couldn't get it going. Gus, one time—he was going to be flying the first flight—he came out there, and he called it a train wreck because of all of this visual gear hanging over it. He hung a lemon on it one day; he was just so upset with how badly it behaved. Of course, there were people working 24 hours a day trying to make it better. A lot of it was due to flight software, and we haven't got into that yet. The way it worked in this case, there was no need to simulate computers in the other simulator up to this time.

What happened is that the people who built this simulator had decided to have a computer to pretend to be the guidance computer on board. The computers—they were just slow, relative to everything we do today, it was very, very slow. The [simulator] computers acted like the spacecraft were there, and there were three of them working together. They were called DDP 224s, and they had all kinds of software modules that we developed for this

simulator, uniquely. They didn't have these computer buses—you plug it in the wall and so much data runs through that pipe now, but then it didn't.

The problem was, whatever they had, it was too slow. Then these actually—these machines, three of them—had common memory. They had developed a software method where two machines could write into the same memory block. That meant if you wanted to give something to this machine, it writes pretty fast, in a relative sense. It would write to the memory, the other one would read it out of the memory. That was so much faster, so this common memory, they call it. It's shared memory, so there was computer one, two, three, if you can imagine.

Then there was a fourth machine for each of these CMS that was called ISAGC. Interpretively Simulated Apollo Guidance Computer, and it was another one of those same DDP 224s, but it's been modified. They physically took its guts apart, and changed it so it had the same instructions that the Apollo computer could do. There's a guy around here named Jim Rainey. You ought to talk to him sometime, just about the ISAGC. It's mentioned a lot in that *Digital Apollo [Human and Machine in Spaceflight]*, David A. Mindell], but Rainey was the king of that ISAGC around here. He didn't know a damn thing about flying spacecraft or anything like that, but he could make computers work. He is a great guy, still, a wonderful human being, and so bright.

The architecture is starting to come together; I'm beginning to see what's going on. It was interesting, because the Apollo Guidance Computer, AGC—the software came from MIT [Massachusetts Institute of Technology, Cambridge], at that time. Literally, they could build the software, write a tape, send it to us, and now we can put the real software—just like it was going

to work in the real vehicle, where the real box is. This is very much different than this simulator computer that we're running.

That's it, the interpreter, and that's what they call it. It's like you took the software for your iPod and put it in an Android machine and it ran. You had to have a package around it to make it feel comfortable in there. That's what this interpreter did; the computer changed so that it wasn't the same instructions. It tells it add, multiply, divide, things like that, whatever you want to do, but it had instructions in the Apollo computer that this ISAGC didn't have, and vice versa. They had to make sure the instruction set matched.

That happened through that summer of '66, they were putting it together. CMS 2 came up and started running, power on it, probably about end of June, the pieces came together. Not the visual, but the systems simulation piece of it. It was a big event. There were eight balls—FDI, flight director indicators, using an eight ball in an airplane—just to power up and see it jump all of a sudden, because here it is sitting in a box all of the time. Put in the item and suddenly power's on, and so the CMS is alive. It was just like the whole device, a piece at a time, came alive. All those devices you see in the movies, like *Apollo 13*, you can see the instrumentation move. They did a great job faking it there, but to see it for real was awesome.

I hadn't yet been to the real spacecraft, I've only seen drawings. Now suddenly, I became totally familiar with the acreage around there. Every switch, they said throw the so-and-so switch, you just reach up and you knew where it was, because it's like your car after awhile. You spent so much time, because you're inside the simulator, sitting. In the simulator, you laid on your back. The guy in the navigation station stood up, so you could do the navigation. That meant you were like when you landed, or when you launched, so you're laying on your back. Am I anywhere that you want to be?

WRIGHT: Yes, it's great. Talk about the work processes though, because everything was moving so fast. You're at '66, you're trying to make it to the end of the decade. Apollo's not up, Gus Grissom's not happy because he feels things should be [better].

HUGHES: Yes, all the stuff that came together. Gus was unhappy—there was a couple things. The simulations weren't working good, because the interpreter [ISAGC] wasn't quite right yet. It was coming together. The simulator systems weren't quite good, but they were coming together. The crew would go across the street to the MSO, where the vehicle was there, spacecraft 12, 012, that's it's designation. There was a whole vehicle. There were two designs, Block I and Block II spacecraft, and there were two spacecraft, 012 and 014 were supposed to be first two flights. Then, they moved to a smarter, better set of spacecraft that would be the Apollo, the ones that would leave Earth orbit.

He was assigned to fly 012, and they'd go over, and it didn't work very good either. They would say, "We're frustrated in all directions." Everything was having difficulties. There was a lot of problem with communications all the time, in the spacecraft. The simulator worked pretty good. He's was always saying, "What the hell, they could get the comm [communications] working better over across the street than it is over here." On the other hand, when he turned on a computer over there, it ran because it was the computer, where ours was still trying to fake this thing into thinking that it's the computer. They were going back and forth. I say that the pace was a big deal [part of their frustrations].

When we were in about July, the simulator was pretty good. When I was first there, in that first month, Gemini 9 occurred. I had nothing to do with 9, except I got to know these guys,

and I was on the console on the Gemini simulator while they were inside. This is Tom [Thomas P.] Stafford and Gene [Eugene A.] Cernan, and it was really cool to watch it going on. That simulator was working pretty good, in a relative sense. It was a very simple simulator, so it didn't have to do much. It did well at what it was doing, because it had matured.

