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EDITED ORAL HISTORY TRANSCRIPT

FRANCIS E. "FRANK" HUGHES
INTERVIEWED BY REBECCA WRIGHT
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The following interview was conducted with Francis E. "Frank" Hughes on September 30, 2013, during a walking tour through the Mercury, Gemini, Apollo, and Skylab exhibits at the Johnson Space Center visitor's center, Space Center Houston. The interviewer is Rebecca Wright, assisted by Rebecca Hackler and Sandra Johnson.

HUGHES: We started my piece of this hardware, not Explorer, but over here in Mercury. What we still have to do is go through the PowerPoint of the history of simulators, if you will, in the near future. You can imagine this method, in each case, the spacecraft was X and then the simulator was about X, that is about at the same complexity. A little more complexity because you had to simulate this vehicle and still be a simulator in the sense you could put in malfunctions and do instructional procedures. In the case of Mercury, the reason I want to show you this is because we build on this initial spacecraft.

The astronaut would get in the simulator, and then there was no visual at all. They just covered up the windows and they didn't care about day, night, didn't care about anything. You just sat in there, and there was less than 100 switches in the whole vehicle; there were very few things to do in the spacecraft. No computer, so this is where, on the window—and the window is in front of the guy [mannequin] here—they would turn it around, and this is where the hatch was. This was closed, although there was a small, square window. In order to do a deorbit burn, you'd look through the window. You actually tilted this vehicle down so that the nose is pointed

down and backwards. You could tell you were going backwards because the Earth went away from you, went up in your window, so that means you're going backwards.

This angle, you'd tilt them to 10, 20, or 30 degrees. There were lines scribed on the window, and that was all you'd pitch to it, and then you'd push the retro button to fire. In Mercury, you could rotate around but you couldn't translate. There was no way to go forward, back, left, right, up, or down in this thing, except for those three solid retro motors that slowed you down to come back down. That was it. There was still a lot of training.

I've got to tell you a story. When Riley [D.] McCafferty, my branch chief, when I started, was training Al [Alan B.] Shepard, there were only two guys that were instructors training him. This is at the Cape [Canaveral, Florida], with the simulator down there. They were so proud of their simulator, they could put in smoke like you had a fire. Years and years ago, if a radio or a TV burned out, you could smell it because there's a thing called a capacitor, and if it shorted out, it would get cooked, so it would make smoke. When it did, it made this unique smell that you would get. In the simulator, they just had a paper capacitor that had no role except it'd sit there held with two alligator clips and they'd throw a voltage on it and cook it. Of course, it smelled like you had fire in the spacecraft.

They gave that malf [malfunction] to Al Shepard one day, and of course, he's buttoned into this simulator with all this equipment around him, and it scared the hell out of him. He thought the simulator was on fire. He says, "Get me out of here!" There's this Navy guy, so a lot of conversation about that was pretty salty. He got out and proceeded to chew everybody's butt up and down the whole thing, all the way up to Deke [Donald K.] Slayton and everybody else. He said, "No more smoke, no more fires."

Coming down in countdown, he's about two weeks away from flight, and McCafferty's out there running this sim [simulation], and all of a sudden, [Shepard] says, "McCafferty, God damn it, I told you no more smoke in the simulator." Of course, they hadn't put any smoke in the simulator. He says, "God damn it, turn it off, guys, get me out of here." Everybody's over trying to get Al out of this thing, and they're already ripping through the simulator and disconnecting all kinds of stuff trying to find out what the hell's going on. Then they hear Al laughing in the background. It was a gotcha—he had put them on entirely. There was no smoke, there was no fire. He was just paying them back for what they did to him.

When we got to Gemini, same kinds of things. This is where, when I got there just before Gemini IX, in this case, the simulator, you sat kind of horizontal. Once you got in, then the visual would come down—this is where you had a visual—over the top. Very simple, it just gave you a TV camera so you could see the Agena target [vehicle]. You didn't see the Earth, you didn't see anything else, you just saw this target vehicle out in front of you if you are near it. The simulation wasn't bad; it just showed target vehicle and it would move closer or farther away, go up or down, left or right. You'd get in and when you did that, you can imagine sitting in there, Gemini III was only three revs [revolutions], 4.5 hours, that was Gus [Virgil I. Grissom] and John [W. Young].

This was where the sandwich from Wolfie's Restaurant, and all this stuff—of course, you know that was bad for them, too, because by the time you got there, that really good bread that Wolfie's used, it had dried out, so when they pulled the sandwich out, it's crumbs just everywhere. It was a mess. Al gave it to John, by the way.

Another time about their flight on GT-3, I talked with John. His first flight and his job on first time in space, he had to do the first number two in space, that was one of his jobs, and the bag leaked.

Do you remember when you first bought margarine, years and years ago? It was white and there was some rules about it and you couldn't put colors in it, so you had a little color dot and you squeezed it? Then you would knead the margarine to spread the dye in that pill. That's what you had to do with your bag of feces after you had filled it. You had germicidal pills because if you didn't use it, the gas from the feces, the same gas that would get loose in your body, it would blow up and break the bag. You have to take this newly-exited material, break this germicidal pill, and then you have to knead the bag to spread this stuff all around. This is one of the good old days that you think about. That all happened in here, in the spacecraft, but you can imagine Gemini VII, 14 days, two guys, 14 days in here, where they're not going in further than right there, side by side, that's all there was. That's what [James A.] Lovell always says, that he and [Frank] Borman were asshole buddies.

WRIGHT: I remember that Borman had taken the book *Roughing It*, by Mark Twain, and I always wanted to know if someone had suggested that to him, or did he bring that on his own?

HUGHES: Probably on his own. Come on over here, one more, before we get around the corner. This is the cockpit for LMS-1 [Lunar Module Simulator], this is the LM Simulator that was here in Houston. In this case, there was only a piece of it. There was more back here where we are standing, and we can talk about this, but you could imagine—come up close so you can see, here—you're standing here, there's enough room for about two phone booths, but actually, it's

bigger than phone booths because it side balloons out. It was a pretty good spacious area. This is the hatch, looking from the inside, down here by the crew's knees.

