NASA Oral History Project
Edited Oral History Transcript 3

David J. Homan
Interviewed by Jennifer Ross-Nazzal
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Ross-Nazzal: Today is July 27, 2023. This interview with David Homan is being conducted for the NASA Oral History Project. The interviewer is Jennifer Ross-Nazzal. Thanks again for driving down, braving the traffic on 45.

Homan: You bet.

Ross-Nazzal: In the writeup that you did, you talked about going to a conference in 1991 on VR [virtual reality]. What was NASA's interest in virtual reality at that point?

Homan: At that point, this guy at [NASA] Headquarters [Washington, DC] had been to Jackson Hole, Wyoming, in the summer, and he wanted to see what it looked like in the winter, so he had this conference on VR there.

Ross-Nazzal: That was the interest, not the interest in VR, the interest in the environment?

Homan: Yes. He kludged up this conference so that he could go back to Jackson Hole in the winter and see it. We were there. It was the week before ski season started. The hotels, I forget how cheap they were. Every morning we'd hear them firing [mortars] up at the mountains to get rid of the loose snow. The conference ended on Friday, and they said, "You can keep your rooms, but the rate is now 300 dollars a night."

ROSS-NAZZAL: That's nuts, especially back then.

HOMAN: Like I said, at the time, I had just moved over to the division, and nobody was interested in going, so I volunteered to go.

ROSS-NAZZAL: What were you talking about in terms of VR? It doesn't sound like it was well established.

HOMAN: Ames [Research Center, Moffett Field, California] had been doing a bunch of stuff in VR, a lot of research: what makes you sick, how can they use it, and looking at wind tunnel data, and trying to come up with things that they could do [with VR].

I saw it as a way of integrating the EVA [extravehicular activity] and RMS [remote manipulator system] training of the crews at JSC [Johnson Space Center, Houston, Texas], which was basically the place where they train the crews. That seemed to be an area that they really couldn't integrate it anywhere else on the ground. They had the swimming pool or the WETF [Weightless Environment Training Facility] at that time.

In fact, I think Jeff [Jeffrey A. Hoffman] talked about that. That was one of the first things that the Hubble [Space Telescope]—they had a payload bay in the pool, and the telescope in the back of the payload bay, except that it was way too big for the pool, so the top half of it stuck out of the water. So, they cut [the top half] off and set it down on the bottom of the pool.

They did have a robotic arm [in the WETF], so that Claude Nicollier, the arm operator, could position the arm at the top of the telescope where they were going to do some work on the magnetometers up there. They could practice doing that in the pool, except the arm configuration that put them next to the top of the telescope in the pool in no way represented how it would actually be.

Jeff and the crew [of STS-61] came over one time, and we put together the configuration in VR. We weren't volume constrained, so we could put together the actual configuration and tie it to the RMS simulation. They realized that the arm couldn't actually reach as far as or get to that position that they'd been working on in the pool. Essentially, they reworked that, figured out how close they could get to that actual position in the real world, and then took that information back to the pool, and made sure that they could do their job from that position and orientation. It was an eye opener, because it wouldn't have been a good deal to find that out on orbit, that they couldn't get to where they needed to go. That was basically [our] first use of the VR.

Like I said, Jeff had been interested in [VR] and worked with us quite a while. At that time, the computers were fairly slow, so if there was too much detail in the graphics, the update rate was really slow. If you moved your head, a few seconds later the scene would catch up with you, which wasn't really advantageous at the time. But he said that he preferred to have more detail in the graphics scene, and they would accommodate the slow update rate by just moving their head real slow. He said that's the way they do it in zero G [gravity] anyway. They move their heads slowly. It was a tradeoff between fidelity of the models and update rate.

ROSS-NAZZAL: When you came up with this idea that you had proposed to the conference, which you said fell flat, were you thinking that this would be a good option for the Hubble repair mission, or were you just thinking in general of all Shuttle missions, given your RMS experience?

HOMAN: Early on in the Shuttle Program, the engineering [team] came up with what they called the manipulator foot restraint [MFR], which is basically a foot restraint that attached to the end of the arm. They did some testing on orbit with it. What became apparent at that time was that it was similar to a utility truck or a cherry picker, where you've got a guy in a bucket up on top moving around to work, except in that case, the person moving the guy in the bucket, in one G, they're usually standing in the same orientation. In zero G, the guy on the end of the arm could be in any orientation with respect to the guy driving the arm. For instance, if the astronaut on the end of the arm was upside down, if he said, "Move me up," up to him wasn't necessarily up to the guy driving the arm. Early on, they found that to be confusing. They'd work things out on the ground, but then when they'd get on orbit in these configurations, they'd have to rethink things.

So it looked like a real good use of VR. Put a VR helmet on the EVA guy on the end of the arm and tie it into the RMS simulation. Have the arm operator and the EVA guy in the actual scenarios or configurations, so that they could then work out, depending on what they were doing, what reference systems or commands would be [used] with respect to the orbiter, move me up or down, or forward or aft. Sometimes they worked with the body coordinates, where the person on the end of the arm would say, "Move me up or down, or right or left," and that's when it got into, what's up and down and right and left?

On the ground, they did it with—let's see. We had the Manipulator Development Facility [MDF], which was a hydraulic representation of the arm. What they'd do is put an inflatable dummy on the end of the arm. They also had an inflatable Hubble sitting in the back of the payload bay. The arm operator would be in the aft flight deck of the [MDF] orbiter operating the arm, and the EVA crewman, the actual one, would be on a catwalk next to the payload bay. He would try to envision what the dummy was seeing and then give the operator commands, which, again, worked fine as long as all three of them were in the same orientation. But as soon as the dummy astronaut was pitched over, or upside down, or some [other] orientation, then the actual astronaut had to try to figure out what he would actually be seeing and then translate that into commands back to the arm operator. It just didn't work well.

With VR, the EVA guy could see exactly what he would see on orbit, and the arm operator would see exactly [what he would see on orbit]. Since we simulated the camera views and out the window views, he would see the EVA crewmember moving around or waving his arms, and the EVA crewmember would see what he would actually see [from the end of the arm]. Even though they could do that in the water tank, they couldn't be upside down in the water tank from a safety standpoint. Even though your suit's neutrally buoyant, you're not. When you're upside down, the blood just rushes to your head. It was a safety concern then. They wouldn't let them be upside down more than a few minutes if they had to be.

In VR, since you're just sitting in a chair and the scene is moving around you, the arm operator can turn you upside down. The only sensation you have that you're upside down is the fact that all the writing is upside down; what you're seeing is upside down. Physiologically, you feel the same thing you would in zero G, there's no difference between being upside down or right side up as the blood flows around your body. In that case, they could work out exactly what they needed to do and how they had to be positioned around things that they couldn't really do in the water tank.

We also looked at [what] if they lost communication; the EVA crewmember could give hand signals or wave his arms, which then you could work out what they meant between the two, which you really couldn't do anywhere else. That was one thing that everybody thought about, but they never really used that. They never got into a situation where they couldn't communicate. That was one of the aspects that we looked at as far as integrating EVA and RMS. Like I said, they used that [to train for] STS-61.

STS-60 was flying after that. That's always confusing, too, because I don't think the numbering system ever lined up [except for] the first flight and the last flight. On STS-60, they were going to fly a payload called a Wake Shield [Facility], which was basically a 15-[foot] diameter plate. How did it work? They'd basically deploy it [with the RMS], and it would sit there and fly into the velocity vector. Everything behind it would be clean, because they had this big circular plate blocking whatever was flowing around, so I guess they had a more perfect vacuum situation behind it. It was passively stabilized, so they'd deploy this thing, and it would sit there and do its thing, and then they'd come back days later, retrieve it, and put it back in the payload bay with the RMS. One of their concerns on that flight was, what if for some reason it starts tumbling? Since they had no active control system, they wouldn't be able to stop its tumbling. So the crew agreed to go out—if they got back to retrieve it and it was tumbling—[they agreed] to go out and basically stand on the end of the arm and stop it from tumbling and then put it back in the payload bay.

They were asked, at what rate would they be willing to go out and do this? What rate of tumbling would they actually be willing to go out and attempt to do that? They just picked a number out of the air. I think it was 10 degrees per second of this thing tumbling. We told them to come over, and we set up a configuration in the VR with the EVA guy standing on the end of the arm and put in the dynamics of this thing tumbling at that rate, so the crewmember could stand there and see what they [agreed to]. It was, sort of, a, holy crap, moment. Why did we pick that number?

ROSS-NAZZAL: I wanted to come back and ask you about STS-61. You had mentioned in your writeup that they were using VR in place of certain items in the WETF, and I wondered if you would explain what they were using virtual reality for versus the WETF for EVA training.

HOMAN: The WETF, you're basically suited crewmembers in their spacesuits, and they have the actual hardware that they could work with. Like I said, they had an arm in there, so as long as they were operating the arm in and around the payload bay or below the waterline, everything was fine, as long as they weren't upside down. But like I said, they didn't have the actual configuration when you had to split the telescope in pieces here and there, so you couldn't actually look at the real on-orbit configuration. VR filled that gap in the training. You didn't go out and physically do anything, but you could actually go see what things would actually look like, or what you would expect to see, and make corrections in your procedures based on the real-world configurations.

ROSS-NAZZAL: Were you working with the Training Division or MOD [Mission Operations Directorate]?

HOMAN: No.

ROSS-NAZZAL: How did you get the information that you needed to put into your models, your computer?

HOMAN: Let's see. Somehow, I started out with a few engineering drawings from Goddard [Space Flight Center, Beltsville, Maryland] of the telescope. It turns out I was probably the only person onsite that had engineering drawings of Hubble. That was when Carol [Homan, my wife], owned the library and the printing plant and that.

ROSS-NAZZAL: I wondered how you got copies.

HOMAN: I worked with one of her people, who worked with Goddard and got copies of all the engineering drawings of Hubble. Essentially, that's what I was building models from. At that time—in fact, the whole time—it was like having a hobby. People go out and build model airplanes. I was able to go build a model of the space telescope in graphics. We worked with the drawings. Then we also got copies of all the close-out photos of the hardware. A lot of the instrument bays, they take pictures, and we could texture map those pictures onto the components, so the Hubble telescope we had was fairly detailed.

In the beginning, when we were working with Jeff, we were looking at some of the tasks that they were doing, which involved removing components from the telescope. We had it modeled down to the little J-hooks on the panels you'd have to open up to do things. We were working with that, and we would have it set up so that you couldn't do something with a component until all the J-hooks had been released. Jeff came over, and we were looking at that. That's when we got into deciding what's important and what's not.

Originally, we had things set up where if you wanted to remove a component, you couldn't do anything until you'd gone through all the other steps. That's when we got into the, well, that you can do over in the WETF, that type of detail. What the component is, and where it is, and where it has to move to is something that we could look at in the VR Lab. So we started working with the WETF folks and [later with] the NBL [Neutral Buoyancy Laboratory] folks. What they couldn't do, [what] we could do, as opposed to trying to replicate or replace something that they were better at.

Later on, John [W.] Young wrote a memo when they were getting ready to build the NBL, and he recommended that they scratch that and do it in VR, which was a headache, until they finally started digging the hole. I think everybody in the Astronaut Office, every time they saw me, lectured me on, "You can't do this. We need the NBL." I didn't argue with them, because I knew it wouldn't happen, but John wrote this memo. Once they started digging the hole, then they were fine with the VR.

ROSS-NAZZAL: I wonder if you would sum up those conversations, so people reading this will understand what VR initially was very good for and what the WETF was better for, in terms of working on something that was so fragile. This was an important mission. NASA had to get it right.

HOMAN: Like I said, the WETF at that time, all the components, they weren't in the actual configuration. Just being able to see what it would actually look like in the real world compared to what they were doing in the water tank was beneficial. We weren't constrained by any volume or anything, so we could build the actual orbiter, the actual RMS, and the actual Hubble, and put them in the right configuration. With the VR helmet on, you were in that environment, the actual environment. You could see exactly what you would see at any point during the EVA.

ROSS-NAZZAL: There were a lot of people working on this mission—it was so important—Randy [H.] Brinkley was the mission manager. There were a lot of people involved. Were you working with those folks? No? Just the crew?

HOMAN: No. Yes, just basically Jeff and the crew. Like I said, there was no requirement for us.

ROSS-NAZZAL: How did Jeff stumble upon what you were doing? It doesn't sound like you were advertising. You didn't have a hook outside of your door that said, "VR Lab. Come in. Check us out."