That's the one where they lost the Agena on the way uphill, and then they scrubbed that day. Then they put it back together, and then they had this ATDA [Augmented Target Docking Adapter]—they were going to dock to this ATDA anyway. Then it came up and the cover wouldn't come off, and that's the angry alligator flight, where they fly and they do it. Then they were going to rendezvous and dock with the ATDA, and [Tom Stafford] was going to hold it all together and Gene would go outside, and that's when we began to unravel all of the problems with EVA [extravehicular activity].

These guys were not physically ready for this; they were not in shape in a relative sense. They didn't have to be. Nobody thought about this. It was going to be easy, because you're going into space. [They thought] there were enough handholds, there were enough places to put your feet. Between 9, 10, 11, 12, all of those things, lots of handholds outside, tethers [were added].

Gene got back in; he was going to fly a backpack [an early version of the Astronaut Maneuvering Unit, AMU] around. It's a good thing he never got it loose, because he was so winded by the time he got back there, and he was overtaxing the environmental system of the suit. When you're in space, you've got plus 250 [degrees Fahrenheit] on the Sun side of your body and minus 250 [degrees] on the other. The attitude that we chose to put him back into that equipment module, by the time he got back there—he was slow moving, so it was dark. It was

on the dark side of the Earth, and although there are a couple of lights, he couldn't see what's going on.

By that time, the suit starts getting cold, which means he started getting vapor on the face plate, so he couldn't see. It was almost like he's blind. Now he's way out of the cabin, a long way to get back. Fortunately, Tom said, "Just settle down. Breathe, settle down. Blow off the timeline and come on back. Just work your way back in, we'll get back inside." Then they could hardly get him back inside, because he was just winded, just tired.

Then Gemini 10 came, that was with John [W.] Young and Mike [Michael] Collins. They did everything they had to do, they did a great one. They had put a couple of handholds on the Agena. They went out and grabbed this package that they were supposed to retrieve; they did everything, except they lost a camera. But they did everything that they were supposed to do. Everybody starts saying, "Oh, we're getting pretty good at this." But John and Mike were in good shape and they practiced continuously.

Then Gemini 11 comes along, and Dick [Richard F.] Gordon goes out—Pete [Charles Conrad] is in the cockpit—and he damn near kills himself out there. He was supposed to do a lot of transition up on the Agena vehicle and retrieve a package there too. Same kind of [problems occurred]. When he went forward, he couldn't hold on. He was trying to ride this Agena like a horse, and it was just terrible, terrible time. He was exhausted. Of course, he smoked till the day of liftoff. Now, everybody's back is against the wall again, saying, "This EVA is really tough." The mockup used for the training at this time is in the same building where we are building the Apollo simulator. I'm in the middle of all this chaos going on. I'm not typically an EVA guy, but it's all going around you, so you make your inputs. This is not a simulator problem; this is a physical EVA problem with mock-ups. The empty parts of the building, there's lots of room, so

they had mock-ups there, in Florida, so these guys could practice right up to the day of launch. It's where other simulators are going to be, but they just rolled in these mock-ups, bringing them down from Houston.

Then Buzz [Aldrin] came along, and did his EVA, and it worked great. He had seen everybody do it wrong, and had time, with a lot of people to see, "Okay, you need more handholds and tethers." That's the first time we had the foot restraint. When he got to some work place, you could put your feet into this support foothold device. Then you would spread your heels out, and that would click into a lock that would hold you that way. That anchored you till you wanted to move somewhere else.

That's what you do when you do an EVA—even to this day—when you ride on the RMS [Remote Manipulator System] on Shuttle. You'd get into this foothold, and so your big heavy boots just slide in. If you put an outward pressure, then you had on the outside of each foot a small steel plate that would fit into a lock. Now you just stayed there, and to get out of it, you just had to move your feet back together and you were free to pull out. That anchor made it all good and EVA is much easier.

By that time though, they had given up on flying the AMU device. Buzz went back in the equipment module and he was playing with this—they called it a busy box. It was where you could turn levers, throw switches, or tighten bolts. The idea was so that you could see that you were counteracting your weight. You could turn a wrench, because now he's anchored down pretty good, so it acts like a wrench, a regular one, and it doesn't twist you the wrong direction. He went out and played that whole busy box device.

All these events were going on, and at the same time, that took us up through the end of '66. At that same time, we had gotten the simulator going, and it got better, and better, and

better. Along the way, my astronomy knowledge kicked in, because on Apollo you had to do cislunar navigation. You had to actually navigate to the Moon and back if you lost voice comm. The crews had to know the stars; there were 51 navigation stars that they had to know. That by itself was a problem. We did some tests on Gemini, and on the day side, it was hard to find any stars. Just because even though you're 150 miles up, there's still a sheen across the sky. There's still enough air molecules that the bright, bright Sun makes it hard to find anything but the brightest of stars.

On the dark side, it was so good, that the people couldn't find the stars because they could see too many. You depend on these bright stars, and then there's a few other stars, when you look at the night sky, maybe you'll see 2,000 stars. It's just amazing, if you get into the shadow of the Earth, you look up, and you cannot see the constellations, because there's so damn many stars in-between all those bright ones that are almost as bright. You see more than 10,000 stars. That was something that I got involved with big time. We took crews up to University of North Carolina [at Chapel Hill]. There was a planetarium up there, Morehead Planetarium [and Science Center], so we took them up there and taught them the stars in that environment.