When you were standing here, the guy would have this hand controller for translation, and this one for rotation. It's right now down; that's so you could put it out of the way, but you'd pull it up to use it, so you had an armrest. You did that as you were flying. See, there's an armrest on each one because remember, you're standing, so you have something to control what's going on. This telescope is for navigation, this is where you'd look to the stars and align your platform, all this stuff that you had to do. We did that really well on the Moon.

What I wanted to get to, though, there was a question about who should go out first, remember, Neil [A. Armstrong] versus Buzz [Aldrin]? The hatch originally opened the other way, and they switched it around. Somebody realized that was a problem, so that the hinge is over there and the latch is over here. In the middle is a [valve] to let the pressure out. That's where you'd de-press. When you got your suits all ready to go, then you'd crack that valve and let all the air out. Remember, Neil's here, so you open the door, pull it open as far as you can against Buzz, and then Neil would turn around, so he's facing backward, kneel down, and then go backwards, crawl backwards out on to the porch and then down the ladder. Then, Buzz would close the door after he took his pictures and did all the planned procedures.

It was about 30 minutes later or something, he came out, 25 minutes. He would close the hatch, move around to the left side, open the door up again, turn around, and go out on the porch and down the ladder. It was easier for him to get down because Neil was down below. Neil would say, "Okay, your foot, move a little bit," you know when you're feeling around for a ladder, and now, you couldn't turn around, so it was even worse.

The other thing I would like to talk about here is the contact light. There's a master alarm on each side, and then on the right side is a little square light, and higher up, there's a little contact light. It created a greenish-blue light at contact.

Remember I told you about those probes that hung down from the legs? I was going to get some pictures so you could see those, but you'll see them sticking out under these landing pads. Through all the years, nobody's even talked about that. If you look at the photos on the Moon, you can see them sticking out from under the landing pads. You can see they're bent all different, and you can see what direction we were drifting as they landed. As they landed, and they were drifting left, all the little probes are sticking out on the right side, all the same angle. That was important to us because we could see which way they were going when they touched down. You can't see it from these pictures, but I will find some better ones to show you.

During the landing, you can hear Buzz, he'll say, "Contact," and then there was a button there called "Engine Stop," and you just punch it and you just plop down, shut off the engine.

WRIGHT: Frank, you mentioned that the size of two phone booths, how much is that per footage?

HUGHES: The square feet, you could see, it's about 3 feet by 6. It's really quite good size. Once you put those suits on, it was pretty full in there, but you gained a lot of space because you had this curvature out, and that's what gave them some space.

[Looking at the Command Module] We flew until 1975. This is the hatch, and this one, we talked about, that the hatch, poor old Gus damn near was killed by his first hatch, when it blew loose, and then this one was coming two spacecraft later. He was on spacecraft 12 and 14, that was the two Block I spacecraft and then Block II, 101 was the one that came along, and it

had this new hatch design. You could do activate this lever three times, and they had a nitrogen cartridge here, it would undo all these latches, or dogs, and then it would just pop loose, in which case Ed [Edward H.] White was in the middle, and he was really muscular. If he had that hatch, he'd have got it open. Somebody would have gotten out of there, even during the fire, they would have had some injuries but would have been alive.

Think about this as a simulator again, step in close so you can see that this is how the simulator was constructed. This spacecraft is tilted more; it would have been leveled off. You slide in here, then you could stand in the lower equipment bay and look through the sextant and telescope, which is way the hell up here, just out of sight. You see the panel, and then you have the sextant and telescopes stick in through there. You'd be laying in the simulator and you'd sit here like this, but we had real seats like these, so then you could fold them down and get them out of the way and do whatever procedure was needed.

On the longer flights, you took out the center couch entirely, folded up to a small thing and just stuck it in the corner. Over on this side, on the wall down here is where the toilet was, the thing that you actually had a little seat and a can below it, and then a hose that led to the wall where there is a vacuum valve. That didn't get used by anybody. Nobody was going to put their equipment down this thing and then open it to space. We'd go through all this. You can see when you're here, there's two windows, one in the commander and one over here in the other pilot, that's looking forward. That's looking at the LM, at the docking target up here. Then, two other windows on the side. They were 180 degrees apart on each direction.

Those four windows, and then there's a small circular window, here in the hatch. I said "small," it's about 8 inches. That was the view you had during launch. When you launched, though, we had a cork shield over the entire spacecraft including the windows because if the

launch escape tower fired, you had to protect all these windows and everything in case you wanted to be able to see later. When you jettisoned the launch escape tower, then we blew the cork cover away. Then you could see out the windows.

When you did this mission, though, this is where you'd come home, smack down, this is the same orientation with the parachutes extended. The parachutes, these are called drogue chutes, these are explosively deployed. You could be tumbling or anything. These two would come out and they would drag out the main chutes, which were here, there's three bays here. See, there's one, two, three all around, so these big things are packed in here.

When you're coming down, there's a pilot chute that came out and it dragged this piece covering the parachutes away, it's pulled away completely, and then that exposed the other chutes. These are drogue chutes; when they fire, that was a big boom, but they'd throw this small parachute way out and they'd pop so that even if it was rolling or tumbling, it caught the spacecraft and stopped it from that maneuver. Then, a few seconds later, the big chutes would come out of there as a package, and they would expand and expand bigger, explosively.

These are all the [Reaction Control System] jets, so there's a set of Command Module, and there's a jet for entry, and another set on the Service Module. There were 16 on the Service Module, and that let you rotate or translate in all directions. It was a marvelously good machine. These things, there's two systems, an A and a B, so that you had one on each side, which by itself, it lets you yaw. This one, it's back to Mercury—you could only rotate, you couldn't translate because now you are on the way into the atmosphere, you didn't need to worry about translating. This one, then over here would be roll. See, they're called "scarfed" when they're built into the [spacecraft], so one is firing at us and one's firing the other way.

