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ORAL HISTORY TRANSCRIPT

STEVEN A. HAWLEY
INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is January 14th, 2003. This oral history with Steve Hawley is being conducted for the Johnson Space Center Oral History Project in Houston, Texas. Sandra Johnson is the interviewer, and is assisted by Rebecca Wright and Jennifer Ross-Nazzal.

I want to thank you again for coming back for your third interview.

HAWLEY: Surely.

JOHNSON: At the last time where we left off, you were talking to us about [NASA] Ames [Research Center, Moffett Field, California] and your time out there. I'd like to pick it up when you returned to JSC. How did that come about that you got a chance to come back to JSC?

HAWLEY: Well, I think when I went out to Ames, I wasn't sure what I wanted to do long term. I wasn't sure where my interests were. I was excited about the chance of doing something different, of getting involved in the management of science, and I always kind of had a plan in my mind that I would do Ames on the order of a couple of years and then make a decision about what I wanted to do long term, stay or do something else.

When I decided that I really liked operations and I wasn't ready yet to get out of operations, I started basically calling the people that I used to work with here and at Kennedy [Kennedy Space Center, Florida], and looked for opportunities. There were opportunities at [NASA] Headquarters [Washington, D. C.], but I didn't really want to go to Headquarters.

There were opportunities at Kennedy, and that was kind of interesting. I remember talking to Aaron Cohen, JSC Director then, about some opportunities back here. It turned out that it worked out nicely that he thought I might be a good fit in the Deputy Director of Flight Crew Operations spot. So when I had an opportunity to come back and basically join my old organization again in a management role, I thought that would be kind of fun. So, somewhat reluctantly left Ames, but had enjoyed the experience and learned a lot and was glad to get a chance to get back into operations.

JOHNSON: Shortly after you got back into that, you were asked to fill in as the Acting Director when [Donald R.] Don Puddy left.

HAWLEY: Don Puddy was Director when I came back. He was actually Director when I went to Ames. In fact, he had done a rotation at Ames, I think, as Deputy Center Director, if I remember right, sometime in the eighties. So he was kind of interested in the opportunity that I had to go to Ames, because that was kind of what he did. When I came back, I was his Deputy for a brief period of time, and then he got a new assignment until they hired [David C.] Dave Leestma to be the Director. I got to serve for probably about three months as Acting Director.

JOHNSON: Is there anything that stands out in your mind during that time that you—

HAWLEY: I just remember being real glad that they finally got around to hiring the Director. [Laughs] That was a lot of work, at least for me at the time, to do pretty much by myself. As the Deputy, I became the Acting Director, but for a while I didn't have anybody to sort of be Acting Deputy. As I recall, I may have managed to twist [Richard O.] Dick Covey's arm into coming up and being Deputy Director for a while. Somewhere in all of that, he got assigned to the first Hubble [Space Telescope] servicing mission as commander, so he left to go do that. So I just remember it being a time when I felt kind of by myself.

JOHNSON: Was there ever a chance or an opportunity that you may take over that position at that time?

HAWLEY: I was one of the candidates interviewed at the time that Dave was selected. Frankly, I didn't think I had enough experience yet, really, to be as good a Director as I would've wanted to be. So I was quite content to continue to do the Deputy job. I had learned a lot about budget and personnel and procurement and just institutional kinds of things at Ames. This was a chance to now take that knowledge and marry it with the knowledge of the technical job that we had to do in FCOD [Flight Crew Operations Directorate]. So I felt that it would be useful for me to spend a few years kind of putting all the pieces together and really understanding in detail how an organization like that works. That was what I wanted to do, so I was happy to get a chance to do that as Dave's Deputy.

JOHNSON: Is there anything that stands out in your mind during that period of about, well, I guess, around five years before your next flight, that you'd like to talk about? Any specific issues or anything you dealt with during that time?