HOMAN: I don't really know. I don't remember how Jeff found out about us or got involved, or how we found out about him. Somehow, we got tied together.

ROSS-NAZZAL: To me, it's an interesting story, because it's such an important mission for so many reasons. There were discussions about all those EVAs, and then we ended up having the wall of EVAs for the ISS [International Space Station Program]. You can definitely see the importance.

HOMAN: That was before that.

ROSS-NAZZAL: Right, so you could definitely see the importance of that work that you were thinking of.

HOMAN: Well, and then the other thing. When we did the thing with the Wake Shield on STS-60, Charlie [Charles F.] Bolden was commander. After the flight, when they were debriefing the senior staff, he threw in that he thought they really ought to spend more money on virtual reality, which was basically the first time anybody had heard about that. I think Carolyn [L.] Huntoon was the director, and P. J. [Paul J.] Weitz was her deputy. She had him go look around to see what was going on in VR. I don't know what ever became of that.

ROSS-NAZZAL: Yes, I was curious about that. He came and did a visit?

HOMAN: I think so, or we talked to him. I don't really remember. We always tried to keep it under wraps from the standpoint of we were there to support the crew. We didn't want a lot of extraneous inputs from everybody else. The crew seemed to realize that, too, that it was something they really didn't want to advertise or publicize. In fact, in the beginning, it was referred to as a hobby shop for the Astronaut Office.

ROSS-NAZZAL: What did the people who were operating the trainers and simulators think of what you were doing, and what was your relationship like with those folks?

HOMAN: It depended on who they were at the time. We had people that liked us and people that didn't like us, I expect. But we worked real well with the RMS trainers, because we'd been working with the RMS trainers from the beginning. We built the first desktop RMS simulator, and we worked on all that, so we had a good working relationship with the RMS trainers. Then the EVA folks filtered in, flight by flight, as the flights went on. We ended up with a good working relationship with the EVA folks and the RMS folks. In fact, what was interesting was, on some of the initial flights that involved EVA and RMS operations, we'd have the crews over, and the EVA folks and the RMS trainers would come over with them. Early on in the flights, there were actually flights where we introduced the EVA folks to the RMS folks. They never really worked together.

ROSS-NAZZAL: That's interesting. Was there ever a sense from people operating, for instance, the SMS [Shuttle Mission Simulator] that you were in competition?

HOMAN: We got into that, I guess, later on. The SES [Shuttle Engineering Simulator]—it was the engineering simulator—the crew, they were actually doing RMS training in that and prox ops [proximity operations] training, just like they were doing in the SMS. They both had scene generators; some of the scene generators were the same that most of the aircraft simulators used, but they were very limited in the amount of detail that they could put in. I think they were limited to, like, 2,000 polygons, whatever you could build using 2,000 triangles.

ROSS-NAZZAL: Can you explain what that means? That was something that I couldn't understand.

HOMAN: Okay. Yes. They were physically limited to that. You had two different groups building the software and building the models for those two different simulators. Then we were building our own. We weren't limited to the amount of detail. We could essentially do unlimited number of polygons, so we could put in any detail that we wanted. It got to a point where the crews would go to one simulator, and if they were doing RMS operations, or track and capture operations, whatever scene they were looking at there, whatever visual cues that provided them, they'd go to the other simulator. They wouldn't have the same model, so they wouldn't have the same visual cues. Then they'd come to the VR Lab and see all the detail that they needed to see. So there was that disconnect between all the simulator worlds and the VR Lab.

ROSS-NAZZAL: You brought up John Young's letter. You said it would never work, which I thought was interesting, given what we know about VR today. I wondered if you would explain, why wouldn't that work? Why not? Wouldn't it be the less expensive option?

HOMAN: Yes, but in VR, you couldn't model being in a spacesuit. How that would constrain your movements. In other words, you have a spacesuit on, and you can't scratch the back of your head. In VR, with a helmet on, you don't have any suit on. There's nothing constraining where you can move your arms. Then for instance, soft goods, or wires, cables, anything that's movable on the Space Station or anything else—you can't model cloth in VR and have it move the same way. Basically, those aspects of it.

And tools, handling tools—you couldn't model how a tool felt or actually worked in zero G in VR. So you had the hardware aspects of the situation that you'd get in the pool that you couldn't do in VR, no matter what you saw on *Star Trek*. Other things like that. What you could do in VR would be different: lighting aspects, motion of the Earth behind things, and the star fields, and day or night passes. You couldn't do that in the water tanks. And like I said before, being upside down, you could do that in VR, but you couldn't do that in the pool. That was basically the difference.

I guess the second aspect of VR that we worked on came on STS-64—that's an example of that, too. On STS-64, they were going to fly SAFER [Simplified Aid for EVA Rescue] for the first time, doing engineering tests of that on orbit, so they needed a place to train for that. That was something you couldn't do in the pool. What you're dealing with in the pool is also the viscosity of the water. So when you're handling objects, if you push them, they're going to stop. You can actually move your arms and swim through the water. The viscosity of the water is either helping you do something or hindering you from doing something. In VR, there's nothing like that.

So SAFER, there was no way they could build a unit to fly in the water. Initially, what they planned to do was, they bought this big-screen TV—one of those projection-type things. They planned to stand in front of that and fly SAFER, sort of like they did with the Manned Maneuvering Unit. They had it set up over in [our] Graphics Lab. [We] were working with them. We were going to provide the graphics for it, and in doing so we saw them setting this stuff up and figured that's a dumb way to do that.

The first time, I think, Mark [C.] Lee came over to train we said, "Instead of doing that, why don't you stick the VR helmet on and do the graphics in there?" We tied the VR capability into the SAFER simulation. They never used that big-screen TV. They did all their training in VR for SAFER for that flight.

Then after the flight, as soon as they landed, Mark and Carl [J.] Meade came over to the lab and reflew everything they flew on orbit with the SAFER, and basically did a comparison to validate the simulation and verify that it was accurate. Once they did that, it basically became the flight simulator for the SAFER unit. That was another one of those things—there was no requirement for VR to do that. We just stuck it in and then, like I said, it became the flight simulator for that unit, so every EVA crewmember came through and learned how to fly SAFER on that.

ROSS-NAZZAL: I wonder if you would talk about the hardware that the astronauts were using initially, and how it evolved over time. You mentioned there was a headset, and eventually you decided you needed gloves with sensors. Can you give some more details about those things?

HOMAN: Early on, we decided that there was really no reason for us or NASA to try to drive the computer hardware or the graphics hardware to use in our system. At that time, the entertainment industry was coming out with *Toy Story* and then the gaming industry—those were the big drivers driving the requirements for graphics capability. So we decided that there was really no reason for us to try to spend money or get them requirements to do something for us. We'd work on the software that would operate that machine, the hardware, as it progressed. So as graphics hardware changed, we would fit new hardware into our software, as opposed to trying to drive the building or requirements for the graphics machines.

That covered the graphics portion of it, and really, VR is only sticking a TV in front of each eye and producing a scene. We always commented on that, too, that your mother would be really disappointed. Growing up, your mother always said, "Don't sit so close to the TV. You'll ruin your eyes." That was the time when VR was sort of a new thing, and people were trying to get into it. There were some commercially available headsets. We purchased a couple of those. We'd get whatever hardware was available at the time and work it into our system. Then they had data gloves or gloves with sensors in them that would allow you to see your finger movements. There were sensors that you could mount on the back of your hands, and on the helmet, and on your body to track your motions, so that you could then feed the simulation or feed the computers with what you were looking at, where your head was, and where your arms were. We just basically cobbled together whatever hardware was available into our particular use for it.

That was another thing. A lot of times, people [would ask us], "Why don't you make a game out of this," or, "Why don't you market this?" We really didn't have any reason to go develop the user interface or the game version of that. We were developing specific things for specific tasks. There's nobody really interested in doing EVA training or astronaut training, except in Russia, and they were so far behind that they came over to use our stuff.

CAROL HOMAN: I still like the story about the first gloves. I think she should hear that one.

ROSS-NAZZAL: That would be great.

HOMAN: Well, we had a set of gloves, and they were wearing out, so we were trying to get new ones, and it turns out they wanted like 10,000 dollars apiece per hand.

ROSS-NAZZAL: Your first headset was, what, 120,000? So that seems relatively inexpensive, compared to that item.

HOMAN: [Actually the first ones were only a few thousand dollars], but we were cheap. We didn't have a big budget, and I didn't want to go ask a whole lot of people for money, because money always comes with strings attached. [It] was no big deal to go out and buy little strips of metal that, as you bent them, the impedance changed. You could tell electronically if you were bending this metal, which is all those data gloves were, fancy gloves with the stuff sewn into fingers. So we went out and, for a few bucks, got some of those, the sensors, and went out and tried to find some gloves that we could sew them into that would work. It was really hard to find gloves at the time that were—they had to be form fitting, stretchy, like ladies' evening gloves. So we went looking for those, but it was really hard to find ladies' evening gloves that would fit men's hands.

ROSS-NAZZAL: Yes, we don't have the same size hands.

HOMAN: I'd go to the mall, in the big and tall shop, or whatever equivalent for women, and go in.

CAROL HOMAN: And that was an evening shop.

HOMAN: Ask if they had evening gloves that would [fit me].

CAROL HOMAN: We were there together. [They] looked at me and said, "What size do you need?" I said, "Well, we need them for him." So [they were] sort of stunned.

HOMAN: I forgot where we finally found some. I took [them] home and sewed sensors into the fingers and made our own.

ROSS-NAZZAL: I was wondering who did the stitching for you.

CAROL HOMAN: He did that.

HOMAN: Yes.

ROSS-NAZZAL: You made your own.

HOMAN: A lot of the hardware that we built was also just PVC pipes stuck together with the right dimensions.

ROSS-NAZZAL: What sort of hardware were you building?

HOMAN: Like the handholds on the instruments on STS-61, on the solar arrays, or whatever they were [using] to pick those up out of the payload bay and maneuver them into position. We just took PVC pipes, because that was one thing we found out—any metal that you put close to these sensors, they were electromagnetic sensors, so it really screwed everything up. You couldn't have metal near this stuff, so we just got PVC pipes and glued them together with the right dimensions so Jeff [could be] holding on to the handling device that he'd be using on Hubble. We had the PVC pipes with a sensor on it, so you could see where he was moving that [instrument] to. There was a lot of stuff that we built out of PVC just to match dimensions of things they were holding, so their hands would be in the right place, and they'd have something to physically hold on to.

ROSS-NAZZAL: You didn't have an end product. You didn't have much of a budget. But where were you able to get money for even the smallest of items?

HOMAN: Actually, I probably spent more [of my own money]—I figured out one time [that] I was paying for a higher percentage of what we were doing than NASA was.

ROSS-NAZZAL: Did that go over well in your house?

CAROL HOMAN: I never thought about it one way or another, but I know that we're the ones who bought the gloves.

HOMAN: All the PVC that we used, et cetera. I wasn't beholden to anybody.

ROSS-NAZZAL: Who was head of Engineering at that point?

HOMAN: Leonard [S.] Nicholson. In fact, after a while, I went and made a pitch to him, and was looking for funding. He said he'd already provided enough. He wasn't going to provide any more. I said, "I plan to go out and see if I can get some more funding," and his response to me was, "More power to you." [I took that as him giving] me carte blanche to do what I thought needed to be done.

ROSS-NAZZAL: Did you approach the Shuttle Program for funding or maybe the Astronaut Office?

HOMAN: Yes. Clay [E.] McCullough originally gave me some funding. I forget how much or where. But yes, we were scrounging for money. We had the support of the Astronaut Office, and we usually had somebody higher up the food chain than liked what we were doing. In fact, I went to some group. I remember giving a pitch requesting some funding to do something, and the chairman of that meeting or that group at the time said—when we were talking about it, he said, "I'm not sure I agree with this, but if we don't fund it, I'm going to be crucified." So they funded it. We always had people higher up that liked what we were doing.

ROSS-NAZZAL: I'm sure I know the answer, but I have to ask this question, because someone might ask. Was there ever a discussion about closing all the simulators and the task trainers and just funneling everyone through to the VR Lab?

HOMAN: No. Somebody may have mentioned it, but that would never work. We had discussions with, a lot of times, astronauts that were concerned about that happening. I always told them, "We can't do this; we can't do that."

ROSS-NAZZAL: How closely were you working with Mission Ops? Because it seems like you went from working with Jeff Hoffman and moving into a more permanent role working on missions, where astronauts would come do EVA, RMS training. Were you working with the flight activities officer, working with people who were doing EVA?