If you can imagine, if you took a thing like an engine bell, but on the side like that, then you'd cut off the edge so one part is gone, so it's only like this. That's what you get. The gas is still coming out like a rocket engine. This was really simple. That is aluminum with this resin, this organic, like the fiberglass and resin stuffed in it, so it burned away. Literally, that was the way it was; "ablation" is the term. What I mean is when it burned away it would create a boundary layer, and so it retarded how much heat was hitting it and then you gave away a little of the fabric. You started out, this is about 6 inches thick, and when you go home, it's about 3 inch thick. Unlike the [Space] Shuttle tiles where you didn't lose anything; those tiles come home all the time. You can see there's dings on this heatshield, but this, when it was sent out, it would have been much thicker, by about half of what's there. The rest has been burned away.

This is the umbilical from the Service Module to the Command Module, so when you separated them, it fired the four jets facing up. Back there, it's an automatic system and it would pull itself away. This thing, it would just pop loose like this, just like a gooseneck, would pop back, and then you'd fly away. This is where the sextant telescope stood out, so the telescope was just a finder's scope with 1X, or one power magnification, and then the sextant was 60-power scope. It was a great piece of optics. We're going to see here in a minute, this went on the front end of a Command Module. Remember that Command Module docked up here, on top of the LM. We can talk through that in here, but the pieces are going to be on the Skylab.

This is nice; I haven't been since '94, whenever they opened this place, because we were putting it all together. This is the ASTP [Apollo-Soyuz Test Project] airlock, we've been talking about that. We had to have an airlock because the Apollo operated at 5 psi [pounds per square inch] while the Soyuz operated at 15 psi. I brought this along, a lot of different books, but this is one—and you guys can take pictures or you probably have the book already.

WRIGHT: We might have that book.

HUGHES: This one is a series that Skylab did, so this is just the smallest one. They're heavy. You know what a Saturn V looks like, but this is, they took the same stages, the first and second and then the third stage, but the third stage, the smaller one right here is the lab. They talked about, for a long time, whether to do a wet or a dry workshop. What they talked about here is that—probably some better lighting—when this got to orbit, then when it had to change the telescope, is up in here, up under the white micro-meteorite shield during launch. Then, when the second skin, or protective shield, would open up, it would expand itself.

Here's the lab, this is the portion that was covered by the meteorite shield that's covered in that white thing, so it's part of it. This clocks 90 degrees off and is the ATM [Apollo Telescope Mount], the solar telescope. This side was always what we call a Sun side, or anti-Sun, when you talk about the airlocks down here. When we lost the double-side over here, we lost the outer skin, then that meant the Sun side had the full heat of the Sun blazing on it. If you put a hand on it, it's like 200 degrees inside, and the air temperature was about 130 degrees. We're going to pick it up from there because what we had to do when we were talking about the flight planning and the training going on, we had them ready to go for a whole set of planned procedures that were all changed. I think we should talk about that later, when we're not here, but back in the office, about how the simulations went.

I'll probably hit into it, but this set of modules were in Building 5, on the south side of Building 5, where the Command Module and Lunar Module Simulators on the north side, where the Shuttle devices were. The workshop was standing upright, so you could crawl up in through

and do all these things in and out; the modules were separated just where they are, where there's about 10 feet between each one and you could do different flights, different training going on at different times. Schedule them out that way, or we'd do one big sim where we'd have people at Control Center, but remember, that's not a simulator, but a mockup. It doesn't make any telemetry, but then we'd have the Skylab Simulator running too, to generate whatever telemetry it did.

WRIGHT: That's a lot of coordination.

HUGHES: Yes, a lot of coordination, and 200 people, three shifts, going around the clock. I want to stop here, you know what this is? [Walking around the back end of the Skylab workshop display] This is a liquid hydrogen and liquid oxygen, but oxygen is heavier, so oxygen—this is the oxygen tank and this is the hydrogen tank—in this one, now remember, when it's dry, NASA talked about launching wet, actually firing it up so it was heavy, full of oxygen and hydrogen. We somehow would evacuate that residual and climb into it and live in it. We didn't do that. It was too difficult to engineer.

This area is where the hydrogen would have been on a Saturn V flight. This was turned into a garbage can. What it did is this long tube just kept bags from banging around, but we had 2 foot by 18 inch canvas bags, effectively, put all the garbage into them every day, and then you would put it through an airlock. Remember this is a vacuum here. Send those bags down here, and they were just floating around all the time, until it reentered. This would have been right at the end of this. This is only part of the hydrogen tank; they cut it off half to fit in Building 5 to make the whole sphere of what this thing would have been here, a little further back. We're just

starting at the garbage end of the space station, but just come up a little bit more so everybody can get in.

This is an airlock, actually, so you had garbage, anything you'd want to get rid of, you would pop the top of this waste airlock, put this bag that was just form-fitted to go into there, and then you'd close the top, open the bottom to turn it loose, and then that handle would actually shove that bag down out of the airlock, down that long tube, and just like sausages, just pushed them down through there. Then, you'd close the bottom again and it was ready for the next time. That's everything we did. I got to talk about that in a minute.

Let's go over here. This is where you slept. For the first time, you had somewhere to sleep while in space, so there's one here, one here, and one here [pointing to the three sleep compartments]. It was interesting, everybody loved them. It was the first time that when you slept, you didn't have to deal with everybody else's snoring and whatever else. They had little folded doors that when you closed, you'd get a little privacy. In here, you had personal items. We were dealing with not eight-track but little cassette recorders in those days, so that's what they used. They had music to listen to, family voices and things like that.