Then we would take them somewhere out in the boondocks in Florida, and say, "This is better than the planetarium, because here it is now. Can you still find Canopus, and Altair, and Polaris, and every one of the 51 stars that you had to know?" You had to develop these gouges like if you take the two stars at the end of the Big Dipper, and if you follow it, it points to Polaris. There were all these things that we came up with. We didn't invent that one, but that's one I teach a lot of people. If you go out in the summertime, and if you find the Dipper, and if you look at the Dipper and you see the handle, the handle makes an arc. You'd say, "Follow the arc to **Arcturus**", which is one of our navigation stars in Boötes constellation. Then you speed

on to **Spica**, which is in Virgo, so that's another. All these little gouges like that are simple, but mentally, they could see. We had a checklist; we had this image. Here's the star, and here's these little gouges with an arc going from the Dipper handle to star number A and star number B, just so they could find them. That worked, that was pretty well done.

Going back on the simulator, that was the best star simulator we had ever had. They had a two and a half foot diameter ball, a black sphere, and they had mounted steel balls on it. They had actually half drilled so you could take a steel ball and set it, and glue it into the ball. They did about 1,900 stars. It's used what is called a specular reflection. If you look at this mouse, it's not round, but this round object, you can see how you're seeing the reflection here. If you have one that's very, very solid that's white, then you'll only see one point. The Sun is shining on it, you have one point. Looking at a distance, it looks like a star. It doesn't show like a ball anymore; it's called a specular reflection.

They were just incredible, gorgeous stars. They even colored it a little bit; some of the stars are kind of like orangey, so they put on little gold-covered ball on there, and you had some image of color as well. It was just something else, so much better than anything we've done, even till today. The digital simulations, if it's a real faint star it's one pixel, and if it's a little bit brighter, it's two pixels. Whoa! Two pixels, so it's a little line there, if you put three of them, or four, and so on. It's never the same, and you're getting more brightness behind more pixels, but that's not the way the world works. We survived, and trained all these guys over the years, but those first ones were the best. In fact, I want to get a star ball and put it over in Space Center Houston sometime, just to let people see what it makes. You could turn on a light and look at that, so you could see what the night sky would look like up there.

WRIGHT: Yes, that would be neat.

HUGHES: Yes. The Smithsonian [Institution, Washington, DC] still has some star balls. There was four big ones and one small one in each of the CMSs, and two for the Lunar Module window. When you looked out the window, you saw the stars. Then they had a telescope for navigation also, so most of those star balls are lost. Probably in somebody's house.

WRIGHT: Yes, somebody's back attic somewhere.

HUGHES: Exactly. Like the pieces that are missing on the Saturn V, we can take a tour around there, I can show you all of the pieces that are just gone.

WRIGHT: Gone over there.

HUGHES: Yes, somebody recycled them actually, I think.

WRIGHT: Yes, I think that happened a lot. Let's talk about January 1967.

HUGHES: All of this simulation activity, I was getting pretty good at this. Luckily I was a pretty quick study, but on top of that, I was single. Everybody else married during that time, or was married when they arrived. That meant at the end of the day, they had to go be married, and do whatever that meant. At the end of the day, everybody put the pieces back together in the book. I'm the only one that said, "Okay," and I took it home. I just sat there and read the damn book at

the kitchen table. First of all, it's like with a new job, you come into town, you have enough money to pay the rent. Then your first check, you pay the next month's rent. It takes time before you start getting ahead, so the first two or three months, there was nothing else I was going to do.

I read the damn book, inside and out, and then of course I had questions. I'd go find the person, or I had to call them up in Houston. I'd say, "Who knows about this?"

They'd say, "Nobody." It was so funny.

"There must be somebody, somebody wrote this. Who wrote this?" They'd help me find out if it was somebody at North American, out in Los Angeles. The nice thing about it is I never had, up to this moment, the idea of long distance. Pick up a phone, dial 9, and just dial across the country. God, it was great. I not only would call them and ask them how it worked, I'd say, "Why does it say this?"

They'd say, "Oh, I meant to change that." It was great, so I'd exchange data with them. Then they just said, "What's your name?"

"I'm down here at KSC." I said, "If you're ever down, come on down here." You start building connections, so it was great.

Somewhere in August and September, we finally put the crew in the simulator for the first time. This is the downfall of the lemon thing. Larry Thompson that I told you about was the chief instructor for the simulator, and he gets in, and there are three or four of us instructors sitting around with our headsets on just being eager to listen in to hear the master doing his thing. It was Jim [James A.] McDivitt, Rusty [Russell L.] Schweickart, and I think Dave [David R.] Scott, and accidentally, the Apollo 9 crew, but it wasn't intended to come together like that, they were just three people sent in to check out the simulator. Hell, Gus, maybe Deke [Donald K.

Slayton], might've already had some idea. There they are, and they get in the simulator, and they got it running, and we launched. On the way uphill there was some question, and they said, "Why is it doing this?"

Larry said, "I don't know. We'll take a note of it, and we'll get back to you and see what's going on."

Then they get into orbit, and there's something wrong with the guidance system. "Should this be like that?" They'd have questions.

He'd say, "Wait a minute, I'll take a note, and we'll get back to you afterward."