HOMAN: It was never an official training facility, per se. We worked with the RMS folks, and we worked with the EVA folks, basically supported them in doing what they needed to do. But there was never any requirement to do that. It was just our personal relationship with these groups. They knew what we could do, and usually if they had problems or questions, they would come to us. Then because of that, every mission that had an EVA planned and RMS operations, we would model that mission, and they would come over and train, even though it wasn't officially a training facility.

I know Jeff mentioned this, too, but we wanted to keep it out of that whole world, because if you're familiar with the SMS or any of those simulations, six months before a flight, they would lock everything down. If changes [in the mission] were made in that time, it was hard to get that changed in those simulators, whereas we didn't follow any of those rules, because we weren't an official facility. We could make any changes that we wanted to make. That was an agreed-to position between the Astronaut Office and us, to have the flexibility to come in and look at different things at any time before a mission. We would make whatever changes they wanted or try to show them whatever they wanted, with the caveat that if they were over and asked for a change, if we tried to put it in, it could blow up the simulation, and basically, they'd lose that hour or whatever that they were scheduled for. They were willing to accept the possibility of that happening in exchange for the flexibility that they'd have to make changes, which would never fly in the simulator or training world, per se. We weren't tied to anybody else's schedule, either.

ROSS-NAZZAL: So technically, someone could just, if you were open, swing by and just say, I want to check this out?

HOMAN: Yes. After a while, it got to the point where they'd call us to schedule their time. Finally, we got with the actual crew schedulers and turned it all over to them. They then kept the schedule. Every Friday, we'd get the schedule for the next week, just like every other simulator. In fact, if we had something we needed to do, we'd have to get on their schedule for our facility. So that part of the Astronaut Office for crew training took care of that for us.

ROSS-NAZZAL: I wonder if you would walk me through an exercise that someone might have come over to work on. What had to be prepared? How long might they come over? How did you deal with things like checklists? Did you have debriefs? It doesn't sound like it, but did you have scripts, or did you determine, this person has to meet this objective?

HOMAN: No. That was the other thing, too. There was no script, other than the EVA checklist. But it wasn't tied to anything particular in the simulation. There was no constraint in the simulator that you had to do this before this, and that, and that, or that. It was basically a dry version of the WETF or NBL, where they could come over and work out what they needed to do.

It operated that way, in that it was just there and they could do what they needed to. They could follow through their checklist, all the RMS procedures, and all the EVA procedures. They could go through and basically visualize them in three dimensions. In fact, on missions, when they had a contingency, during the flight, they'd send a group of astronauts out to the NBL and a group of astronauts to the SMS to do this, and they'd send them over to the VR Lab, also, to sit there and work out what needed to be done.

ROSS-NAZZAL: Was there one mission in particular that stands out to you when there was a need to come over and work through an issue?

HOMAN: Yes. I forget what the number was, when they [were] deploying SPARTAN. Was that [STS]-87?

Anyway, when they got ready to deploy it, they released it, but it didn't go through whatever it was supposed to go through as a setup, so they went back to grab it to retrigger that sequence of events. The arm operator actually hit the grapple fixture or closed the snares outside [off the grapple envelope]. Something happened where they tipped it off with the arm and it got to tumbling, and it was tumbling too bad. They couldn't retrieve it. So what they did was backed off and planned to go back a few days later with the EVA crewmembers standing in the payload pay on foot restraints and fly up to grab it by hand and then berth it.

I spent, I think, a whole night there looking, scrounging for things to work with, so we'd actually set that up where the astronauts would come over and look at grabbing that payload by hand and berthing it by hand. What was fortuitous about that—previous to that, the actual crewmembers had been in the lab, and they'd actually played with that same sort of scenario: the two of them handling the satellite by hand and berthing it by hand. That gets into the Charlotte aspect of it. That's where that—

ROSS-NAZZAL: Yes, would you talk about Charlotte and why you decided to build her?

HOMAN: After STS-64, of course, came STS-63. On that flight, McDonnell Douglas had created this tendon-driven robot, which was basically a box about the size of a VCR [videocassette recorder]. At each of the eight corners of the box, they had small electric motors and reels of cable. [It was manifested] in the [SPACEHAB], which was flying on that flight, as a proof of concept. They could actually take this box, reel out the cables, and attach it to eight hard points around the module, and then by controlling the motors—and reeling in cable, and reeling out cable—they could actually drive this box to any position and orientation around the [SPACEHAB]. When the crew went to sleep, you would have this thing with cameras and other devices on it that they could move around the lab and stare at anything they wanted to all night long, so they didn't have to stop the experiments when the crew went to bed. They potentially had this thing to go around and flip switches and look at things. They could control its position and orientation anywhere within the lab.

When they were demonstrating [it once in our conference room], Charlie [Charles J.] Gott and I got thinking about that. I said, "If you can control that box," its position and orientation via computer, "if you get rid of all the cameras and all that other stuff, and replace it with a load cell, a force torque [sensor]—like a bathroom scale—mount that on the box, and then mount a handhold on that, so that as you pushed on the handhold, the force torque sensor would measure the force that you're inputting, and then you could have a dynamic simulation of some object in zero G."

If you knew the geometry of where that handrail was with respect to the center of mass of the object or payload that you were holding, when the force torque sensor measured the force, then the simulation could calculate the motion of the object based on that force, and then drive the box to that position. When you close that loop, you essentially have a zero G mass simulator, where you could put in the mass properties of the object, which would also control how fast the box moved based on the forces that you were inputting, and the geometry would be in there, so you'd know where you were pushing on the actual object. We created this zero G mass simulator. I looked at doing that, and actually went out and got some money—it may have been center discretionary funds—to go build a version of that that would work down on the ground. It had to be a bigger box and bigger motors. McDonnell Douglas put that together for us.

On STS-63, they were also doing mass handling evaluations EVA-wise, where Mike [C. Michael] Foale and Bernard [A.] Harris were on an EVA. During that EVA, they'd go back to where the SPARTAN payload was. I think it weighed 3,000 pounds. After they'd retrieved [and rebirthed] it, they'd do this EVA. They had different handling devices that they'd mount on it, pick it up, see what it felt like, and how the handling devices worked on this payload.

We had [our] Charlotte built. When they came back, as soon as they landed, they came over to the lab, and we set up that configuration with our robot, our mass handling device, with the devices that they were using. They evaluated that, compared our simulation to what the real world was. That's how that thing got verified. So we validated it for 3,000 pounds. Then on a later flight, it was a Hubble flight. They were handling objects on the order of 700 pounds, so we did the same thing there. We mocked up those configurations, and the crew came back after the flight landed, came over to the VR Lab, and compared our model of what they were doing with the real world and validated it for that.

We knew this thing worked for 700 pounds, and we knew this thing worked for 3,000 pounds, so after that, then, it was just mathematics. You put in different configurations. So then they could come over preflight and handle the objects that they were expecting to handle on orbit and get the real feel for it. That's what they did on STS-87. They used those robots.

After STS-63, sometime in there, we also went to the center director and asked him for some money to build a second robot, so that we could have two of those mass handling robots that we could integrate together, so that two EVA crewmembers could handle the same large object from two different vantage points. When they were tied together like a seesaw, one guy pushed on his, the other guy would feel it in his. Then with the VR helmet on, instead of seeing the box and the wires, they saw the actual object that they were holding. We were the only simulator that could simulator contact conditions.

ROSS-NAZZAL: What do you mean by contact models? I wasn't really sure what you meant.

HOMAN: For instance, in any other simulator, if you pushed on [a payload] with the arm, the arm would just go through it, visually. It didn't know anything was there. But we could model the contact between the end of the arm and the grapple fixture, so that you could hit it. We could also model anything. For instance, you're going to take an object and berth it to the Station.

When you hit the guides, you could actually feel that in the robot. In other words, it wouldn't allow you to push anything through something. We could model those contact conditions. It would be like in the NBL. If you had an object that you were going to berth to the Station, you could actually feel the metal-to-metal contact. We could make it feel that way with this robot.

ROSS-NAZZAL: How do you come up with these ideas? Are these things that you see that are problems or are these things that the Astronaut Office or someone who's working on a test says, I can't believe this goes through the object instead of stopping. It would be great if we had some way to not do this.

HOMAN: I guess when we first saw the need for that was on [STS]-41C, when they were going to deploy LDEF, which was a Long Duration Exposure Facility. It was just a big passive cylinder that they were going to deploy with the arm and go back in what ended up to be years later and get it. Again, it didn't have any active control system on it. During one of the simulations, they were running out of time, and the simulator had problems, or they put in problems and they were running out of time. Crip [Robert L. Crippen] just said, "We'll open the latches in the payload bay, and I'll just back away from it," which he could do over in the simulator. In fact, he could have flown up and had the thing go through the bottom of the orbiter. There's nothing to stop it in this simulation. That's when it dawned on us that, you know, they're fooling themselves if they think they can fly away from this thing without hitting it with anything else.

The first contact conditions we put into our RMS simulation were the trunnions on the payload and the V-guides in the payload bay that they'd have to berth a payload into. We had a dynamic simulation of the arm that included these contact conditions, so that you could actually slide the payload down the V-guides, like you could in the real world, and the arm [reacted] accordingly.

In fact, that may have been STS-63, too, when [Vladimir] Titov, the Russian cosmonaut that was flying on that flight, was doing arm operations and berthing the SPARTAN payload into its attaching mechanism. There was a small square peg that had to go into a square hole to get this thing lined up. The tolerances were really tight, and it was hard to do that. He actually said he worked out in the VR Lab the way that he got it to come down into position. Basically, it was, get it in position and then shake the [hand controller] to get [the payload to vibrate a little]. He had worked that out in the VR Lab with the contact models that we had there that seemed to work on orbit. Nobody ever requested that capability. It's just something we added in. Figured they needed it and built it.

ROSS-NAZZAL: It's interesting how people approach problems, so I was just curious how you approached some of those things.

HOMAN: The graphics part of it was Brad Bell, who'd been working with me since '85; I think. He knew everything there was to know about graphics at the time. I figured if I could provide him with whatever the state-of-the-art hardware was at the time, he would play around with it and make it do whatever [we] needed it to do.

ROSS-NAZZAL: How did you get access to flight plans, checklists? I was thinking about these common visuals that you all came up with, lighting conditions. There's so much, and you were a very small lab. You didn't have a lot of folks working there.

HOMAN: Like I said, I built the models and Brad built the software to display them and manipulate them. I don't know. It was like model building. I had a good time building these models and trying to find pictures or drawings of the actual hardware and build from those to try to make it as accurate as I could, which none of the other facilities could do, because they didn't have the graphics capability.

ROSS-NAZZAL: I was thinking, for instance, when you're on EVA, you're going around the Earth, and the lighting situations—you mentioned the lighting models, which I thought was very interesting that you could model that depending on where they would be and where the Sun would be, shadows and things.

HOMAN: That was a Brad thing. He didn't have a college education, but he knew everything. He's one of these kids that had a computer, a Tandy or whatever they were at the time, and made it do what it could do, but then you can take it apart and make it do more. He did all the software work, and then as he would read different papers [he would] come up with algorithms for lighting. He'd sit there and play with it and incorporate it into our stuff. He'd tell me what models needed to be built or how to do them, and he'd add in all the different lighting effects [like] the Sun glinting off the foil on the payloads and making the cameras bloom. He could program in all the camera characteristics so that they would, at that time, bloom. You'd lose focus and that. And shadows. He came up with all this stuff and incorporated it into the software.

When you looked at STS-87, the reason that they tipped off the payload was, essentially, the Sun was right behind the end effector camera looking at the payload, so the gold foil on there was making the camera bloom in and out, and you couldn't see, and then you also had the shadows from the Sun being behind you that affected all that. What we did was produce that same lighting effect capability for that payload. The next time they flew it, they came over to the lab to train to do that, because that was the only place that could produce those lighting effects. Then the same thing with the Earth and the Sun.

Brad just created an Earth model, and we'd go to the [U.S.] Geological Survey, USGS. Get their texture maps of the Earth from the Landsat satellites. He'd take that data, and we could produce the ground tracks that they flew, so they could start anywhere in orbit and over anything and at the right inclination. They could see what land they'd be flying over and that. Same thing with the star fields. [Brad added] the 10,000 brightest stars. The way we could justify doing that kind of stuff, which was just fancy stuff, [was that it would be seen during an EVA].