Some crews, they liked the music the same way, so they'd have the music floating around in here, they'd have it playing all the time, so a lot of batteries went up with them, AA batteries. When you'd get through that, you can see the black devices on the wall—a towel rack doesn't work with no gravity, so when you had a towel or washcloth, to dry it out, you'd take the corner of it and stick it in there, and then that'd just float around. Mostly, when we were training, they were hanging like that [towel] does, and we got them out of the way because it was a pain in the ass to deal with them. Each person had a communications unit so you could talk to each other

around the lab or to the ground. There's one in each of the compartments. If somebody could call you during the night, you could be in contact right away.

This is a rotating litter chair, you've heard of this thing, where they're trying to figure out space sickness. This chair was used to see how to make them sick. That's some stories I've got about the zero-G airplane [KC-135], but I'll tell you about that later. Here, they really were very tolerant of this kind of thing, but the way this worked, you would sit in there like a barber chair, and they'd spin it. Then, you would have to do this thing [showing head motions, left and right, forward and backward] to try to elicit nausea. If you got nausea, you'd stop, and that's what they did all the time. We did this on the Vomit Comet [KC-135 reduced gravity aircraft] all the time, on the ground and then with the crew flying in orbit. You know what this is? Just look at it. It's a fire extinguisher, just pressurized. You'll see those around the place, different places.

WRIGHT: Important not to have fire in space, isn't it?

HUGHES: Yes, yes. Let me go up here. This one up here is the bathroom. Stay where you are, you might come over here a little bit closer, but you want to see, this is the top, if you think about it, so that's a light up on top. What you've got down here, there's three silver-looking things. That's the urine pool, that's a urine collector, one for each crewman. Males, the plumbing is a lot easier to deal with than it was later, although we worked all that out, but the fact is it was a 2-liter bag, a plastic bag in there, and the way the protocol worked is you would work—remember, I'm the flight planner, we've got to deal with all this stuff to get it done—you would get them set up, so they would put a new bag in, in the morning. You would use it all day, and then, when you went to sleep, if you had to get up during the night, you used it, and then when you finished,

the first time you used it in the morning, the first one, that created a flight-planning day. Then, you would draw a 100 cc samples out of each one, and then you'd put those bags down this trash chute. Put them into those canvas bags and trash them. Those would sometimes freeze and they'd break. It didn't matter to us because it's just out there. When you did it, then they were little plastic cube bags, made special, and they would be stored in the freezers. The freezers are up above your head, over there. I'm going to talk about that in a minute. We called those urine cubecicles.

If you had number two, when you go to the bathroom, see where the mirror is? The mirror was really important to you, but the white [seat] is where you sat. There's two anodized-looking blue, green handles because you've got to hold yourself on the seat. There's a thing between your legs there, and the legs would be in that hole there, and then you would have the condom-like thing that's on you during that time. Each one does this thing in a bag. The nice thing about this is this had a door. It's been removed so you can see everything here, but in fact, this is it, right here. I'm just looking at it, this is the door right here, but it would flip around and close. You had a modicum of privacy, which you didn't have in any of the other [spacecraft]; you were just there.

Of course, most people came back constipated—they would do anything to avoid this on those shorter flights. There was low-residue food and all that sort of thing; not a lot of fiber until they got home. That's the deal. What you would do, though, when you filled up a bag, also if you barfed, we'd catch it in a bag. Then, those six gold-looking things are ovens, so you'd put the new stuff in here—you didn't have to worry about kneading the thing like earlier—you put it in there and dried it, and then you stored that away, and that was part of the sample material

coming home. This whole thing, everything else in there is supplies, plastic bags, vomit bags, feces bags, the little, tiny icicle cubes, urine-cicle cubes that we had.

This is food, up here. When we launched it, almost all the food is in here—all the dry food, and utensils. They had these wonderful things. See his feet, see the triangle? See these [grids]? Wherever you were, you could put this through here and twist your foot a little bit, and now you're going to be able to stay where you are. That was really a nice [feature].

See those big tubes coming from up there? Those are bringing that fresh air through the air conditioning. The air conduits came down here, underneath the floor. It's like a plenum, and then the air would flow up back to the top. We talked about that you'd hate to fly with people that had dandruff or everything else, but that's the air return filter up there, the six-sided thing. That was vacuumed out about twice a day, to get all the stuff out.

Now, let's come back down here. The food, for the first time, they had trays. See, it's a white tray, and some of the things, there was a place where you put these little aluminum cans in them, and they would get heated. For the first time, we flew with shrimp and spaghetti and steak, but everything was in a goopy sauce because it wouldn't come loose. You would cut it, like the steak, but it stayed in there because the goop would try to keep it all together, and then you would just spear them with a fork and pull it out. The food was way better than anything we'd ever flown before.

This is a thigh-grabber, see, he's [the mannequin's] kind of climbing onto it, but this thing's hanging out here, you'd get up to it and you'd put your thighs between the two pieces of metal sticking out from the table, and then there's stirrups at the bottom, so you slide your boots into that, and so you'd be comfortable. It was really quite good.

Wonderful window, this is called the wardroom, and you can see there's a big window, which had a thing you could cover it from outside, but open it up and you could see the Earth going by. There were two decks—this is the lower deck. This is where you slept and go to the bathroom, and then this is all the medical experiments. We have the shower, now the shower, you had 2 quarts of water, 2 quarts of hot water, and what you would do is you'd get in there, it took about an hour, you'd get in and I've read some people that say they didn't do many showers, but as far as I know, they showered all the time. Once a week, I mean, not every day.

It's like Saturday night, we used to joke about it. When they say they do it, they get in like that, it was a beta cloth tent, and with two hoses in there, and soap. You'd spray some water on you and then lather up, and then you would spray a rinse water on you, but then you'd have a vacuum hose that vacuumed it off because there's no gravity, there's no drain, it just stayed there. They made a lot of jokes about the face that the water, the surface tension, all the water would be under your left arm or between your legs, things like that. They'd suck it off and get through it, so it was good. They loved the sense of just pure water. Sometimes they would towel themselves off, but then they would, on a daily basis, but on this one, they just used pure water because they found it was tough to get all the soap off. They liked to do their hair, they used the dry soap on this.