The third time, I said, "Larry, I think it's because this. If they do this or throw this switch, it'll be all right."

He said, "Are you sure?"

I said, "Yes."

He said, "Why don't you try turning this switch on," and it worked.

They said, "Okay," and then they just went on. Two or three more times like that, and each time I happened to know because I'd memorized the damn book. I learned how it's supposed to work.

Each time Larry said, "I didn't know that."

"Just have them try it." He did; a confidence building up kind of thing.

Then they asked something else, and it was more involved. By this time he goes, "Do you know?"

I said, "Yes, I think it's this."

"Well, just tell them."

Of course I said, "I think try this, da-da-da-da."

They did, and then McDivitt said, "Who's this?" He knows Larry; they've worked together for a couple of years. Larry introduced me, and from then on, I began gradually to be the go-to guy. If it was simulators, then go to Frank. There were a lot of other good people, I just happened to be there early on, and it came together. It was that same thing.

Then they'd start to say, "Go to MIT next week, because there's a new software load coming, and we're going to do something." This was this guy named Riley McCafferty [Branch Chief]; he had no clue what the hell this thing did. He knew Gemini but he didn't know anything about Apollo, except whatever we told him. He said, "Go to MIT and get smarter. Go for a week." So, I did, and it was funny. Now it was getting into November. I went up there, and it snowed like hell. Have you ever been in Boston in snow? I had to be in Cambridge, that's where I'm staying because MIT's Instrumentational Laboratory was part of the school at that time. Later it became independent and became separate.

I went to this Greek restaurant that I found; somebody at the hotel, at the Marriot sent me down the road, and said, "Go to this place, it's really good food." I do and the food is great. Now it's snowing again, it's really snowing. I've got this rent-a-car, and I'm in the middle of Cambridge, lost. There's a cop going by, walking the beat.

I said, "I need to get back to the Marriot."

He says, "Oh, okay. You go down this way, you turn left into—no." Then he says, "Now you go here, and you turn immediately right here, and then you go to your right—no." Then he says, "I don't think you can get there from here."

WRIGHT: Oh goodness.

HUGHES: I always loved that. I wanted somebody to tell me that. "I just don't think you can get there from here."

"That's okay, I'll find it." I got to the car, and I went to the river. I know the hotel was on the Charles River. Turn left, and there it was. I treasured that memory, those two things that happened that night. There was that conversation with the police officer, and my first time I had baklava. It was all good.

I started going to Boston a lot, and then in the middle of January, they had a simulator out in Downey [California] called ME—it's a Mission Evaluator simulator. They had real computers in it, real flight computers. They weren't trying to fake anything; it was the real deal. There's a simulation of the system, which was pretty good too. Not as good as ours was supposed to be, but damn good at the time. I wound up going out and spending the week of 15 January there, with the Apollo 1 crew, and it was a really good time. The simulator worked well, they got a lot done that week, and they got a lot of confidence that they knew what the hell was going on. The mission was coming together.

They were three weeks away from launch, and our simulator was still not doing as good as it should. There were still so many problems. If you align a platform, that is, you had to look up at stars and actually tell the platform where it was, so you could then rotate yourself around and know what was going on. It didn't work; I mean the real one didn't work, the real spacecraft. They would just find ways to work around that, and we did that. In the ME, we were getting it all done. I learned a whole lot of things, and it was like being with your family. We were just close, going out after work. It was interesting, some nights one or the other one would be gone somewhere with family, or friends, or whatever out there. We'd go to dinner, and then

everybody would split off, because they had things to do and study, or cat around. I was just bombarded with information.

Then we flew back home. I left Friday night, got back to Melbourne [Florida]. We landed—Orlando or Melbourne were the two places—we used to routinely fly into Melbourne; nobody does that anymore. Then I went in on second shift Sunday night and all week with the idea I was working with the visual guys. They said, "This is how it's got to do. This is how it's got to be," and with the AGC guys, the [Apollo] guidance computer guys. "I saw it do this, this sucker's got to do it, because I just saw one do it." It was a really profitable week. I didn't see the crew, because they were on day shift and I didn't overlap coming in. I'd come in at 3 [p.m.] and work to 12 midnight or plus.

They were in the building, our simulator building, on Thursday, because they ran a sim [simulation] with Houston. Then the next day, the backup crew was in the simulator, and that one, I did see Wally [Wallace M. Schirra]. They were just through with the sim, and they were leaving. I said, "We had a great week in Downey, and I got some of this new information, and you've got to see some of this next week."

He says, "Cool." They got in their cars and left, and then get in the T-38s and go home.

I was the only NASA guy there in the evening this week. You'd always have somebody who was in charge, that's like a building manager, that's what we called it. Contractors would come and say, "We need to do this or that," and they'd just bless them and say go for it. They knew what they were doing. It was always easy to work them that way, if you know what to do, go do it.

About 5:30, or something like that, somebody says, "Something wrong with the crew? Have you heard anything?"

I said, "No."

He says, "Well, somebody called me from across the Cape."

I says, "I don't know. They were in yesterday." They were in the spacecraft, so I try to walk in and call, and the phone was ringing. From then on, it was all hell broke loose. The crew was injured; at first, that was what we knew, that they had an accident. Then it just got worse, and worse, and worse. The crew was dead. By 6:30, my boss came back. People don't know what to do, they came back in, and we were sitting there for a while.