HAWLEY: Gosh, I'm not sure I remember. That was the period of time, as I recall, where we were flying frequently and very successfully. I remember specifically we had the first Hubble servicing mission which was considered to be, by some at least, the most important mission NASA was to undertake since Apollo 11. Having deployed Hubble, and then having returned as FCOD Deputy during that time, and being involved in a lot of the meetings about how this was all to work and all that was at stake, that was memorable when we finally launched in December of [19]'93, as I recall.

Normally, the Director represents Flight Crew Operations at the launch site and is in the control center for launch. For whatever reason, maybe just because I was familiar with Hubble,

but I don't remember, but whatever reason, he didn't go that time, and I got to go. So I was the one that was in the launch control center and got to be there for Hubble's launch and the Hubble servicing mission. That was special.

I also remember, for whatever reason, I don't remember when it took place, but I do remember being there on another occasion as FCOD representative in the control center for a launch that was supposed to happen at three in the morning, or something like that. I remember being tired, and I'd probably been up all day, and now we were up all night, and this could have even been the second or third day of trying to launch, because I don't remember the circumstances. But I do remember for an instant sitting there thinking, "Jeez, I'm tired. Here it is three in the morning," and in the next instant, remembered thinking, "This is really amazing, though, that of all the people in the country or the world, there's about ten or fifteen of us that are allowed to sit here in this room at this time and do this thing." And suddenly the fact that it was three in the morning and I'd been up all day didn't seem very important. It was the fact that I was privileged to get to be a part of this, and that was really nice, and that was one of the things that I remember from that time.

JOHNSON: When did you begin training for the next flight, for STS-82?

HAWLEY: It was February of [19]'96, as I recall.

JOHNSON: How did you get assigned to that flight, and what was the progression?

HAWLEY: As I recall it, Dave had a chance one day—I was sitting in his office. I don't remember if he called me in specifically to discuss this, and he asked me if I wanted to fly again and wanted to fly on the Hubble servicing mission as the arm operator. I guess, to make a short story long, when I left to go to Ames, I expected that I would never fly again, and when I came back from Ames, I expected I would never fly again, except knowing that I was back, and back

in FCOD, I thought, well, you know, there could be some chance that there'd be that opportunity if the right situation came along.

But I remember thinking that it's not the sort of thing that it's appropriate for me in this job to lobby for. I thought if the circumstances were right and other people thought, "Hey, you know, Steve would be the right guy to do this," that I would entertain that. But it wasn't something that I sought, at least not that I remember seeking.

But it did come up. The circumstance was right, hopefully, for them to need an experienced robotic arm operator with some Hubble knowledge. The servicing missions were very high profile then, as they are now. As an experienced astronaut, I hope they decided that I was the right person for the flight. But for whatever reason, they asked me to do it, and I think I said, "Well, let me go ask my wife." I think I said, "Yes, I'd like to do it, but before I commit, I'd better go ask her what she thinks." So the next day I told them it was okay. So that's how I got assigned. That was about a year, as it turned out, a little less than a year before we actually launched.

JOHNSON: While you were training for that, did you still keep up your duties as the Deputy Director, or was it something that they had a temporary person for?

HAWLEY: No, they had a temporary person. I probably did it for a little while subsequent to the announcement, while we brought a new person over. I don't honestly remember who it was. We had several acting deputies during the time that I was on [STS-]82 or [STS-]93. Linda [M.] Godwin did it for a while. [Curtis L.] Curt Brown [Jr.] did it for a while. I think [Robert L.] Hoot [Gibson] did it for a while. [Robert D.] Bob Cabana did it for a while. It may have been Linda that did it initially, at the time of STS-82, but I don't remember. But it wasn't too long. If I was assigned in February, it may have been early April that I went into full-time training. I'd like to think that I continued to consult from my other office, even while I wasn't official Deputy. But typically, they would leave me alone to prepare for the flight.

JOHNSON: Tell us about that training. How was it similar to the first time you trained for Hubble? Just compare some of the training for us.