This is a bicycle ergometer, and they'd have masks on and all of the information was being recorded in these [devices]. This is a lower body negative pressure [experiment], do you guys know about this one? It's nothing but an empty can, but there was a dam, or tight elastic cloth, around here, this would close around your body. When you go to space, gravity quits happening, and so all of your body migrates up, and so, then you get rid of all your body fluids.

You lose about 15-20 percent of your blood because you just urinate it away, the first three days you're up there.

If you put these guys in and then pull a partial negative pressure, so you use the vacuum outside, but very carefully, you'd lower the pressure here, so then the blood would go back down in your lower extremities. That would give you the sense of being lightheaded. It's a simulation of what's going to happen when you go home. They did this, everybody did it, and the way it worked, everybody did it, like, once a week. Everybody did the ergometer every day, just for exercise. There's other things, where every morning, you got up, you weighed yourself—that was another thing—and how do you weigh yourself?

Let's go up here. This is how you did it, right here. What it amounts to is a pendulum, if you have a pendulum and you make it go back and forth, if you've ever done that, if you've ever controlled a clock like a grandfather clock, if you change the length of the thing, you can change how fast it goes, or you can change the weight, the mass. In this thing, Bill [William E.] Thornton invented this, and it was really good. It's a pendulum, except when you sit in it, it had four steel blades, so the thing would allow you to move back and forth this way, so you slid forward and back. Your mass would change how long it timed, so there was a little thing that timed you, how long it took to make one cycle. That would translate directly to how much you weighed. They weighed every day, after the first urination, and then that would be the standard for that day, and then everything else going on through the day. These are filters in here, other filters and motors that drove the flow of air going around. It's nice, I think a very smart thing, to have all this open web work so that the air just flowed along. The air conditioning and everything was up on the exterior around the airlock.

That right there, the next module up, is the airlock. You'd go in there, close this hatch, close the one on the other side. The one guy not going out is up in the Command Module end because the Command Module would be docked up in that end, way at the other end, and we'll talk about that later. This is the workshop, that's the airlock, and the next part is the solar experiment area. That's where you ran the space telescope, the solar telescopes and Earth resources, and experiments like that. This thing here, these nitrogen bottles, we brought an early version of the astronaut AMU, the Astronaut Maneuvering Unit. It's a far cry from the one we actually flew a lot on Shuttle, but we flew it around in here about three times. We had a lot of fun and it worked very well. Remember, this thing was all launched pretty much ready to go, so these tanks are all the water you're going to have on the whole time, so all the way around, the buff-colored tanks.

The white lockers are equipment, cameras, everything like that—film, remember, you don't have digital at this time, it's all film. It's here, it's underneath this. We had a coffin, almost, it was very thick. It was funny, it was made of very, very heavy aluminum with some kind of thing mixed into it, an alloy, but it was where you put all the film. The thicker part, the part for Skylab 4, was thicker than the one to try to give you more protection, so the Skylab 2 had less protection because you're going to use it up, and then 3 and then 4. The heat screwed it all up, so we had to bring film up all the time. Some of the film, they were able to test it and they got some out of it, but mostly, it was all destroyed because the 100-and-X degrees in here during the time after you launched.

Before you come in here, everybody sees a movie, and part of it. This [mannequin] is supposed to be Paul [J.] Weitz. Remember you saw them, Al [Alan L.] Bean was a diver in the Navy, at the Academy. He was able to jump and turn and spin and do all this stuff, and he

stopped, obviously. A lot of them got to learn how to do a little bit; he was really, really good. Some of them just jumped around here. This is off-duty. It's the kind of thing where so many times, [the film we see is] what they're doing, eating, whatever, that's because they didn't have time to do filming when they're working. It worked out pretty well.

All of this equipment that you see, and then the blue handholds, just literally, we were worried about people getting trapped, getting stuck in the middle. Of course, what did they do? They're guys, so they tried to trap themselves out in the middle. That is, they tried it. They would put them out with zero movement and then turn them loose, and you could swim out of there. You could not get trapped. If you could do swimming motions, it wasn't much, but just like air is so much different than water, you could gradually make a motion, forward or backward, and you could drift over and get to a wall. If you're a mile out from there, probably not going to work, if you drift away from the spacecraft, but in here, this is good.

There were nine people who flew up here [on Skylab]. On one of the flights, [one of the astronauts] found the little bedroom compartment confining; it was a little bit too confined to be in that little coffin-like thing to sleep. So, when it's time to go to bed, the other two had disappeared in their little cubbyholes, and he'd take two lanyards and stick himself between the wall, and he'd sleep here. He'd just curl up, turn out the lights—and turn out the lights meant close the windows, too, because it's day/night and day/night, it could drive you crazy. It also made a significant change in temperature, even with everything else. It was nice. He found it very, very good.

This is the anti-solar airlock. There were two airlocks built into the [module]. This is a great idea, and we had all these experiments that would plug in. You have like a 1 foot by 1 foot [pallet], you put an experiment on here that was a telescope or it was going to look outside, or

you slide things outside and expose them and then bring them back in. This is the anti-solar airlock, and this is the solar airlock up here. This is the one where in the 15 days between May 1 and May 15, we re-engineered all these kinds of things. A guy came up with an idea, Jack, it begins with a K?

WRIGHT: [Jack A.] Kinzler.

HUGHES: Yes, there you go. He and his guys engineered this parasol. In other words, you had one of those strapped under the Command Module, brought it up here, and they put it in, and then extended with some poles, extended out, and then it popped out, and then you pulled it back in tight and tied it off, and then that was it for that airlock. We lost it because that's the Sun side. Just as soon as it went out there, the temperature in here started dropping. It was incomplete in the sense that the guys had it cocked off about 15 degrees, so there was still some hotspots, but it worked. Everything that we wanted to do, it worked. It could have all been fixed, but somebody said, "Leave it alone." It's one of those things, like, if ain't broke, don't fix it because it's working.