Like the SAFER trainer—early on, there were no lights on the Station. If an EVA crewmember fell off the Station, the odds of them coming untethered during the day were the same as the odds of them becoming untethered at night. Initially, the way they trained to fly back to the Station was—after they stopped tumbling—first they'd try to find the silhouette of the Earth, so they had a horizon, and then try to find the silhouette of the Station against the star field, because there were no lights. That's how we justified putting those in. Then the motion of the Earth was the same thing. If you're trying to track and capture something, or trying to fly SAFER back, and the Earth is in the background—you've got the motion of the Earth that you've got to contend with in the background. So we added that capability. It was basically Brad doing stuff that he liked to do, and me building models that I liked to do, and then we let the crews use them.

Let's see. We've been over the RMS, EVA integration, SAFER, and the Charlotte, the mass handling stuff. At some point—I forget when it was—they reorganized and created the EVA Projects Office, XA. Don [Donald R.] McMonagle was the first head of that. At that time, I went over and talked with him. We decided that I would give him my funding source, and he would control the lab, and then I'd basically report to them, work through the EVA Projects Office. My funding source at the time came from Headquarters, from Bill [William F.] Reedy, who was the associate administrator for Human Spaceflight. He was funding me. This gets convoluted. The reason he agreed to fund that was because he was interested in the visuals.

Before that, I guess, it came to a point where they decided that they needed to update the visuals in all the simulators, because the astronauts had been complaining that they'd go from one simulator to the other and never see the same thing. We took one of our older graphics machines, and moved it over to the SES, and hooked it up to the graphics in the dome, and produced a side by side [comparison]; this is the scene generator that you have now, and this is what you could have. A bunch from the Astronaut Office came over to evaluate it. We could show them side by side. This is what you'[ve] got, and this is what you could have. They were all interested in changing the graphics processors for the simulators.

Sometime in there, Bill Readdy came over and looked at it. He was interested. He would fund us if we would look at producing common visuals in all the simulators. So we went and made a pitch to Tommy [W.] Holloway, who was the orbiter program manager at the time, to upgrade the SMS scene generation capability to what we were using, the Silicon Graphics Inc

(SGI) machines in the VR Lab, and basically convinced him to upgrade. If he would upgrade to the hardware that we were using, we would provide the software and the model database to produce what we were producing in the VR Lab for the SMS. He agreed to that. I think [he] gave [them] 5,000,000 dollars to reproduce the hardware that they needed. That's when we got into this.

He had one of his people form a committee to go look at how you would upgrade all the scene generators, which excited the contractors, because they were getting new hardware, and they could go now play with all this new hardware. They looked at it as a way they could sell [NASA] something new. They'd have to produce new software and produce new models. This committee was put together to look at the best way to do that. We went to the meetings, and we read some of the emails, I think. It was preordained, what was going to happen. We told them what was going to happen, that we'd give them the software, and we'd provide the model database, and they'd be the same [in all the simulators]. That, basically, we forced them into [common visuals].

At the end of that meeting with Tommy Holloway, I went and sat down and talked to him and gave him a heads up that probably SSTF [Space Station Training Facility], the Space Station simulator, would be asking him for the same thing. That's when he said to me, "Hey, look. If I wait six months, there's going to be bigger and better stuff out there. Why would I want to do it now?" I said, "Well, at that six-month point, you could also say, if I wait six months, it's going to be bigger and better. You've got to draw a line in the sand and bite the bullet. You either upgrade them now, or you never upgrade them." So he did that. That's when I told him to expect the same thing from the SSTF, and we made the same deal with them. We'd provide the software, and we'd provide the model database. So on all the ground-based simulators, we forced the common visual. That was part of Bill Readdy's reason for funding the VR Lab. We had agreed that we'd try to produce common visuals for everything. That's how the common visuals got forced into the system, and that's where my funding came from.

So when XA was first organized, I went and talked to Don McMonagle about that, and he took over my funding source and gave it [back] to me. It became a passthrough from Bill Readdy through XA to me. It turned out that I never had to justify the funding. XA never had to justify the funding. It all came through [that chain]. What it did was kept it away from anybody in Engineering.

If you're familiar with the way that all works, somebody runs out of money and needs money, they go scrounge it from somebody else. They didn't have it, because it was XA's, so I got out of that whole mess, and basically had constant funding for the last 15 years—I don't know what they're doing now—of my tenure. The funding source was always there. XA didn't have to justify it. Nobody else could get into it. In fact, I upset my division chief one year when I had 12,000 dollars left over at the end of the year. He came to me and said he'd really like to use that for something else. I said, "You're going to have to talk to XA, because I already told them they could have it back." That's when he gave me the lecture on, "You never give money back, because you'll never get it back the next year." Well, it really didn't work that way.

ROSS-NAZZAL: So you still stayed with Engineering, but your funding was coming from a different source.

HOMAN: Yes. So nobody could touch my funding, and I only had one funding source, so I only answered to Bill Readdy and then Bill [William H.] Gerstenmaier.

ROSS-NAZZAL: That was a smart idea.

HOMAN: Yes. Later on, it got into a lot of points of contention, where we were doing different things and weren't following everybody's rules. I got threatened a number of times. [Whenever] we were doing [something] that they didn't like, they'd go and [threaten to] get my funding cut for that. It was, sort of, "Go ahead. I don't have any funding for that." What we're doing is free, because the only funding we had was for VR, and anything else we did was a byproduct of that, so we could quit doing that, but there was no funding for that. My funding would never get cut by any of these other people, so the threats never meant much to me.

ROSS-NAZZAL: These were coming from people in Engineering?

HOMAN: No. Some of them were the program offices. This is where it gets convoluted again, too. It was from software that we were providing that was on board Shuttle and Station that didn't get there through the normal channels. That was because later on, XA, when they were getting ready to build the Station, after the first flight, the first expedition crew was up there. Greg [Gregory J.] Harbaugh, who replaced Don McMonagle, asked if we could put together a SAFER trainer for onboard [use], because they did some evaluations in the VR Lab with SAFER and found out that after a month or so, they lost proficiency with using the hand controller. It was not an intuitive thing. What they didn't want to do was be on the Station for six months and have an EVA at the end where they couldn't fly SAFER anymore so they wanted to know what we could do about that.

They had IBM laptops, ThinkPads at that time, that had some graphics capability. So what Brad did was converted all our graphics software to Windows-based software so it would run on the ThinkPads. In doing that, we had to do some things where we cut down the different levels of detail in the models, so that you could fly SAFER and see what looked like a Station there. So we put together that graphics package on the laptop and had crews come over and evaluate whether or not it was sufficient for what they wanted to do with it. They deemed that it was. But since it was the same software that we were using in the VR Lab, they could also have all the details that we had in the models in the VR Lab.

We put together a package, which was the SAFER trainer that had the VR graphics and went through all the hoops to fly that on the Station. Once that was on the Station, it flew up with Expedition 2. Once that was on the Station, and once we had it on the laptops, you could also put it on the Shuttle side as a situational awareness tool. By tying the RMS telemetry, the joint angles into it, they could produce a synthetic view of what was going on with the actual arm. That replaced a similar package that somebody in Engineering had put together. [Their's] cost money. It did the same thing, but the models they were using—it was a mess. We proposed that since our software was up on the [Station] laptops anyway, they could just use it to replace their situational awareness tool [on the orbiter] with that. On that same flight—I think it was that one—they were going to do an evaluation between the two packages, the one that they were paying for and the one that was already up there for free. From what I understand, they never even took the other package out.

At that time, we provided the situational awareness tool for both the Shuttle arm operations and for the Station. [For the] Station, this [same] group had put in a bid for, I think, 3,000,000 dollars to produce this thing and upkeep it. We said, "You can use the SAFER trainer graphics for free and do the same thing, and it's exactly the same software and database that's running in all the other simulators on the ground, so you not only have common visuals on the ground, but they're common with what's on board." The way that got on board, then, was not the usual route, because it was already up there for some other reason, so it didn't jump through all the other hoops that you had to go through to provide software for this, which upset a lot of people. But like I said, there were people higher up the food chain that liked what we were doing.

ROSS-NAZZAL: I was thinking, when you mentioned you developed all of this software, it seems like there was a cost savings to the program and perhaps the center. Was that something that you ever did to justify your funding? Because that's so important these days, how much money are you saving NASA—

HOMAN: No, no.

ROSS-NAZZAL: —to justify your work?

HOMAN: No. It was just another thing that we could do. We did a lot of other things, too. Once we had it on board, since it was all common, the EVA folks or the RMS folks could sit at their [desks]; they all had laptops that [used the] Windows [operating system], so we could provide that software to them. They could actually take the database and configure it and save that state of the graphics and take that state and then uplink it to the crew on board, and they could see exactly the same thing on their machines on board. It worked vice versa. The crew on board could come up with something, save the state of that computer graphics, and send it down to the ground, and they could take that over to any other simulator on the ground and see exactly what they were talking about. That's where we got into the whole DOUG [Dynamic Onboard Ubiquitous Graphics] conflagration.

ROSS-NAZZAL: I didn't quite understand the acronym issue that the astronaut had. You mentioned that she thought it might be confusing.

HOMAN: Yes. Where that came from was, some magazine did an article about the VR Lab, and the writer kept referring to somebody named Doug doing this or that. There's nobody named Doug in the lab. Of course, when we got this new software converted to laptops, we had to come up with an acronym for it. Actually, we had DOUG, and then we had to come up with what it meant.

ROSS-NAZZAL: You did it the exact opposite, right?

HOMAN: We did it backwards, yes. It was Dynamic Onboard Ubiquitous Graphics. There was one astronaut that really didn't like DOUG, and she hounded me about that all the time. It would confuse the Russians and couldn't we change it? One time, she called me up to ask if I would come over and demonstrate it to the office at one of their morning tag ups. I said, "Sure." While she had me on the phone, she got into the, "Can't you change the name?"

I finally said, "How about if we make it something a little shorter and more concise? How about Graphical Onboard Displays?" She thought that was great, and then a few seconds later, she thought DOUG was all right.

ROSS-NAZZAL: She didn't like the idea of G-O-D, god?

HOMAN: Yes. She'd been told by one of the other astronauts. He told us later he told her that she should me ask me once, and if I said no, to drop it. She refused to drop it, but [eventually] she did.

[Break in audio]

ROSS-NAZZAL: We were talking about DOUG, the other crewmember, I guess. Talk about DOUG and why it was important; why you created DOUG.

HOMAN: It was exactly what they saw in the VR Lab. In fact, it went up on Expedition 2, just because they didn't have any [EVA] capability on Expedition 1. It went up as a SAFER trainer. Then it was also available as a situational awareness tool. That's probably the first use of augmented reality [(AR) on the Station], which you have now. On Expedition 2, the SSRMS [Space Station remote manipulator system] was going to go up on one flight, and the next flight they were going to send up the airlock for the Station. When the arm, SSRMS, got up there on one flight, in order to train—they didn't have an SSRMS trainer on board like the SAFER trainer; they were still developing that. The way they trained would be just fire up the arm and drive it through the motions that they would expect to go [through] based on [their] checklist. There was nothing there to see. It was just the arm going around. And there weren't cameras on the Station at the time, other than what was on the arm itself.

With DOUG, they could tie that in as a situational awareness tool, tie that into the telemetry stream and drive the arm in graphics based on the real arm motion. Since DOUG could create any view, we could simulate any camera view, and we could simulate any configuration up there. On DOUG, you could put the orbiter docked to the Station with the airlock in the payload bay. In fact, you could link two or three of these DOUG laptops together and have the different camera views simulated, [including] the orbiter camera views, even though there's no orbiter actually up there. The arm operator could look on DOUG and set up the camera views in the orbiter payload bay looking at the airlock, which wasn't there, either, and then drive the real arm, and DOUG would track the real arm. So then you could also go down and grapple the airlock with the Station arm, and in the camera view on the real arm, there's nothing there, but in the camera view on DOUG, you could see the grapple fixture and actually drive the arm to that position, as opposed to just driving it around in free space. Then you could attach the airlock to the graphical arm, and then maneuver the airlock to the berthing port on the node. And using the orbiter cameras that were simulated, you could see all that happening. In graphics, everything was there, but in the real world, only the arm was there.

ROSS-NAZZAL: That's pretty cool. Were the Expedition astronauts going to be taking the airlock out of the Shuttle payload bay with the Shuttle RMS?

HOMAN: No, they would take it out with the Station arm.

ROSS-NAZZAL: So they could practice before they arrived. That's fascinating. I didn't know that. What sort of feedback did you get from the crew?