Then it was amazing how fast it went. They knew the crew was dead, they were gone. I'd never had anybody in my life who died, and now you have three in the same day. That was bad by itself. Then Deke called, and he talked to McCafferty, my branch chief. He said, "We need to get somebody to go out and check the switches in the spacecraft. They're not sure that the crew might've thrown a switch or something that caused it. Can you get one of your guys to head out?"

He said, "Frank's here."

Deke, who I knew well by then said, "Perfect. You two guys come over." We jump in the car and we drive over to the 34. They wanted me to slide in on a board and write down all the positions of the switches before they took the bodies out. I'm handling this, driving over, thinking about how this is going to go on.

We got there and stopped at the pad, and Deke was there. He said, "No. We don't have to do that." He said, "Some of the switches are melted; they're going to have to take them apart to find out what happened." Of course, he was saying, "They didn't cause this." There's no way that you could do it. At least I did not have to slide in with people that you know, and work

with, and love and whatever else. Then they went back, and they said, "Okay, but since you're here all night—," looking at me.

I said, "Oh yes."

He said, "Okay. Go over to the MSO, and you're going to put everybody up in the crew quarters. People are coming in from all over the country, give them one of the rooms in the crew quarters, and set it up." I was like Howard Johnson for the rest of the night. All these people were showing up, big name scientists and everybody. Frank Borman came running back out of Houston. He jumped in a T-38 and ran down.

The whole idea is that they were starting the investigation group. So, everybody was coming in, and they'd say, "Have you still got room available?"

I'd say, "I got room, send them out here," so that they'd be here, they'd be able to go close to the spacecraft. Compared to the investigations from the other accidents that we had later, it was so professional. So, I worked until about 10 the next morning, and then I went home. I was the quartermaster to make sure there was enough food; I got extra cooks in to cook up [food], send them off and get food so everybody could get breakfast. All this just to keep it going, which is great, because I didn't have to think too much about the rest of it. It was a hell of a day.

WRIGHT: Considering what, less than two years before you were in Idaho.

HUGHES: Oh yes, freezing my ass, trying to stay out of the snow.

WRIGHT: Now you were in the midst of an accident investigation.

HUGHES: Yes, in fact, one year it was literally [one year]. It was January, because I came in in May and January is when I'd—it's one year, almost exactly to the date. Yes, it's a date and two weeks.

WRIGHT: Time only in calendar days though.

HUGHES: Oh yes.

WRIGHT: You had had many, many nights of [work]. We'd like to hear the rest of this episode of the following days, and how things started moving forward.

HUGHES: Yes, it was interesting, because immediately these really good people—and again, I just met people. It put me in a position where I met all kinds of other astronauts. Like Borman, I just met him there. Of course, we worked closely on Apollo 8, later. He knew what I could do, and I could get anything. After work sometimes I'd just go over and look at the spacecraft. It's the best thing about working in Florida instead of Houston. At Houston, it's just a white-collar job. Get down to Florida, and it's a dangerous, highly industrial business. Everything will either burn you, freeze you, poison you, or crush you. Those guys down there at KSC are in the real space business.

We up here [at JSC] are like spectators, that's what it really amounts to. They think they're in the catbird seat, but really they have no clue. I always say nobody should be able to work in the Control Center unless you go down and not just see a launch, but you see the ballet

that goes on before it's ready. With all those guys, and the escape suits, and all the dangerous fumes around, and all that they have to do. That's the real world. Sometimes we'd be very frustrated, and we'd step outside. You'd just think, "Goddamn simulator, I want to blow it up." You'd walk outside, and they'd be moving a piece of hardware. Real hardware, going out to the pad. You could say, "This is the real world." Kind of get reanimated and go back into the building and work hard again. All of us, we talked about that a lot down there.

The guys here were so good, the people that did all the jobs, and I'm talking about not just everybody in Mission Control, but that simulator team. We just lucked out to be in this other place, where the crews would come through there, and they got to know them, and do everything, and they put their fingerprints on.

You come down here, and then it's almost like life and death. This is real now. It's not like you're just farting around in the simulator, but now I need to know how this works, because if it doesn't work right, I'm not coming back. It was a different level of animation, involvement, and it's not just me, it's everybody that worked there. We felt we were blessed to be at that end, and it doesn't exist now. The same thing happens here, now, and you have the generic simulator training, then flight specific. That's what you did; you did generic training here in Houston. This is how the electrical system works, this is how the environmental system works. Down there you got more of a vision of the whole mission, what has to get done.

There were three parts after the [January] 27th, because you had to bury the crew. Everybody got ready to do this investigation about what happened. For a long time there were people going up and down the pad, working to get the spacecraft safed. It was already loaded to go, so it had hypergolics in it. People had to unload that, the professionals that would do that.

Then they had to lift it off there, lower it down, put it on a truck, and take it over in the building across the street, in the Mission Operations building.

When you get all that going, then you had to stop, go to Arlington [National Cemetery, Virginia]. I didn't go, but you had to go up there and go through [the funerals]. Everything stopped for a day or two; everybody in the world was watching what was happening up in Washington, and at West Point [Cemetery, United States Military Academy, New York], by the way. Two [Grissom and Roger B. Chaffee] were buried in Washington, and Ed [Edward H. White] is at West Point. Then the hard slogging, of going back to work, because then all we could do is keep one eye on this investigation, but we had to make the simulator work. Now the date is no longer three weeks away; it's never, if we don't figure out what's going on here.