The second crew brought up a parasol that covered the whole thing; it's a Sun shade that had wires and ropes. They went out on an EVA [extravehicular activity] and fixed it. That made this workshop livable. You imagine, the Command Module's way up there, we're going to go outside and go around, it was not bad by the time you got in past this hatch. This is the place where they weren't even sending air down here because it just was so hot, it would overload the air conditioning system as it's running. They would stand up there, they were shirtless, just a

pair of drawers, gym socks, and shoes, and work gloves. They got some burns because if you touched anything, it was really hot.

They would come down with the idea of putting that thing together, and they'd stay down here about 60 to 90 seconds, and then they'd have to scoot back up. It was too damn hot, and the other guy would come down. Seems like we had only two of those work gloves, so we had to swap gloves around, and Pete [Charles C. Conrad] was smaller, the other two guys were about the same size. They got it in there, put it up, and immediately, it was good. By the next day, the temperature was down, like, over to 100, and the next day, it stayed at about 80. Until we got the other second cover up, it was not great, but beat the hell out of everything else you had. I'll stop a minute, you guys have questions in here?

WRIGHT: No, no, it's great. Thanks, though.

HUGHES: I always feel that you guys are at the place where you should understand some of this material, just how we went through, so you can imagine the scheduling nightmare we had because all of the experiments and procedures we were going to do these first few days when they got up there, that's out the window, and you just start over, and we did. ASP [Activities Scheduling Program], even though it was a terrible thing, it beat the heck out of drawing on paper and doing everything manually.

Do you remember on ISS [International Space Station], we have gyros? Here, they had three on here, so this is one of them. We controlled the attitude not by firing engines, but by using the momentum wheels. Remember, this is the airlock, and this is the systems module, if

you will, so let's go the other end and then we'll try to look back the other way, just to get a little distance.

Remember Gemini? Remember this Skylab was built by McDonnell Douglas, that's a Gemini hatch, so they just took one and plugged it into that. This is where you came out to do EVA, so if you go back and look at the Gemini with the two hatches that open up, they just took one that they had, still, saved the money, and that's what it is. The two guys would get in there, close that hatch and this hatch, and then the Command Module's docked down here, so one guy's back here and he could watch them outside, there. They'd close up and then they'd come out, and they were not on PLSS [Portable Life Support System], like they used on the Moon. Instead, they had an umbilical cord. This is when they went out the first time, Pete did this, and they went out with cutters because remember, one of the solar rays was still jammed down against the side of the workshop, so they went out and cut it, and they went up and the array flung him to the full length of that umbilical. Paul was out there and just pulled him back down. Joe [Joseph P.] Kerwin was inside.

All the tanks, again, this is breathing oxygen, all the stuff like that around this one, right in here. That white thing, there's three of those momentum gyros at different angles, and those are the gyros, CMGs, Controlled Momentum Gyros. If we're thinking about a rescue, this is the main dock. You would come up and dock the Command Module into this thing [??]. This was a rescue one; we fixed it up so there was another place to dock. What it gives you is a chance, now, I want you to stick your head in here. This is toward the workshop, if you look down there, and this is, I think underneath, this is the solar control, this is all the six telescopes and all these different controls.

This is the sunward side, you remember that thing is pointed out that way, and there were six telescopes in there. This was the best thing we'd ever done as far as telescopes looking at the Sun; we just blew everybody's science away. It was amazing; all these things we thought, you know, when you go up and do a couple of experiments and you start over because everything you thought before is just wrong. I talked about this before, but these are latches for the drogue. I'm going to talk about that in a minute, how you dock, because it was back to Apollo through here. Let me get myself oriented.

This is the ATM, this is Apollo telescope right here. This is the EREP, the Earth Resources [Experiment] Package, here. What they would do is they'd lay on this surface, and this, actually, they tracked targets, it was like a telescope. When you flew over, the thing stayed in an orbital rate, we called it. It would rotate around the Earth, so the Earth was down there. This was when you're doing this experiment, so you got people on the ground, people in the airplanes, and now we're going over the same target, and they would track it with the little bar and take pictures with all these six different cameras simultaneously, in different frequencies.

This became the prototype for [Earth observations], and doing multiple spectrum pictures going on. That was a scheduling nightmare, but you could see that you had to get a place, and that was postulated ahead of time before the launch. Then, you had to put this other guy in the field in Mongolia or wherever they were, somewhere. They were all over the world, I mean, anywhere except China and Russia, at the time. Everybody wanted to, "Come take pictures of my terrain, or rivers, or lakes, I want to see the disease I've got, the quality of the thing, or the advance of deserts," or all of the things that you care about.

This is the second docking slot; now, let's go talk for a minute about docking. This is a different view. This is the hatch that we looked from the other one. Here's the same three things

we'd get in, and then you'd stand down on the lower equipment bay. There's a hatch right here that kept you safe. You would undo that hatch and you pulled it down out of the way, you physically removed it form there and set it down underneath these things. Let's talk about docking. This was the way Skylab was, but it's the LM, too. The top of this thing, this was a probe and drogue, is what they were called, and then below that, there was another hatch on this side.

The guys who invented this, I always thought they were marvelous. You had to fly this thing so it would come down—you can see the size, you can see the little latches on there? There's three of them around there. You flew it such that the probe fell down in and when it went through the hole, these little latches latched it. That's called "soft dock." It's about 2.5 inches across, and so is that hole, about 3 inches of the hole. You'd snap in, and then you would throw a switch, and this thing would suck down in. There's a little pressurized cartridge in here, and it would pull you back down so that you pulled yourself together, here. See the O-Rings right here? This flat spot here is going to match on with here, and so you've got an airtight seal. That's pulled back, so that's called "hard dock."