HOMAN: I'm not sure we ever talked to them about that.

ROSS-NAZZAL: It sounds like the Shuttle crews, at least, would come back and give you feedback, or at least benchmark, "This is what we saw in space."

HOMAN: Yes, we'd go to the EVA debriefs and the RMS debriefs, and they'd give us feedback.

ROSS-NAZZAL: Would you make changes based on those debriefs?

HOMAN: We'd add things to it, which upset the program people. One time, they came back and said, "Is there a control board that we can go to, to get you to add the capability of looking at contact between the arm and another structure? Could we look at getting that added to the situational awareness tool?" Which upset SR&QA [Safety, Reliability, and Quality Assurance] and the program office, because they really didn't want the crew flying the arm based on this graphics thing.

That came up at one of the debriefs, and I said, "You don't need to go fill out any forms or go to a CCB [configuration control board] for that, because that's already in there. We just have to set the right flags, because it's exactly the same stuff we use in the VR Lab, and we need to know where objects are. You need to know where your hand is with respect to a handrail, so that you can grab the handrail; so we can know where any other object is with respect to any other object, so we can turn that on and add that capability," which, like I said, upset the SR&QA world. But there were people higher up the food chain that thought that was a great idea.

They had no cameras and no lights up there on the early configurations. When they were moving the arm around and going back to put it away or put it in a configuration that they usually left it in, occasionally the crew would come back and say, "It was dark out. We couldn't see, but we didn't want to wait. So instead of doing that, we just used DOUG to fly it back to its configuration." That really upset a lot of people. After a few times, we finally convinced them, if they were doing that, not to say that when they came back. But they were actually using it to fly the arm around. I talked to some people and said, "If they were going to use it that way, you wouldn't use it to see how close you could come to something. You'd use it to make sure you were as far away from objects as possible. But still, don't come back and say that you used it."

ROSS-NAZZAL: I can see why Safety wasn't too excited about that, but it wasn't your idea. It was the crew's idea.

HOMAN: Another thing. Before Ken [Kenneth D.] Bowersox flew [on Expedition 6], they'd taken up one of the tourists. I think his name was [Mark R.] Shuttleworth. [He] was a tourist, a guy that paid, and he flew up [to Station]. He flew up with a bunch of laptops that were a whole lot more powerful than the ones they had on board that he was using, and when he came back, he just left them up there.

Some people weren't sure how we found out about that, but we put together a DOUG version on a CD and gave it to Ken, and said, "You can take this up there and run it on these machines, and it will be a whole lot better than what you've got. They aren't official machines. So he stuck the CD in his spacesuit someplace, flew it up with him, and they put it on board there and used it on those machines. Some people, really, like I said, were interested in how we knew that those machines were up there, because we did ask them if we could use them for that. They did.

Then when they came back, Ken pulled me aside, and he said, "That CD we took up with us, I know it's not up there anymore, and I didn't bring it back. I think maybe the Chinese might have it." It doesn't make any difference. It wasn't source code or anything. It was just a bunch of ones and zeroes. There wasn't anything they could do with it. He thought that the Russian guy took it back down with him.

ROSS-NAZZAL: At any point did you start modeling the interior of the Station?

HOMAN: No. It really made no sense there, because one, so much stuff changes inside. Somebody leaves a bag over here, a camera over here. There's no way to keep track of what the actual configuration would be. And it was so confined that you would always be sticking your head through the wall. There was nothing to constrain you from doing that. With EVA, you're either on the end of the arm, somebody is driving you around, or you're moving hand over hand. But inside, it's too much of a mess, and there was no way to keep track of the configuration, and that wouldn't be of any value. So we just concentrated on the outside configuration.

ROSS-NAZZAL: I've noticed that now you can actually go out and download DOUG. It's freely available. Other than for Station, what is it useful for? If I wanted to download it? What would I use it for?

HOMAN: It would just show you what the Station was. You could keep up with what's up there now.

ROSS-NAZZAL: Okay, the current configuration now.

HOMAN: It's DOUG. But you can have it.

ROSS-NAZZAL: I wondered about that. I wondered if there are other uses, like tech transfers and things like that.

HOMAN: From that, we put together a version of that called EDGE [Engineering DOUG Graphics for Exploration]—the D in there is DOUG. It's basically a package that anybody could use and put in any models that they wanted. It was DOUG software that they produced for public use. But DOUG itself, I controlled that.

ROSS-NAZZAL: I wondered if you would talk about how the VR Lab changed from your inception of it until you retired. I imagine that things changed fairly significantly. I'm thinking about the gloves. You went and bought these gloves.

HOMAN: Well, yes—sometime in there, we were looking for new head-mounted displays, and we had a lot of vendors come out and try to show us their products. One cool one came out, except that partway through the demonstration—in fact, before he started, he asked if he could borrow a soldering iron.

ROSS-NAZZAL: That's not a good sign.

HOMAN: Yes. There were others like that. Then there's a company called N-Vision. The salesman came out, and he had a helmet. We hooked it up. That's all we did, was plugged it in, and it worked fine. He said, "Why don't you play with it, and I'll come back in a month or so and pick it up," and we did. All we did was plug it in, and it worked. It was fine, so we bought a couple of those. They were higher resolution. The helmets we originally had were 640 by 480 pixels, as far as the resolution, and I think these things were 1,280 by 1,024, and had special optics in them—well, not at that time. Anyway, they had this high resolution, and they worked fine, so we talked to him about producing a helmet for us based on what we were looking at. They went off and did that and produced this helmet with wide field of view, bigger stereo overlap, and high resolution. They cost like 120,000 apiece, but they basically produced them for our specs. I think they made 9 or 10 of them, and we had serial numbers 1 and 2. I think they made some for the Department of Defense. They were high-end things. They weren't something that the normal consumer would go out and buy.

We used those for a long time. Then they came out with liquid crystal displays, which are smaller and higher resolution. Brad took the helmets home, and he modified some stuff. Kept the optics but replaced the big CRTs [cathode ray tubes] in these things with little displays.

That's how things went for a long time. In fact, even after I was gone, he would modify things. I think the first time these little LCD [liquid crystal] displays came out, you could pay a fortune, and they'd sell you a developer's kit, where it had pieces. It had a display and the control box, and those were more expensive than the helmet that they had produced with two displays in it. What we did was just bought the helmet, took it apart, took the display hardware out, and put it into ours for a lot cheaper than what the development unit would cost. Brad did all this in his garage. We updated the helmets like that until, I guess, just recently. The consumer helmets that they've come out with now—I don't even remember who makes them, but the gaming VR helmets that they advertise, I think they're finally going with those.

ROSS-NAZZAL: Off-the-shelf technology?

HOMAN: Yes. The other thing, they kept wanting to put VR on board. Like I said, we had the helmets, and all that stuff never seemed to work, until Brad had this idea—we sat down and thought about it. Of all the hardware that was on board: there was a laptop, they had DOUG software, they had webcams that they used, and they had the SAFER hand controllers that they used for the SAFER trainer.

Since it was in zero G, we figured we could take a laptop and produce the stereo pair, two different views on the screen. One half of the screen would be one eye and one half of the screen would be the other eye. Then Brad produced this hunk of plastic that fit on the screen and held a couple of lenses at the right position above these two views, so when you strapped it on your head, you had a VR helmet. Since it was in zero G, what we did was, we turned the display upside down so that when you put it on your head, the bulk of the laptop, the keyboard, was over your head and the screen was in front of your face. Then you put this hunk of plastic that held the lenses on there and strapped it to your head. Since it was zero G, it didn't weigh anything, so it was no big deal.

It ended up having higher resolution and better field of view than the helmets we had on the ground. All the stuff was up there except for this hunk of plastic, so everything else had been certified to fly, so we didn't have to go through any of that certification stuff. You had to go through whatever it was to make sure that the plastic didn't outgas and all that. So we put this thing together and proposed that. Acronym-wise, we called it SLOTH, Space Laptop On The Head. They ended up flying that, and they used it for probably six years before these other commercially-available helmets were there.

ROSS-NAZZAL: They were using that for DOUG and the SAFER training? Is that what they were using SLOTH for?

HOMAN: Yes. There's pictures of them with this thing strapped to their head.

ROSS-NAZZAL: I think the presentation that you sent me had it. I saw that on there.

CAROL HOMAN: Did they ever complain about it?

HOMAN: Complain about what?

CAROL HOMAN: Did the astronauts ever complain about putting laptops on their head?

HOMAN: No. In fact, Ellen Ochoa was the center director when we proposed this whole thing. Actually, we proposed it to some EVA guy. It was something where they would provide people with 25,000 dollars to go look at certain things, and he wanted to look at that. We said, "We'll do this. You can keep the money. We don't want the money." So we put this together for him, and he presented it. Ellen Ochoa was at this presentation. She turned around to me and said she really liked the acronym. Then I think once I retired, they changed it to VR Trainer or something.

ROSS-NAZZAL: That was rather amusing.

[Break in audio]

ROSS-NAZZAL: We had chatted about how technology had changed, and you talked some about the headsets, but one of the things I was curious about were the gloves. You had talked about buying those evening gloves. I imagine the technology on those had changed. You weren't continuing to wear evening gloves the whole time, were you? Or the crews weren't, I guess?

HOMAN: One of the girls in the lab did the same thing, except with gardening gloves. I don't think they've ever bought any gloves since that first fiasco. And we didn't buy those. Somebody else did. We just used them.

ROSS-NAZZAL: I figured you were just buying something off the shelf.

HOMAN: No. I don't know what they're doing now, but by the time I left, they hadn't. We continued to build our own. We were cheap.

ROSS-NAZZAL: I was out at White Sands many years ago, and one of the guys told me they were known as the *Sanford and Son* shop. That's what they did. It made me laugh.

HOMAN: They kept wanting to remodel our lab, too. It had a raised floor with the two-foot carpet panel things on them. They were all stained. I told them paint don't make it go. In fact, one day, one new astronaut came in. That was the first time she'd been there, and she dropped a bottle of water, and I yelled at her, sort of. I said, "What are we going to do? Now we've got a clean spot in the carpet."

ROSS-NAZZAL: Some parts of the center are like that, yes. One of the things we didn't talk about was the *Columbia* accident [STS-107] and the role that your lab played. I don't think many people probably know that story.

HOMAN: Yes, I figured we'd get to that sooner or later. That's one thing, too. If you hadn't noticed, there's now two things, VR and DOUG. They're two separate [concepts] but the same things. We did VR training, and then we supported on-board operations, and on the ground preflight planning, and PAO [Public Affairs Office], and all that stuff with DOUG. So it divides into two, and then it gets complicated.

ROSS-NAZZAL: You were supporting PAO with DOUG? Can you elaborate on that?

HOMAN: Have you ever seen any of the preflight EVA briefings where they show the animations of the EVA tasks?

ROSS-NAZZAL: I guess I haven't.

HOMAN: Well, that came about. There was a bunch of PAO stuff. Let's see. *Aviation Week* was down. They were doing an article on Space Station, and somebody had provided them with six or seven pictures, graphics pictures, of different events or different views of what was going on. They called over. They didn't think they were high enough quality for what *Aviation Week* wanted, because originally, they wanted one for their cover. So they asked if we could replicate the pictures that they had with our graphics and our models, because they were higher fidelity. So we did that. They gave them to *Aviation Week*. Their article had a bunch of the pictures in it, but luckily, I guess, they didn't use one for the cover, because after it was in the magazine we pointed out that the name on the Shuttle wasn't *Discovery*, it was *DOUGscovery*. We went through that a lot with PAO.

What we did with DOUG was supported—when they were having EVA, they'd have discussions on the ground with the crew, go over the checklist, what they were going to do, and send stuff up. With DOUG we'd take the checklist and go through it step by step, and put each step in the graphics, so that you could go to the first step, and they were all labeled the same as the checklist labels. You'd start, and it would highlight the translation path to get them from the airlock to wherever they were going, and then the eye point would follow the translation path, and get to wherever they were going, and show them what handrail they were going to tie things off on and move on, or what articulating portable foot restraint they were going to pick up, and then it would move on to the next point, and show them what the configuration of the foot restraint was, and where they were going to stick it. Basically, it would go through the entire EVA. Even the arm—when it was also done in conjunction with the Station RMS, we would have the arm in the right configuration and move it. It would go through the whole EVA process.

They started what they called DOUG reviews. We'd put this all together. They'd uplink it, and then the crew would sit there, and they'd go through it. They could step through it, and stop at any time, and move their eye point around, and look at it from different [perspectives]—basically interact with it.