HAWLEY: The training was really excellent. I think it helped some that our flight was a lot of people that had Hubble experience in one form or another. Of course, I'd been on the deployment flight. [Kenneth D.] Ken Bowersox, who was the commander, had been on the first servicing mission as the pilot. Both Mark [C.] Lee and [Gregory J.] Greg Harbaugh had worked Hubble EVA [Extravehicular Activity] tasks previously. Greg was the backup EVA crewmember for the first Hubble servicing mission. Mark had worked Hubble tasks even, I think, back before we deployed Hubble in the first place. So we had a lot of experience. I think the models in the simulators were better.

This was the first opportunity I had had to train in an integrated way with an EVA crewmember and the robotic arm. We were the last flight that trained heavily up in the [NASA] Marshall [Space Flight Center] tank. Right before we went to fly, I think in January of [19]'97, we opened the NBL [Neutral Buoyancy Laboratory], and we got to move the training here. But for most of our training, we were going up to Marshall and using their tank. But that was probably as good a training for anything as I've ever had, because it's very realistic training. You actually had the real space-suited crewmember on a real arm. It's under water, but you can actually maneuver him around. That experience, I thought, was extremely valuable to learn the task that he had to do and the task that I had to do, and learn how to communicate back and forth. I just remember that being just fantastic training.

The NBL was the same way, although I didn't get that much time in the NBL just because we only had about a month before we launched. But they were very sophisticated by then, having been through both the Hubble original deployment mission and one servicing mission, so the training is excellent. The Hubble team is well experienced. The [NASA] Goddard [Space Flight Center] folks and the Lockheed [Martin Corporation] folks that worked

the Hubble servicing missions know what they're doing, and that's just really, really a phenomenal team to be part of.

JOHNSON: So were you able to go through the entire missions at the NBL or at Marshall?

HAWLEY: Yes, we really were. You really could do that. In fact, we got to where you could run each EVA day pretty much end to end, as it would really work, with quite high fidelity. Of course, that gives you a lot of confidence, going into the flight, that you really have thought through the things you need to do, to do the tasks. So you can't beat it.

Most of the arm training I had done prior to the deployment mission had been in simulators where the arm and the Hubble were computer images. So this is really the first opportunity to do something with a real Hubble mockup and a real EVA crewmember and a real arm. We had the MDF [Manipulator Development Facility] for training for the Hubble deploy with the balloon, but I didn't think that training was very realistic because of the dynamics of the balloon and the way it moved around in Building 9. But this was very realistic, and we were able to do each EVA day just pretty much exactly as we did it in flight.

JOHNSON: So the launch, was this the one that went off without any delay?

HAWLEY: Yes, in fact, we launched two days early, for whatever reason. I don't actually now remember. I think when we were assigned, our original launch date was February 13th, and they ended up moving it up to February 11th, and we actually launched on February the 11th. It was the most amazing thing.

JOHNSON: No delays.

HAWLEY: No delays, yes.

JOHNSON: After you launched, and I think it was Day Three when you actually prepared to capture the Hubble, can you describe that for us and walk us through that?

HAWLEY: Yes. Boy, a lot of thoughts there. It may be a little bit different now with [International Space] Station assembly, but at least back then for a robot arm operator, there's probably no greater task, no more rewarding task than to do what we call a track and capture. When I deployed Hubble, that's what I did. I lifted it up, and it wasn't moving, and picked it up out of the payload bay and let it go. It's a little different to go capture a free-floating object, and then to berth it and to move EVA guys around on the end of the arm. So that's about as challenging as it gets in the robot arm world.

So I thought about that a lot and was looking forward to it. I was also wondering what it would be like to see Hubble again. It was about almost seven years later after the original deployment mission, and I thought, "You know, that's really going to be something when we actually get to see it," me for the second time, Sox [Kenneth D. Bowersox] for the second time. You know, I guess maybe some of the same thoughts you had going through your brain back in the original deployment mission, which is, you know "Don't screw it up."