When you got a good thing, you tested, made sure there's no leaks, then the guys would open up this hatch in here. They would come up in here behind it, and see, there's a handle here and there's another handle over there. There's a couple things. The first thing you do is you undo these little latches, you just pull them back in, so now, this handle would cause those three things to fold up, so they're out of the way. You could now pull this whole thing back inside. It'd fold itself out, you could see, this, when it folds out, when you pull back, these things got broader, they filled up the whole space. Now, by taking the pressure off this thing, he was able to remove this whole thing, just pull it back.

So he's looking through the hole at the drogue, so they come up inside. You could get the drogue and you'd rotate it. It was just like the top of a jar lid, that was in there. You'd twist it this way and you pulled it out, then you'd pull it back in. Now you're looking at the hatch, mounted up at the LM, or in this case, Skylab. But now, see, these latches right here, there's 12 of them all the way around here. They would lift them up and snap them down, and they'd bite into the inside of there. Now, you're structurally good, so that puts it all together.

This one, we just went all the way inside, but on the LM, then you would connect up a wire, so now you would have power going from the Command Module into the Lunar Module, so now you could talk to it, back and forth. The only thing we wanted to do now is later, when you were ready, you'd fire a switch and you'd blow the LM loose from the slot SLA, the Spacecraft [Lunar Module] Adaptor that's holding into it, then you'd pull it out. We'll go over in the Saturn V, if you want, and we can talk through that step. You can see what we're doing here, anyway.

Then, when you're ready to land, two guys would get in the LM, they'd go up, they put the drogue together. There's two guys now in the tunnel because you have somebody on each side, and so one guy's snapping the drogue in, the other one's putting this docking probe together in an un-pressurized way, and then push it in there so it latches into the hole, establish all these connectors. Each side closed the hatch and then when you're ready, 3-2-1-0 and they throw the switch, and they extend this thing. They just throw it away, which just gave a gentle push and the two vehicles came apart. Then, they were just free-flying until it came back after the mission, and then you went through all this stuff to get the transfer back through the hole. This is where you have a really rigid mechanical thing, and yet, you're disassembling, you get it out of the way, and you could go back and forth through the tunnel that was opened up.

WRIGHT: It's amazing when you take it apart one piece at a time to look at the engineering.

HUGHES: It's just amazing, and good, good teams worked on each of these things. This is amazing, and sometime, we have to find you a picture of them putting a Rover on the lunar surface. There's picture I know they took at Grumman, and I even have a video of a long time, it's a VHS, so I'll still try and find it. You might, you guys, be able to find something like that. It's the damndest thing—I remember Charlie [Charles M.] Duke and John [Young] were on [Apollo] 16, and they were up in Bethpage [New York] at Grumman doing these procedures. I was looking at this picture and I thought, "I'll be damned," I even know some of the guys that worked on it, but I was, again, more impressed—and I was impressed a lot by these guys—how good they were at what they did. It was just amazing.

Look over here. You can see the probe in there, in the hole. Above it is the same thing we used in the RMS [Remote Manipulator System], when you put the RMS and grab things, this target is, there was a COAS, a Crew Optical Alignment Sight, and you would look back down here. If you lined that out, then the probe and the drogue were lined up, just calibrated to do that. COAS is a Crew Optical Alignment Sight. It's a manual device like a gun sight.

Here's the solar telescope. Remember, it was launched in line, and then once it was there, it was clocked over by 90 degrees, and then it just stayed there. It was never to be moved again; that was its position to be. It had four solar arrays, so that's what kept the vehicle alive when it launched. Those spread out and did everything, so that's why there was power with this upper end, here, but no power down below because one solar array is gone and the other one was

jammed shut. Did you talk to any of the guys who did EVA on the way back? Al [Alfred M.] Worden, people like that?

WRIGHT: Yes, but it's been a while since that.

HUGHES: They would actually go out on the way home, after you're out of lunar orbit, so you did EVAs far from any planet. They'd open the hatch, they'd de-press the [spacecraft], open the hatch, and they would crawl down to about in here, and get film out, big things where they took all kind of pressures when they were in orbit around the Moon, and they would haul it back in, put it inside because you were going to lose all this on the way home. Remember the 16 jets, they're around the [module] and you could see how they work as couples. It's called a couple, where if you fire, like, I'm looking at you but I want to look at you, then one jet forward to you and one back here would fire and move over here, and then I'd do the opposite ones to stop. If I want to pitch up, you'd have one this way and one back this way. Or, if I just want to move towards you, then the four behind me would fire and I'd go this way. It was just the logic of making all that happen, where you just did the stick at a time.

WRIGHT: Lots of parts had to come together and work well in space.

HUGHES: Yes, yes. Let's go out and look at these telescopes because the EVA, every two to two-and-a-half weeks, we had to go outside. This is just an antenna. This is just for radio communications. Here's the gyros, now, and they're at 90 degrees but different angles, so you'd still be stable. Some of the telescopes, you had to come out and get the film out, they're all film.

You had to get the film out of here and take it back in. Back there where the guy is, one guy would stay back there and the other one would go out, and they had an extendable pole that would go out that's called an AstroMast, and it's an amazing thing. It's like a coil of wire, but as you turn it on, it'll extend. It's like a spiral of aluminum foil. If you can imagine, if you just made a spiral of it and then you take the inside of it and you stretch it out so you can make a long tube, it's a little bit thicker than aluminum foil, but that's what it did. The motor would turn on and you'd extend the sucker out, so there were some of them—come over way back here.

These were where the six telescopes, and you'd open, so the Sun is that way. They'd come out and they'd reach down and get film packs up here, or on the side, depending on which instrument it was. All six were there all the time; we didn't change any of this stuff out like Hubble [Space Telescope], we went up and changed whole cameras and everything, but not on this. All the electronics were here, so you could get them either down here or up at this business end. That's why this one, that's why there's a handrail there, that's the one that you had to come all the way out here. The guy would come up on his umbilical to his fresh canister, and then he'd send out, these were big canisters, and so they're hard to attach them on this thing. Then, the guy back there would bring the used canister back down, and they took turns, who got to go way up here versus down there, because there was a hell of a view.