The EVA folks were putting together their presentation for their preflight press conference, and we'd sit down with them. They'd send over somebody from PAO with a recorder, and we'd go through the thing step by step. Then the EVA person would make notes. We'd record that, and then they'd leave, and we'd put it together on a DVD [digital video disc] in the right format that they wanted and send it over. We were doing that. It took a while, because you'd start and stop the recorder, and do this and that.

We were about halfway through [one of those sessions], and the PAO person, her eyes got real wide, and she said, "How long has that been there?" I think it may have been *DOUGscovery*. She turned to the EVA guy and said, "What are you going to do when somebody asks about that?" "Nothing," [he said]. But when they put the video together for the preflight briefing, I don't know how much time they spent, but somebody sat there and put a little white bar over that name. It moved around. So we did that for a while.

After that, we just said, "Heck, we'll just take this whole list of checklist things that we did that you step through one by one on a pulldown menu, and at the beginning of it, we'll just put a command that goes through it continuously." We'd do that and generate the PAO video for them based on the same stuff that we were sending up to the crew. Like I said, the PAO [stuff] always had *DOUGscovery*, or *EnDOUGvour*, or *DOUGlantis*. They really didn't like that. Then after the *Aviation Week* thing, they were a little upset, too. Nobody had caught that. We hadn't said anything to anybody.

ROSS-NAZZAL: Now I'm going to have to look for it. So you were talking about the split between VR and DOUG, and we were going to talk about *Columbia*.

HOMAN: Yes. Once we ported the software over to the Windows laptop and created DOUG, then we'd do the VR training. You used DOUG software in the visuals. So you had VR training, and then we had DOUG, which supported, like I said, the DOUG reviews on board, which were separate too. Preflight, we'd always deliver an updated version of DOUG. The version was the same, but the graphics was different, of whatever the configuration was at the time. We'd load that on the Shuttle computers and uplink it to the Station, so everybody had the same things.

That was another thing that we screwed around with, too. We basically had complete control over it. They finally made us start going to their avionics lab to check out the load before we uplinked it, to certify it. The problem was, they didn't have any hardware to generate the SSRMS telemetry, so we had to write a program that would generate the data that fed DOUG to certify that we [had DOUG approved before flight]—so we controlled all that, too.

In the stuff that we'd uplink—like after every EVA, the EVA folks would give us their notes, which said what was left at the end of that EVA, like the settings on all the APFRs [articulating portable foot restraints], where they put them, and what else had changed. Then we'd put that into the software or DOUG load, and uplink it so that the configuration was always up to date on board. Preflight, we'd take the checklists and put them together, give one to PAO, and then we'd uplink that to the crew, so they could do their review. On most of them, what we uplinked wasn't necessarily what we provided everybody else on the ground, or even what we gave the software people on the ground.

We always added stuff in too. An example of that was, when they were only flying two people on board after the *Columbia* accident, Bill [William S.] McArthur was up there with the one Russian. We also did the same thing for the Russian EVAs. The Russians would send us over their checklist, and we'd basically incorporate that into DOUG. They were always doing PR [public relations] stuff. On one of [their EVAs], they were going to hit a golf ball off the Station. I'm sorry, that comes a little bit later. But with Bill McArthur up there, they were going to go out there and take an old Orlon suit, the Russian spacesuit that they were going to get rid of anyway, and they put a radio transmitter in it, and then they were going to throw it overboard. Then ham radio operators and everybody could track it until it burned up.

We modeled that. First step, they come out of the airlock and take the suit, and then we provide a jettison cone, which defined where they had to throw it so it wouldn't come back and hit them. We set that up, and they stepped through it. The EVA guy is there. [Demonstrates] He jettisons this old suit that they had, and it floats off. The next step in the EVA was to translate someplace and do something. So we do that. When it's finished that step, at the end, we had the suit just come floating back through the view, sometimes one way, sometimes another way, sometimes tumbling. Each one of those—it did that every time.

Bill McArthur called down after the EVA and was saying how much he appreciated DOUG and what we did, and went on, and at the end, he said, "And I really liked the Easter eggs." Nobody had the foggiest idea what he was talking about. So we started doing that on every flight. One flight, they were going to hit a golf ball first thing. So we set that up, and he goes through the steps and hits the golf ball. After he hits it, then we shifted to another view, which was a green with a golf cart and another EVA guy holding the flag there, and the ball comes in and plops down. Just stuff like that. That never showed up in anybody's [DOUG] on the ground. That kind of stuff, I guess, if SR&QA would have known about that, they would have gotten even more upset than they usually did.

After *Columbia*, well, one, they were trying to figure out how to survey the orbiter. During those meetings, I found out that the Structures folks, after each vehicle was on the launchpad ready to launch, they had a database of all the tiles and blankets that were on the vehicle, since between each flight, they'd change out damaged tiles. So they'd come up with a different serial number and a different size. I found out that they had that. Each flight, they created that database that gave the dimensions and the locations of each tile and the name of each tile. So I asked them for that database, took it back, and gave it to Brad. He created a program that would translate that into models of all the tiles and blankets on the orbiter, so we'd have an orbiter in DOUG that had all 25,000 tiles for that particular flight and that particular orbiter. And also the leading edge panels, the RCC [reinforced carbon-carbon] panels on the leading edge. We got high fidelity models of those, and converted them to what we needed, and put those on there.

Then a couple of things. The tile database, we set it up so if you knew a tile number, you could go to a menu and pick out that number, and it would highlight the tile on the orbiter. So if you knew the tile number, you could then find out where it was. And the reverse was true. You could put the cursor over a tile on the orbiter in the graphics, and it would tell you what the name was. You could also go in and highlight individual tiles.

Then as part of the survey on this boom that they created to do the leading edge [review], there were CCTV [closed-circuit television] cameras, lasers, and a bunch of instruments that looked at RCC and provided data back to the ground people that were looking at that for damage. The instruments had a very specific field of view. You couldn't be too close to the panel, and you couldn't be too far away from the panel. There was a range that you had to be in. Since the leading-edge panels were curved, there was an incidence angle. In other words, the camera had to be pointed within a certain angle to survey a particular area. If you were at the edge of it, even though you could see the whole panel, the instruments wouldn't be effective if it was over this curvature, so you had to basically move the camera to various places.

Preflight, the RMS group would put together an auto sequence that moved that boom on the end of the RMS and moved it along the leading edge to survey the RCC panels. It was a matter of moving along, then changing the camera, and moving back. You had to change the camera and pause a bunch of times to make sure everything was within the requirements of the camera. Brad built a model of the camera. He could control all those parameters, and he could paint the leading edge as the camera went by. Any part of the leading edge that met those requirements, it would paint that a certain color. Then the next step, it would paint another color.

In preflight planning, they could create these trajectories based on painting the whole leading edge to assure themselves that the cameras were in the right place. Then on orbit, they would see the same thing when they'd tie the orbiter telemetry into the situational awareness display. It would also paint what it was seeing on those tiles, so it would give them some idea that they were doing the right thing. Anyway, we created that.

So that was one thing [we did after *Columbia*]. We added this whole tile database to the DOUG program, and we'd control that to the point where we could send it out to whoever, the crew and other people who required that, but not everybody could use it, so we only sent it out to specific people. That was loaded into their version of DOUG at the time, so they could use that. The tile highlighting stuff worked.

We used that on the Return to Flight, when they got up there and found the gap fillers that stuck out, and they wanted to remove them with an EVA. What we did on the ground was took the location of where they [the gap fillers] were. We could highlight the tiles around that area in the software, then also put together the arm configurations, and how they got from one place to another, and where they would be standing to remove the gap fillers. Also where we suggested they position the second EVA crewmember to monitor all this, and put that all together, and then uplinked that to the crew, so they had that to review before they did it.

I guess one thing that came out of that was, at one of the debriefs, I left to go out in the hall to take a phone call, and Eileen [M.] Collins followed me out and said, "We used that in DOUG," and if they hadn't had that, she thought they would have had to extend at least another day to become comfortable with what they were expected to do. So she said it saved them all that time. She also said, "I hope you don't mind, but when we went to debrief the senior staff, we took a laptop and a copy of DOUG, and showed them all that, and how it all worked." They were cognizant of the fact that we didn't really like to advertise all that stuff and were sort of apologizing for doing that, but that was okay.

The other thing that came out of the *Columbia* accident was photographing the bottom of the orbiter from the Station, where they'd fly to the R-bar and 600 feet below the Station, stop and do this end over end flip while the Station crew photographed the orbiter. We knew they were trying to figure out how they would train to do that on the ground, and they had all these wild ideas.

We just took one of our old VR helmets, one of those original ones that we'd gotten, cannibalized that, took the CRT displays out of it. Then there was a group in our division that was playing with the stereo lithography, which was early version of 3-D printing. They made us a couple of telephoto lenses or replicas of the 400 and 800 millimeter lens that they were going to use to photograph the orbiter. We took those and mounted the CRTs inside them, and then got some old cameras that had the lens-mounting hardware on it. We took that off and mounted it on the fake lens that we had, so that you could attach a camera body to it. Then what we could do is drive the CRTs with the display of the orbiter as seen from the Station at 600 feet away with a 400 millimeter lens and an 800 millimeter lens. Then photo people would bring cameras over, and we could mount those to our fake lenses. What you saw through the viewfinder was what you'd see on orbit.

We had sensors in those that would track the camera. We counterbalanced it with weights and pulleys off the ceiling so that it was basically free floating. The Station crews would come over and practice photographing the orbiter. We took the trajectory that Eileen had flown in the SMS or SES, or someplace, of this whole thing, and took that segment where she did the backflip, and we could play that back through, so that the orbiter would go through the correct motions in the [correct] amount of time. I think they [had] only like 75 or 90 seconds to do all this photography. The photographic people had a specific sequence that they wanted them to take pictures of, an actual sequence of the orbiter that went back and forth in a very specific way, and then repeat that as many times, as opposed to going in and just taking random pictures of it. They'd come over to the VR lab and basically practice that, shooting it. The 400 millimeter [lens] you could see most of the orbiter, but the 800 millimeter [lens] was like looking at a brick wall. You had to pick out different points on the orbiter to make sure you were covering it correctly based on different tiles that were there.

As part of that, there was also an instructor console that showed the orbiter. Every time they snapped a picture, it would draw that camera field of view on this model of the orbiter, so after they went through the whole sequence, they could then come out and sit down with the instructor. They could show them exactly what they photographed; what they were doing right, and what they were doing wrong. That put the kibosh on all the other wild plans they had for training. So we ended up being that trainer for that, also.

Another part of it was the repair of the tile. If they had a damaged leading edge, they would pick up this 50-foot boom with the RMS, put a crewmember on the end of the boom, and then position him wherever the damage was. For RCC damage, if they found a crack, to fix it, what they do is have to go out and drill a hole in it that they'd slip this patch with a molly bolt on the back, put this thing in, and then tighten it down from the back. The hole had to be a certain size. They had a special drill bit made up. I think it was maybe three feet or so, two feet long. They had to break it in two. It was a step drill that went from a small to a large hole. Then they'd put that in the pistol grip tool [PGT] and drill a hole. But in order to get the hole started, they had to take a spring-loaded punch, like a center punch, and chip away enough of the surface of the RCC so that the drill bit would start in there. If they didn't do that, it would just dull the drill bit.

But in order to do that—basically, you're standing on a hundred-foot diving board bouncing around—they were trying to figure out how they would mimic that on the ground. I forget. There was some other group that ran the precision air-bearing floor. They'd come up with this Rube Goldberg contraption that you could lay a crewmember on, and he could do this stuff on the air-bearing floor and move around. They tried to convince everybody that it was accurate, in that it mimicked what was going on, but there was no way that the crewmember would come up off that floor, so it was all in one plane.

So we took Charlotte and our RMS simulation, put in the boom, and the dynamics of the boom and the RMS, and put the EVA guy out on the end of it, positioned him in front of the leading edge. Then Charlotte, the robot, became the orbiter. We got some panels of RCC and rigged them up, mounted them on the load cell on Charlotte, and positioned them there so that—essentially, standing there in the real world, if the EVA guy pushed on the leading edge or on the orbiter, he'd move back. We fixed this up so that he's standing there, and if he pushes on the orbiter, it would move away from him. So the relative motion was the same; he wasn't moving, the orbiter was. It would move in all six degrees of freedom, so you could push on it one way, and it would move in a different direction. It was all dependent on the arm configuration, whether you pushed on it and it moved up. It was sort of random and all related to the arm configuration.