During that time, really good people came down from Binghamton [New York]. It started a whole different set of things. A lot of changes to the spacecraft started coming through. On the bottom on the inside of the real spacecraft—and also in the simulator—they had wire runs. Literally, wires were tacked down. You'd have a screw and a clamp and it would hold a bundle of wires running around. They were not armored or anything, so in the simulator you were walking on them. Now these were fake wires, but you could see how they could break. The real wires had Teflon insulation. Now Teflon—it wasn't new—but it was new to being used as an insulation. It's a great insulation, but it's brittle. So if you put it in a place where you stepped on it, you could crack the insulation.

Everybody gradually began to believe that the reason for the fire is that some of this insulation on some wire was broken, one way or another. Up underneath Gus's [seat] on that left-hand side, which is where the environmental controls system was. Then when the test was

going on, there was a short, and the short was near someplace where they used an aluminum tube carrying poisonous fluid, ethylene glycol, like antifreeze in your car.

It's the [liquid] that kills kittens if you get a puddle in the street. It's also flammable, so why we were using the damn thing? We had a pure oxygen environment, and we had this flammable liquid used for cooling the spacecraft.

[Ethylene Glycol is a very efficient fluid for moving heat in a system. We used it for pumping the heat out of the Command Module out to radiators that were mounted on the Service Module. The tubes that carried the fluid were made of aluminum. The fire inside the Command Module was caused by a short circuit somewhere under Gus on the left side of the spacecraft, melted one of the tubes and turned the glycol loose in the spacecraft. (This was our best guess at the time of the accident and I never heard anyone give a better explanation.) Since it occurred in the module with 100 percent oxygen, the combustion of the glycol was explosive, very fast.]

Everybody is now thinking, "What the hell were we thinking about?" We flew the whole flight still with ethylene glycol, because we couldn't change. AiResearch [Environmental Control Systems], the company that did that design, that was a done deal, it was completed. These designs were built into it.

At least we got rid of the pure oxygen on the pad, for as long as you could during some phases of the flight. When we started out, we did oxygen-nitrogen, and then you purged it out as you went up during launch. Part of it is [when] you launched, you went 15 pounds [atmospheric] pressure, and then as you gained altitude, it dropped down [depressurized] to 5 pounds. That spacecraft only operated at 5 pounds pressure; that lets you be a very weaker structural shell. It was great, we never heard about anybody having the bends in spacesuits, because when you went in the spacesuits, they were the same pressure. That's why it was done.

We're still stuck with these 5 pound spacesuits today. That means you have to go from 15 pounds [inside the ISS or Shuttle] down to 5. Now you're actually having nitrogen bubbles appear in your blood stream. You can be a damage entity when you get through that. We've spent all this time with pre-breathing [to get rid of the nitrogen in your blood], and it took some doing. If you could even get an 8 pound spacesuit, you wouldn't have to go through much of that. [No good designs have occurred because of mobility problems, the suit is too stiff.] Sometimes they would lower the Shuttle pressure down some, and help them with their pre-breathe interval. Everybody breathed a little bit less. It's like if I took you to Denver's [Colorado] altitude or something like that and then that makes it easier for them to get into their 5 pound suits with less danger [of getting the bends].

All those thoughts were running around. Simulator changes started coming in—changes to the systems, and we had to just make sure it all works. Suddenly they sweep all this bottom of the spacecraft clean, and put cable trays in the bottom of the simulator, which just matched up what they were doing inside the spacecraft. Now spacecraft 12 is the one that burned up. Spacecraft 14 is the next Block I; they just nixed that off. We were going straight to Block II, which is S/C 101, the first one, so that was the spacecraft that had all this new configuration. It had a hatch that you could open quickly in an emergency. It was right in line coming; it's like the changes we did sometimes on the Shuttle, too. There was a better joint in the solid motors, and it was coming three flights later after [Space Shuttle] *Challenger* [STS-51L accident], instead of somebody saying, "Stop, fix it now. Put that one in."

The only reason this really difficult hatch was on the Command Module was because of the hatch that blew on Gus Grissom's Gemini flight. Then it killed him, because they couldn't get the damn thing opened. They were all going to burn pretty badly when that fire started, but

there was no way to open the hatch. It was like three minutes to open that hatch. Where after the new Block II hatch came along, it took about 10 seconds, because the middle guy would reach up and push a button and activate this pump handle three times, and that hatch would pop loose. By then, they could've kicked it loose and the middle guy would've got out for sure. There would have been accumulating damage on the other side. Roger was hardly burned at all; the fire was over on the left or Gus's side.

WRIGHT: That's a tough time through that investigation, I'm sure.

HUGHES: Yes, it was. It was tough times, and they roasted us all the time. "Did you tell them?"

"Yes, they designed it. They're part of the design process, so yes."

It was not near as much as the *Challenger*; we got a lot more from this simulator on that one. "Did someone tell Christa [McAuliffe] that this was a dangerous business?"

I said, "Yes, I think." Really I'd get kind of pissy with the guy. I said, "Listen; she's a smart lady. If we could take the elevators all the way up to the top of the launch tower, and walk across, and get in, and strap into this spacecraft. And then know that everybody else has to get three miles away. If she didn't figure out that this is a dangerous business by now, there was nothing that I was going to tell her was going to make any difference." Buy yes, we did tell her.