WRIGHT: How long did they stay outside?

HUGHES: Two, three hours. It wasn't bad. They were not huge, challenging EVAs that way. It went through at least two orbits, so you had day and night, but they had lights, there were lights mounted along them, so they could turn them on and do their thing, even in the dark.

Sometimes, they noticed it was colder, the suits were earlier, so it was a little bit colder. They were Apollo suits, basically. In Apollo, you were always in daylight on the Moon, so you didn't notice that as much. They were good to handle warm; they weren't so much at heating you up; you had to do the heating, they were good at pumping your heat away.

WRIGHT: Pretty amazing.

HUGHES: Yes. Anything else we can do in here?

WRIGHT: No, I don't think so. It's up to you because you know it better than I do.

HUGHES: Any questions on here. Sometimes I don't want to bore you with too much stuff.

WRIGHT: No, it's not, ever.

HUGHES: Let's move back this way, all the way. Just talk about this—when we launched it, this was the outer skin. When it went on, the micrometeorite shield was made so it was overlapped like this. It was spring-loaded, so once it got to orbit, they would just release some pins and it would clock out. It rotated out, and I'm trying to do this [demonstrating], but I can't make my fingers do the right thing. It got bigger, when it did its thing, and that's a problem.

At max Q [maximum dynamic pressure], you know what max Q is? You've heard it, but basically, as you go faster and faster and faster, you build up pressure on the vehicle, the atmospheric force on the vehicle gets higher and higher and higher, but the pressure itself, you're

getting less and less atmosphere. There's a point where you go, the fastest point you go, going through the thickest part of the atmosphere. There's a curve, and max dynamic pressure means generally about 110,000 feet and about 3,000 feet a second, or something like that.

In this case, somebody screwed up in the design and it was kind of open, looking forward, so that pressure got underneath this thing and ripped the second skin away entirely. The skin inside was typical Saturn stuff, one of those big, heavy, iron, but it had a gold coating over it, the idea being it was for temperature change. This piece went away, and what happened is that these things were supposed to pop out like this once they got to orbit.

When it started ripping down from here, this is where it went, it just tore everything off. One of these solar arrays was just gone, just three or four wires hanging out, and there's photos of that. The other one, let's say it's this one, it was down, but as the skin ripped down through there, it just jammed this one down. That's when the guys came out of the airlock here, remember that's a Gemini airlock, they went over here and Pete crawled down here, and then cut some of the pieces of metal that are holding the array. They had a big bolt-cutter. That's when this thing suddenly went up, so it was good, that is, now we got much more electro-power to run it. We had beaucoup power, with the two of them, we flew without all that.

This is the one where it was just like a gymnast, you know, he was like flung. There's no way you could type what he said during the time because it was one of those, "Holy shit!" moments. He was good, it was all anchored pretty good, and Paul had the other end of it. He took all the force on his shoulders.

Talking about this, the day-to-day things, then it started picking up because this was done, the temperature was under control. The guys took a couple of days to just rest, I mean, it was so enervating to get through to work this heat, but they started to do things and they got

going and they got the rhythm going, and they were really good. They started doing the experiments.

They all lost weight, when we started out, they lost weight because of the sweating they did, but that came back up. It was really impressive to see how they settled down after about eight days after launch, and they were running just like we'd been there forever, like everything was normal. They got it all together. There were some things periodically, we'd have to stop because it is hotter in here than we thought it would be, we had to change some things. When they did the ergometers, it was a little bit sweatier because they lost heat that way. Overall, the guys were just running really good.

When we left, when it was going home, so now they'd undock. This workshop was under control of the MCC [Mission Control Center]. The nice thing about it for me is we'd go back to the office because I had no crew to train, so we'd go back and be working on the plan for the second flight. We had a guy sitting there still who worked a flight plan for the flight controllers because they had to still run it, keeping it alive, so that the guys coming back—you'd have ready for what was the second crew. SL-3 [Skylab 3], but it's the second crew, and all that stuff, SL-1 being the launch of the vehicle itself. What saved them is the big iron, that this stuff was up here, out of the way. It was not bothered by the accident during launch. When it got up there, the ATM flipped over, and all these things worked, so that Skylab would have been a dead duck if this ATM solar array had not been there. They got this electric power out of this thing running the radios and everything.

If you think about it, that was May 1, and we launched on May 15 with a totally new mission. The idea was, yes, we'll do all that other science we planned to, if we can, but different. They flew them up with three different options of different ways to do—[the parasol],

the first one we used, was great, but we had two other planned ideas of how we would approach the flight.

[Under the LM display] I took you through the dismount here, but now, think about it—see these guys inside the LM, and the hatch is open, so this would be like when Neil's down and Buzz is about to come out. You can see, you'd turn around and you'd come outside on the porch, and then you'd come all the way down the ladder.

This is the one we joked about, Neil landed pretty softly, Pete Conrad landed even softer than that. Each LM leg had crushable aluminum structures like a shock absorber, but it's a one time, it would come down and stop, it didn't rebound. That's why if you landed semi-hard, it would crush down some of the thing, so the distance between the pad and the bottom of the ladder was smaller, and made it nice to step out. Almost nobody crushed that so far. They landed really well, but that's why when Neil put it in, it was down a couple of inches, maybe, but that's when Pete says he came down and he had the whole jump, it's about 2.5 feet, he had jumped down there. "That might be a small step for Neil, but it's a big one for Petie!"

Around the side, there's different bays, and so, one like this would have the [Lunar] Rover in it. You pulled it out and you came down, and then the sucker would fold down out of there. If you think about each of these angles, there was a triangular thing going in, inside there, and if you look at a drawing, you can see, in the center part is the engine, going up the middle of it. It's kind of like a square space, then these things all around in each of the triangular areas. Behind the leg is oxidizer and fuel tanks.

[End of Interview]