We set that up, and they used that to train to drill the RCC. The crews would come over. They'd bring a pistol grip tool with them, and we'd hang that from the ceiling with our pulleys and counterweights to offload it. First thing they'd do is stand there and push on it and watch that it didn't move the way you would think it would move, so they'd become comfortable with the random motion. Then they'd start out with the punch tool to chip away the RCC, but again, if you pushed too hard on it, and you moved yourself away from the orbiter, you could slip one of the joints in the arm. Even though they had the brakes on, you'd slip it, which then you would never move back to where you wanted to be. So you'd have to stop what you were doing. The arm operator would have to take the brakes off, put the arm in mode, move you back, and then start over again. What they were learning to do was come up with a technique that they could chip away at this without disturbing the arm configuration.

And the same thing. Once they chipped away the portion of it, then they'd take the PGT and the drill bit and start drilling. You had the same thing. You had to apply pressure, but you couldn't apply too much pressure, because it would move you out of the way. As soon as you got through the first drill bit, then you had to back it out slowly, change out drill bits, and start over again and continue drilling. The whole time, the thing is moving around. It turned out that that was the only place on Earth that they could do that. Every EVA crewmember on a flight went through that training.

Where they used that on another place was on one of the flights—and it may have been [STS]-115. Another one when they opened the payload bay doors, the blankets on the OMS [orbital maneuvering system] pod had peeled up, and they were going to go out and try to repair that on an EVA. Before they did that, you had a crew that goes over to the NBL and a crew that goes over to Building 9. We set that same configuration up with our simulation and the robot, and then they brought over a panel of blankets. One of the astronauts tried the different techniques that they'd come up with of sewing it together with wire ties, and they also had a medical staple gun, like you put staples in your cuts. They came over and did that, and based on that they changed the way they were going to do it and sent that up. Danny [John D.] Olivas was the astronaut; [he] went out and did what they told him to do.

That was another thing. There was no place else on the ground where you could get all the six-degree freedom motion in what they were doing, so we could mimic that. Again, that was something that nobody asked us to do.

When a crewmember would come over and photograph the bottom of the orbiter, we would take a set of those pictures that they took and send them over to the photo analysis people, the people [who] would be going over the photographs looking for the tile damage. Sent it over to them, so they could practice looking for damage. We could make damage on our tiles. They had a certain criteria that if it was below a certain dimension that was fine and depending on where it was on the orbiter. So we could add in all this damage and then they'd go through and try to find it. Of course, we upset them when they went through and found all the damage, and they [found] where we'd written the name of the girl that was responsible for that first dataset we sent over to them in one of the tiles beneath the damage requirements. That was another area that we got involved in that nobody asked us to be involved in but ended up being the only way that they could actually do it.

ROSS-NAZZAL: Did you spend time using these systems before you invited the astronauts to come over and try things out?

HOMAN: From the standpoint that it didn't necessarily work the first time. We'd get it working, and then have somebody come over and look at it. Say we solved their problem, and they could quit doing what they were doing elsewhere.

ROSS-NAZZAL: One of the things that you had mentioned was that you had a chance to go to Headquarters to work on some VR issues. On your resumé, you were talking about potential uses for VR. That was not something that you did?

HOMAN: It was not. That was something you sent out.

CAROL HOMAN: I know. He wrote it, but [who] was the one who sent it. It was an old one.

ROSS-NAZZAL: I was just curious about that, because I was wondering how NASA was thinking about VR and sharing what you had done, and the benefits that it could be used for.

HOMAN: No. The only thing we did with Headquarters was, like I said, Bill Readdy and then Bill Gerstenmaier were funding it. They'd come by every once in a while to see what was going on.

ROSS-NAZZAL: Were you partnering with any other centers? I was out there digging around the other day, and they were—

HOMAN: No.

ROSS-NAZZAL: —talking about Ames and Goddard, different places that were using VR.

HOMAN: No, they were all doing research or trying to come up with stuff. Like I said, any place outside of a mile or two away from JSC weren't doing EVA training. We didn't have any desire to build some sort of package that we'd try to sell to somebody else to do something there. We had enough on our plate to keep us entertained.

ROSS-NAZZAL: I noticed in the presentation that you sent me that you had come up with a patch for the VR lab. I wondered if you would talk about that.

HOMAN: Yes. On STS-88 or [ISS Assembly Mission] 2A, the first Station assembly flight—what was it? I think Nancy [J. Currie] asked us—they were all over there. That whole crew came over. I think they spent 145 hours over there. They asked if we had anything we wanted them to fly for us.

So we made up this patch. Brad brought in his wife's embroidery machine, and we worked on sewing a patch. We found out that Rick [Frederick W.] Sturckhow really hated the color purple, so we put that in there, for sure, since he was the one that was going to have to carry it up. That was interesting, too, because somebody was over training once with the helmet on. "What's that noise?" It was Brad back on his embroidery machine. We were sewing up the patch. So that's where the patch came from.

Then we had some patches made up, not the furry kind but the stick-on kind, and we passed those out. One of those ended up on the robotic workstation on the Space Station. It happened to be the one that the moved up into the Cupola when they put that up, so almost every shot of somebody in the Cupola has our VR patch in it.

ROSS-NAZZAL: Any symbolism behind the patch? I'm just trying to recall what was on there. Your names were on there, I do remember that.

HOMAN: Yes. In fact, I found something on the Internet. I guess at the end of one year, NASA had its 15 best pictures or something. You go to the first one, and it was a picture of Chris [Christopher J.] Cassidy in the Cupola. [The guy] pointed out that [if] you look at that picture, and down by [Chris's] right knee is this patch that says "VR," which stands for virtual reality, which proves that the Space Station is a hoax.

ROSS-NAZZAL: You also talked a little bit about your work with IMAX. I wonder if you would talk about some of that or any TV documentaries that you were all featured in.

HOMAN: How much time you got? Toni Myers, who was a producer-director—IMAX started flying on—I forget what the first one was, *Columbia* something or other.

ROSS-NAZZAL: Yes, pretty early on.

HOMAN: Yes. They were going to track the Space Station development. Toni came over to our lab to see our visuals. The first time, on Expedition 1, they were going to reposition the Soyuz. They had an IMAX camera on board, and Bill [William M.] Shepherd called down and said he was going to take it with him. What would they like him to shoot, from what vantage point? This was a Sunday morning. Toni called me up and asked if I could come in. We sat around.

We had the Station configuration and flew around. She could get an idea of what she wanted him to shoot.

After that, which one was it? Oh, as a continuation of that movie, on [ISS Assembly Flight] 6A, when they took the Station arm up for the first time, they were shooting. They had an IMAX camera on there and were shooting stuff. One thing she wanted to show was an astronaut coming loose and falling off and flying back with SAFER. We sat down with her and went over that. So [we] had the Station configuration, and the astronaut was way up at the top, at the other end of the Russian service module, and the orbiter was at the other end of the node. We produced him crawling hand over hand on the handrails and getting to the end, and then looking down the entire stack, a visual effect, and then pitched him off. Jeff [Jeffrey] Hoblit, who was our SAFER guy, did the stunt flying for this. [He] tumbled away, stabilized himself, turned around, and flew back to the Station. We did that in the IMAX format that they wanted. I think the frames are 4,000 by 4,000 pixels, and we did stereo pairs for the whole thing, with the same lens characteristics as their cameras. I think that was the opening scene in their Space Station movie. We produced that for them.

The last IMAX movie they were going to make about Hubble, that was after the accident, and they weren't going to fly it, and then they were going to fly it. When they flew it, they had a second orbiter sitting on the pad in case they had problems and would have to go up and rescue them. There was a whole scenario for doing that. What she wanted to do was show that as a piece of the movie, even though it didn't happen, but just what would have happened. They allotted us 37 seconds.

ROSS-NAZZAL: A lot of time.

HOMAN: It wasn't 37 seconds to put it together. It was the result had to be 37 seconds. So we put that together for them, one orbiter coming in and grabbing the other one with the arm, and rotating it around, and getting in position. We produced that in the same format that they required. Like I pointed out, she'd worked with us long enough to know that if she didn't specify that she wanted *Atlantis* and *Endeavour*, she was going to get *DOUGlantis* and *EnDOUGvour*. She did specify that.

So we did those two things, and another one for the STS-125, the last Hubble mission. They had an IMAX camera in the payload bay to record the EVA stuff going on. To operate that camera, they'd put together an application on the laptops that gave them a display of all the camera parameters. From on board they could select what lens to use, and it had how much film was left, how much film they used, temperatures, and all kinds of stuff. They also had a TV camera mounted with the IMAX, so that the crew had a little display window on that application that showed them what the IMAX was going to be seeing. But they had no way to train the crew to use that. So we sat down with them, and they gave us a copy of their display and showed us what it did. Brad put together a simulation with that display, and it could manipulate all the parameters. Then we put in a little display window to represent the TV camera that was on board.

They'd take that application out to the NBL where they were training and operating the NBL arm, and that was all realistic, because it was deep enough and below the waterline, so they could do that. They could drive their display with the arm just like on another situation display. We provided the graphics of the real-world situation in the display window so that as they were training out in the NBL and driving the EVA guy around on the arm, what they saw in that display is what would actually be seen on orbit. So they could train there and still train to use this application while they were doing that, to come up with where in the checklist they wanted to turn the cameras on, because they knew what they would be seeing at the time. They could train on how to use this application and the IMAX camera.

ROSS-NAZZAL: That's quite a bit.

HOMAN: Again, there was no reason for us to do that, other than Toni asked us if we could come up with something.

ROSS-NAZZAL: Thinking back over your career, are there some lessons learned that you would share with other people? You've had a very—

HOMAN: Unique.

ROSS-NAZZAL: —unusual career path, I think, not your traditional approach.

HOMAN: Sort of, in that I never really had anybody that tried to control what I did specifically. I guess it started with Ivy [F. Hooks], in that she gave me enough free rein—she'd make sure I wasn't screwing anything up, but she didn't get in the way or anything. She let me do what I wanted to do or what I thought needed to be done.

It went on like that same thing when I went to MPAD [Mission Planning and Analysis Division], working with the SRMS [Shuttle remote manipulator system]. It was Charlie Gott and me, and nobody else cared about what we were doing, so we did our own thing, did what we thought needed to be done. When I went to Space Station, it was the same way, in that I'd become involved in all the assembly analysis from an RMS standpoint, which nobody else was doing, so almost every Station redesign or design, I always had an assembly option. I always tried to make it option number two, because that's one thing I found out during all this thing. They always selected option number two. I got chastised for that.

Then when the VR thing came along, nobody was interested in VR. So it was up to me to do what I thought needed to be done. Like I said, there was usually somebody higher up the food chain than anybody else who could complain about what I was doing, from a standpoint of Bill Readdy and Bill Gerstenmaier. I told you that George [W.S.] Abbey liked what I was doing. In fact, Charlie Bolden, who was the one that, after STS-60, said they had to do more in VR, he was the administrator. Anybody who complained about anything, there was always somebody higher up that supported me. I pretty much had the complete support of the Astronaut Office. In fact, this whole DOUG situation, SR&QA really did not like having that on board, having not gone through all their preflight certification.

There was one guy over there that was really fixated on that, and he kept threatening if we didn't do this they'd take it off the flight or take it off the Station. It had been up there for years. It was passive. It didn't control anything. It was a Crit [criticality] 3 thing, so that if it didn't work, that didn't make any difference. But since we hadn't jumped through all their hoops, they were really onto us about that. One of the old RMS trainers that we were friends with and had worked with a long time moved over to SR&QA. Somehow, this guy found out that he knew about DOUG, so he was complaining to him. He said, "Yes, and I think I'm going to make them take it off the Station." And the guy looked at him, and he said, "How big is your office?" The guy said, "I don't know. Why?" He says, "How many astronauts do you think you can fit in there at once?" They pretty much left us alone after that.

CAROL HOMAN: I think there's significance, too, to how much PAO was able to use the VR Lab for outreach, because that's not something that NASA spends a whole lot of time on. There's been criticism of the public perceptions of it, that if more was out there, that that might make a difference. I think probably more than anyplace else, Dave used to say, famous people come to see me. That was really true, because they could bring VIPs of all different kinds. When he had Clint Eastwood, and Ron Howard, and Tom Hanks, and all those people coming to experience it in ways they couldn't otherwise. They could bring them in and show them and have them experience things from the program that they really couldn't in any other way. I think that was a very useful tool for the center in ways they didn't anticipate or weren't originally asking for.