That whole summer of '67 was making the spacecraft right. Chasing our tail in terms of they changed it one way, and then they'd change it another way. But it got better. Along the way, the simulator itself kept getting better. The simulations settled down; the flight software got a lot better. It's like one of those things where you call a halt with a lot of crazy work and then other things were happening that were really heartening to us. Like the first Saturn V;

Apollo 4, and then Apollo 6. Apollo 5, the LM [Lunar Module] they lost in South America. We got smarter at a lot of things like that. It flew off in that last burn; they intentionally burned it to depletion. Someday somebody will find that sucker in the jungles of Peru or something like that. It's like the Skylab over at Australia. It was going to go somewhere safe and then, they said, "It isn't doing that. It's going somewhere else."

WRIGHT: Were you going back and forth from Houston to Florida still during that summer?

HUGHES: Yes, I was here. One thing that happened—I never thought about this for a long time—I became a guidance navigation guy, if you were saying what my specialty was. They created a group called the ISAGC [Apollo guidance computer] Control Group or something like that. I don't [remember] the name, it hardly matters. A guy named Clair [D.] Nelson was an instructor down here in Florida, and we co-chaired this group so that now we knew whenever MIT put out new software, we had a role in making sure that software was moved quickly into both simulators, so the crew sees this new software. It meant that there was feedback when we found something wrong with the flight software, even though we're not officially verifying software. We put a crew in there with the software, it's like the million monkeys joke*. They're not going to do everything that you thought they were going to do, and they'll do new things. That allows you to find out what does not work correctly.

*[Million Joke: If you put a million monkeys with million typewriters, over time, one would write something Shakespeare wrote.]

Then if something breaks, or it doesn't run, it's wonderful, because we feed it back. We say we saw this happen. It was like that. Clair was just a great engineer; he was really smart.

Between the two of us, we would wind up getting the crew the best training we could in that regard. Everything followed along. If this AGC needed something, it got done, and that ricocheted down. This system had to get better down here, because the flight computer needed a better set of data, or cleaner data. You had gyros and IMU simulations, inertial measurement units. It got better; it made the simulator better because the demands of the flight computer were so rigorous. They had to be.

Through '67, it was really good. If I wasn't in Downey or Houston, I would be in Cambridge working with the MIT guys. I remember we got up there and it started getting serious; it's at the end of the year. It was November or December of '67, I guess it was. MIT had put a set of navigation gear on the roof; it had a little observatory cover on the roof, and so you could actually look up at the stars and use it. They had a real system, so you saw the telescope, and the sextant, and everything. We'd go up there with the crew, and it was wonderful. Of course, it only took them about 37 minutes until each crew figured out that the nurses' quarters for Massachusetts General Hospital was right across the river. This 60 powered telescope works really good.

WRIGHT: Oh gosh. Keep focused, right?

HUGHES: It was heavenly bodies.

WRIGHT: A new kind of star. Oh, how funny.

HUGHES: Everybody learned how to use this equipment really, really well. So, we get into '68, more of this. It was just really a downtime, but the two Saturn rockets launches helped so much just to reanimate everybody and get going. Even though the Saturns had a couple of problems with pogo [oscillation] and early engine shutdowns. But we got through with that. Those guys were really working on those. There was 15 Saturn V rockets built along with another called F1. Today, we've got two left. The Saturn here [at JSC] is a real one, that's number 514, and the one at [NASA] Marshall [Space Flight Center] is number 515. The one at KSC is a mockup. KSC doesn't want you to know about that. It was made to train the crane operators to lift it, and it was called F1. It was a full simulator, except it didn't have real engines on it. It didn't have real this and that.

If you ever look down there again [at KSC]—and you don't have to tell the KSC guys this, because they don't want to hear it—if you can look into our engines here, you'll look and see the injector. You'll actually see all the little holes that were used to spray the fuel and oxygen in. It was an important process to mix the kerosene and oxygen together in the engine. At KSC, they have one real engine on there, and then the next is not. If you look back up where the injector is, it's just a blank wall. In other words, it's just a mockup of the engine.

In '66, '67, we used to play in the VAB [Vehicle Assembly Building, previously Vertical Assembly Building]. We would go in there and we'd run races. We'd [use] a stopwatch. There's 16 different stairways that go all the way to the roof. We'd take one that was away from the KSC security, and we'd start somebody, and they'd start running up the stairs. We'd go over and get in the elevator, go up two different elevators and get out on the roof, and wait for him. After you wait for awhile, pretty soon you'd see a little hand going back and forth, back and

forth on the banister, getting up there. I did it once, and I damn near died. This one guy, it was four minutes and 20 seconds, or something like that. These guys were in shape; they're young.

WRIGHT: That's amazing.

HUGHES: Yes, it is. Just straight up, just going straight up. Obviously, they'd slow down. They'd start going pretty fast, but you can imagine, that's 450 feet. They had to go 450 feet to the roof. We did a lot of that. We'd get in F1 when it was there, and I knew some guys, and they said, "Yes, come over." So, we climbed up inside the engines; in and around the thrust structure of this whole thing. It was a real one, so I looked at it. It was just an amazing thing to me. The bottom of the kerosene tank comes down, it's curved. Then they had I-beams, literally, that were cut so that they were welded onto the bottom of the tank. That's what supported all this weight. It is like they put this whole building together and it will fly. I looked at one I-beam, and it says, "American Bridge [Company]," which is the I-beam part of, at that time, U.S. Steel. In other words, they just took these big I-beams and shaved them off, and built them into this huge rocket. Boeing [Company] doing that one, at Michoud [Assembly Facility, New Orleans, Louisiana]. It was just amazing, the size of it, just amazing. Then to think that this sucker's going to go somewhere.