HOMAN: We always had open houses.

ROSS-NAZZAL: We don't have those very much anymore.

HOMAN: We'd move stuff downstairs and run a bunch of wires, and just set it up where the guy with the helmet on was just flying around the Station in a loop. We always had people lined up from before the place opened till after they closed everything down. To encourage people to leave, they'd start shutting off the lights. All they'd do is move over and get in line with us. We'd have a thousand people go through there during an open house, some strange ones. One guy I remember standing in line—I mean, the line was continuous—but standing in line for I don't know how long. He finally got up there and wouldn't put the helmet on. I said, "Why not? You stood in line." He said because he was afraid that if he put the helmet on, that NASA would gain control of his brain.

One of the RMS trainers that we hadn't known, they had a display set up close to us, and she sat there for a long time just watching what was going on. We came to a lull or got to the end. Maybe it was the end of the day and we were about to clean up. I said, "Do you want to come over and try that?" She says, "No way." I said, "Why not?" She said, "Well, I've seen how many people you have put that thing on, and you haven't cleaned it yet."

ROSS-NAZZAL: That's a good point.

CAROL HOMAN: Probably couldn't do that anymore.

HOMAN: But that, and they used to, during the summer, have big groups of teachers that were going through things, and they'd bring them over. We snuck all of them a copy of DOUG. Then all the press days that they'd have, they'd bring groups over continually. We had to set it up for all them.

ROSS-NAZZAL: It's a great way for people to get to experience space that are never going to be able to afford to get that opportunity to see what it's like.

CAROL HOMAN: Twenty years before the VR headsets that they still aren't really selling for people to use in their homes.

HOMAN: Yes. VR died out for a long time in there. In the beginning, it was hyped real big with the movies, *Lawnmower Man*, and the one with Michael Douglas that was all VR [*Disclosure*], him and what's her name, Bruce Willis's ex-wife.

ROSS-NAZZAL: Demi Moore?

HOMAN: Yes.

ROSS-NAZZAL: I'm not sure I remember that movie.

HOMAN: VR was the big portion of it. It was a whole thing about—I don't know. But then it just sort of died, because nobody could afford it, and nobody could come up with anything real to do with it. Then it came back.

I think one reason that we were successful at using it was the environment, in that in zero G—well, on the ground, the things that they'd come up with, moving around in the VR environment wasn't natural, because you could only walk as far as the cable on the back of your head would allow you to go. So to move around, they had different things that you'd use to point this way or point that way and move up and down. You weren't moving around anything naturally. But in the EVA world, in zero G, you're either in a foot restraint and somebody's moving you around; SAFER, you're flying around; or when you translate, even though it's called a spacewalk, that's a misnomer, because you're moving around hand over hand. You can do all that stuff in VR [while] just sitting. In fact, you can crawl the entire 350 feet of the truss on the

Space Station and never move from where you're at, but it would still be realistic, because it's just hand motions. You're doing hand over hand crawling. SAFER is the same way. You can sit there, but you can fly all around the Station. Integrated with the RMS, it's the same thing. Somebody else is moving you around. So you never have to physically move, but you're still moving around in the way that you would actually move in zero G.

ROSS-NAZZAL: That's amazing. Did you all get a chance—I think it was last year. They had, somewhere up in Houston—

HOMAN: No.

ROSS-NAZZAL: I took my family to it. We went, and it was an opportunity to experience being on the Station. It felt like you were floating in space and walking out in space.

HOMAN: Well, yes, but the only thing about that was, it was from a fixed position. I mean, you could move to different positions, but all you could do there was stand there and look around. You couldn't interact with anything. So from a training standpoint, that really wasn't [useful].

ROSS-NAZZAL: Oh, yes, not for training.

CAROL HOMAN: He wasn't interested in going. I thought that seemed really neat.

ROSS-NAZZAL: It was really cool, yes. My son really enjoyed it.

CAROL HOMAN: But he's beyond that, so he's not interested.

HOMAN: The ironic part is that I've never been able to see in 3-D. My eyes have always been independent. I either use one or the other. Everything is two dimensional. I really don't like going to IMAX, because I've basically got to sit there with one eye closed. Otherwise it's just a blur. I very seldomly would put on the helmet. In the 20 years I did it, the only time I'd put it on was to see if it was turned on or to check something specific.

One day, I was looking at something. We could set it up so that you put in the correct interpupillary distance for a crewmember, how far his eyes are apart. They'd go over to the clinic and get that measurement, and then bring it over. Then we could put it in the software so that the view was from that eye spacing for them. Well, I had the helmet on one day. I was checking on something. All of a sudden, everything was in 3-D. It was really neat. They were playing around, and they'd set the eye spacing to 10 feet. It was cool, but I can't see that. So that thing that you went to wouldn't be any more than a 2-D thing.

ROSS-NAZZAL: Yes, once you got the headset to work [at the Infinite it was cool]. There were a lot of headset issues, I will admit. Why did you decide to retire?

HOMAN: I had my 42 years in. The most gratifying thing when I retired was the Astronaut Office went to Engineering and insisted that I be replaced by an astronaut.

ROSS-NAZZAL: Who was that?

HOMAN: Steve [Stephen K.] Robinson. They wanted to do that to make sure that it continued to run exactly the way it had run, because there were a lot of people in Engineering that saw this as an opportunity to take over, get the funding, and either add their stuff in, or add it to their stuff.

ROSS-NAZZAL: Yes, their kingdom?

HOMAN: Yes. So Steve came and replaced me. Then when he retired a year later, James Tinch—he wasn't an astronaut, but he worked in that office—came over and ran it for two or three more years. So the Astronaut Office basically made sure that it ran. I think what they did was buffered the guys working in the lab from any of this other distraction stuff.

ROSS-NAZZAL: Yes, that is interesting. I imagine you received a Silver Snoopy, for your work in the VR Lab?

HOMAN: For the Hubble stuff. After STS-87, the one that got SPARTAN tumbling, after that, I think it was Steve [Steven L.] Smith got everybody else in the lab, everybody but Brad and me, who already had one, he got them Snoopys.

ROSS-NAZZAL: What do you think was your biggest challenge, if you had to say, looking back over your career?

HOMAN: My biggest challenge? I guess to have people leave me alone.

ROSS-NAZZAL: I get where you're coming from.

HOMAN: You know?

ROSS-NAZZAL: Yes, I do.

HOMAN: There were times, like when I went to work for Space Station Level II, and I was going to go work for Dick [Richard A.] Thorson. I knew Dick, not well, but I knew of him. I figured that it was the end of that, and he was going to rein me in and control me. But he never did. Matter of fact, he basically let me do my own thing and supported me.

ROSS-NAZZAL: You think that was just their approach, or do you think it was more your personality, like, I can do this, let me just go off and do what I need to do?

HOMAN: I guess I never said the let me do this part. It always seemed to be that I could come up with something that nobody asked for but then nobody could do without.

CAROL HOMAN: I think it's a little of both, though. I think it's part of the way JSC works. In that all the years I spent working with engineers, they each, even when they went into management, tended to have their own niche, their own area of expertise and experience, and cling to that, even when they got into managerial levels. So that gave some space for everybody to do that, too. If you found your own channel, you could sort of follow it, because that was really part of their collective personality, is the way I think of it. When everybody's in the same culture, that's what they get used to. But I think that's a part of it. So if you're a rule follower, you look for the rules, and you're willing to follow them, you may actually limit yourself more than you have to, just because of that larger community thinking.

HOMAN: I was in a meeting. It was when we were still fighting about DOUG getting on board after the accident. It was me and an astronaut meeting with the guy who was responsible for Shuttle software. He told this astronaut, because he went over with me, he said, "Just because an astronaut wants something doesn't mean that they're going to get it." I thought about that, and I guess my philosophy was, the only reason we're here is to support the astronauts. It's the Manned Spacecraft Center, and the only reason it's here is because the astronauts are here. The only reason is to support what needs to be done. Most of the time, the astronauts know what they need in space or on orbit. I guess that's why it was viewed as an astronaut hobby shop; we would try to support anything they needed. Otherwise, there was no reason to be here.

ROSS-NAZZAL: What do you think is your greatest contribution to JSC or to human spaceflight?

HOMAN: I contributed more to the savings bond campaign.

ROSS-NAZZAL: That's what you would say? Really? It's okay if that's your opinion.

HOMAN: I'm not sure. I mean, I never wanted to be a manager. I moved up the ranks technically as high as I could go, as anybody could go and still do technical work or what I wanted to do, as opposed to managing something.

CAROL HOMAN: I think the VR Lab was a contribution that probably can't even be calculated. If the other simulators had gone out to have software developed to get to the level that they were at between he and Brad, there's no telling how many hundreds of millions—literally, because I did the contracts for those things, I know what kind was involved and what corporations could do to sell those kinds of things. So to have accomplished what they did by getting the software, to build those common models, to coordinate all of those simulators, all those methods of simulation, I think that any other way of going about that, having that developed outside of JSC or anything else that would have made that happen would have probably been a whole lot more expensive and taken a whole lot longer than it did just because of what Dave and Brad did. Nobody would probably measure that or know what that is, but my guess is, it was a lot of money and a lot of time.

HOMAN: I guess the biggest thing I did was force commonality amongst all the simulators, not only in the visuals, but there was another part of our division. It was the SES people who had this simulation that they'd been using since—I think they still had Gemini math and models in it. It was kludged up over the years. As Apollo came, they added stuff to it. They never took anything [out]. And then Shuttle was the same way. They added stuff to it. They were using it for analysis, also. The Structures people have a math model of a mechanical device, like the latching mechanisms for the payloads, and they'd provide the model to these guys to do analysis, but in order to get it into their simulation program they'd have to mess with it and do stuff to it. Then when they'd come up with a bad answer, then they'd say, "Well, it's a Structures model, but Structures didn't have any control over what these people did to it, so they had no way of knowing what was wrong."

Another group in our division had been, back in MPAD, they put together a simulation architecture called Trick. It's not an acronym for anything. They just called it Trick. But it was a dynamic simulation that they could model—in fact, that's where we got the contact modeling and the dynamic simulations of the robotic arms. SES moved over into our division. And for the longest time, I don't know how many people they put over that branch, and the division chief even decreed that they would move to this Trick simulation base, and they basically refused to do it. They could never get them to do that.

So what I did for them was, once we went with the common visuals, we were providing the software and the model database for their simulations, also. Sometime in there, Brad was over working with somebody in another group and had his display software over there on their machines. While he was working with them, somebody from this other group had gone in and made a copy off the machine. They were using their simulation software to drive our graphics package that they now had control over. They were putting together a desktop sim. They really screwed up when they demonstrated it for Charlie Gott, who was our branch chief at the time. He asked me to come over with him. While we were standing there, I pushed some keys, and figured out that that was our software that they were using and putting together the simulation to sell back to him. So we went back, and Brad and I worked—what did we do? We changed the format on the models so that they wouldn't work in that. We changed the version of the DOUG software so what they had was no longer compatible with anything we had.

Then, like I said, for years they were trying to get them to change over to this Trick simulation, and they refused to do it. They had enough data to go up to one [particular] flight. So since we provided the graphics package for the SES, we went back in and changed the model format so that after that particular flight it would no longer work with their simulation, so they had no graphics for their simulations. We changed it so that it could only be tied into the Trick simulation. The Trick simulation was the only other simulation that could drive the graphics package. Essentially, they were at a point where they either changed to Trick, or they were out of business. That was the simulation that the SSTF folks were using, and I think the SMS folks ended up using it. The Structures folks used it, so when they developed a math model, it could drop right in without changing anything, so they knew exactly what was in there and what that meant to the results. So at that point, even though we had nothing to do with the simulation side of it, we forced common simulation software on all the simulators, too.

ROSS-NAZZAL: That's pretty important.

HOMAN: I was not always popular.

ROSS-NAZZAL: That seems to be a common theme.

HOMAN: In fact, we'd have meetings where Charlie and I would really get into heated discussions with these people. I guess I always looked at it as bad cop, worse cop.

ROSS-NAZZAL: Well, I wonder if you had anything else that you wanted to share before we wrapped up today. I know we covered a lot of ground today.

HOMAN: Not unless you got any more questions or could think of anything.

ROSS-NAZZAL: No, I went through my list while you were out for lunch, and I think we hit all the highlights. Thank you for coming out. I appreciate it.

CAROL HOMAN: It's been fun.

[End of interview]