WRIGHT: When you said you knew something inside and out, I guess you really did.

HUGHES: Yes, we did, we did. We just went around and we had our daytime job, and then we were so tied together, we'd go over and do something else. I was kind of an outdoorsman in

Montana, do whatever. Go to Florida, it was a strange business. I remember two things very early when I was there. You know what a heron is? A great blue heron?

I lived in Titusville for a year, and then I moved to Cocoa Beach. I was driving down to one of those back-ass roads in Merritt Island, and there's a heron, and he grabbed a snake. I just had to stop the car. Fortunately there was nothing around. This happens all the time probably, but he grabbed the snake behind the neck, so it couldn't bit him. The snake is doing its dance, there. The bird got ready, and got ready, and got ready, and then he flipped the snake up into the air. Just flipped up in the air, and kept its mouth open. The snake just slid down, just completely. I couldn't even drive, that is the damndest thing I've ever seen. How do you eat a poisonous snake if you're a bird like that? He probably crushed it, broke its neck by this point, with the bite. Then flipped it, and this damn snake stretched out, like almost straight, and it just "foom," disappeared.

WRIGHT: Not in Montana anymore, are you?

HUGHES: That's right, you're not in Montana anymore. Then the other thing that happened, is I met a guy sitting at a bar, and he was an Indian. He'd just come back from Nam [Vietnam] during that time, and he was kind of screwed up. He was [from] the tribe down there in the south part of the state, a Seminole. We became friends, so he took me out, and I got comfortable in the swamp. I mean, we would go out in airboats, and canoes. We would see alligators, so many things that went on out there in those swamps. In fact, because of this, I wanted to count how many alligators were in KSC.

I went to KSC, and they said, "We don't know how many." I got the park's approval to check. Then I went down to the Audubon Society in Melbourne, and I recruited a bunch of little old ladies who would bring their canoes. They were so excited because they got to come inside KSC. It had been closed off for years. [I had] my canoe, and a couple other friends, and then we had about four or five of these things canoes. We would give each pair of ladies a canal to go down. Three nights, different times, we'd have a square mile set aside. We had canoes come in at different angles, and they would go through their area.

This is after dark, and so you go through it with a canoe and a real bright floodlight, and you would point it ahead. If there's an alligator there, they would look at you. It's like a deer; they'll freeze. They'll just look at the light. You could just count the lights and divide by two, and that's the number of alligators. I kept thinking, "These people are going to get lost." But no, the only one that had a close call was me. I had a buddy and we were going along, and I was paddling, and he was counting. Got to this point during the night, and he says, "That's it, turn around, I'll do it now [paddle]."

I said, "You okay?"

He says, "Yes."

I said, "Okay," and we just flipped around and he was paddling. We're going along and here's this big gator coming up.

He says, "Okay, this is a big one." He can tell, because they're hanging down in the water, still.

What's beautiful about this is the water's still, the stars are here, but then you have stars underneath. It's almost like you're in space. Black vegetation on both sides, stars, and stars, and if you're cruising along, it's noiseless. Here's this big [alligator] coming up, and they're sitting

the way they do, draped down in the water with the nose and the eyes up, and everything else is down. I said, "Okay, just take him to the left, so we can see how really long it is." Whatever happened, little puff of wind or something, just the operator error in the back here, and we nailed him right behind the head. That sucker came out of the water, literally out of the water, and slammed his whole tail down the side. I was sitting down so I'd keep the center of gravity low. He was sitting up more in the seat.

He took that entire boat out of the water and moved it about three feet sideways. I had a bruise, my whole right thigh, because the canoe is dented in. It's a good thing it was a metal one and not a fiberglass one. He was gone. I had a brand-new Nikonos underwater camera, sitting behind me. I saw this splash—"sploosh!"—and then—"kschetch!" My \$300—then—camera was sailing through the air during that dead space until it landed somewhere out there. Since I didn't even know exactly where I was, there was no chance to ever go back to find it, because you're this many minutes into the thing. My transition to knowing Florida, and know what to do, and go out and everything, was just amazing.

WRIGHT: It's interesting that you were able to put that excursion together with all the confidentiality, or the security of the whole Cold War race.

HUGHES: Oh yes, they loved it. It's that same old stuff. They were all kind of interested too, so we did three different one-mile squares, different, one a week apart. It was so great, but we got incredible results. It was like 45,000. You counted how many you see in this mile and we just multiplied it by so many square miles of KSC. It was like 40,000 alligators or something like that. That was then, and I think that there's only so much that they can eat, so they've probably

stayed pretty close. You see them around everywhere at KSC. Maybe if you just see some around here, go down to Brazos Bend State Park. They're just everywhere.

WRIGHT: Yes, very large.

HUGHES: Yes, very large. Don't bring your dog.

WRIGHT: No kidding. Or small children without leashes.

HUGHES: Yes, exactly.

WRIGHT: This might be a good place for us to stop, and then—because it'll be easy to pick up where we left off when we come back.

HUGHES: Sure.

WRIGHT: Thank you so much for this morning.

[End of interview]