I mean, we did talk about it on the crew that the first servicing mission crew had it easy, because everybody thought Hubble was broken, even though Hubble actually was still a pretty good telescope. So we joked that they really didn't have anything to lose. Now here we come, several years later, and Hubble's working great, and the science is phenomenal, and now here we go with an opportunity to really break it. So we thought about that, talked about that some.

But also, frankly, because of the training, I really felt that we were very well prepared to go do this, and I think, having been through dealing with Hubble once before and knowing the dynamics of the big telescope on the end of the arm, knowing what to expect once you capture it, all that was helpful. So maybe I didn't feel as intimidated as I might have had that been my first experience with a large payload like that.

JOHNSON: The actual capture, did that go smoothly?

HAWLEY: It went great, yes. In fact, I told my wife when I got back that it was the best one I'd ever done, counting training and everything. Of course, a lot of things, when they go right, make it almost easier. The visuals, of course, are real good in the real flight environment compared to the simulator. Sox was a great pilot, and it was very, very stable, and Hubble was exactly where it was supposed to be in terms of attitude, and the arm worked perfectly, so all those things made it relatively easy.

I had developed a technique. I developed it for me. I don't know, other people may have developed it for themselves, too, of how to fly it. One of the things that the arm will do is, it will begin to oscillate if you start and stop it too much, particularly if you're using relatively lower rates. So the technique that I found that works well for the task of tracking and capturing something like a Hubble is to put small inputs in and leave them in. Don't be driving it and then stopping it and then starting it up again, because you'll get these oscillations which will make it a little more difficult to align properly. If you put in small inputs and just leave them in and make little corrections as you go in, it's a lot easier to control. I thought that worked great when we did it for real. So I think I came back and told people it was a good thing to do.

But I remember being real pleased with how it went, and the subsequent maneuver to berth it over the cradle worked well, and the capture all worked like it was supposed to. You know, you have nightmares about capturing the thing but somehow not being able to get it properly grappled into the cradle at the back of the payload bay, but that all worked okay.

JOHNSON: Went smooth.

HAWLEY: Went smooth, which enabled the EVAs to take place, which was, of course, the point of the thing.

JOHNSON: Tell us a little bit about those EVAs. In my notes I found that the first one was delayed slightly because of some movement in the Hubble solar arrays.

HAWLEY: Yes. That was one of the more memorable things from the flight, I guess. We coincidentally were trained to recognize an uncommanded slew of the solar arrays. If for some reason the solar array drive motor should fail in some manner, and they'll start to drive, you're trained to recognize that. In fact, you can send a command that will disable the motor so the solar arrays don't drive into something. So it's something in the back of your mind you have been trained to look for, the solar arrays slewing on their own.

So [Joseph R.] Joe Tanner and I were on the flight deck. Mark and [Steven L.] Steve [Smith] were in the airlock ready to go out, and I think Sox and [Scott J.] Doc Horowitz were on the mid-deck helping get them ready and closing out the airlock. So they began to depress the airlock to get down to a vacuum to go egress. This was the first flight of *Discovery* after they had installed the exterior airlock. There was actually an interior airlock that had been removed, and they had replumbed the way the air is evacuated from the airlock volume. As luck would have it, the way the air exited was through a pipe that came out under the HST [Hubble Space Telescope]. We didn't know it at the time, but what people on the ground figured out was the air from the venting of the airlock impinged on the solar arrays and started them moving.

I remember seeing it out the window, seeing the solar arrays starting to drive, and my first thought was, "They can't drive that fast." Your first thought is, "That's uncommanded motion," but it was far more rapid than uncommanded motion is supposed to be. So we were very confused as to what was going on.

I remember saying something to Joe like, "Hey, Joe, do you see that?" [Laughs] And we both looked and saw it. Fortunately, or—well, I guess maybe fortunately, I had the cameras targeted on the hatch so that we could film the guys as they egressed from the airlock, because there wasn't anything supposed to be happening on Hubble. So there was no video of what was

taking place. I think on the ground the space telescope guys could probably see the position of the solar arrays, and I'm sure they saw something that confused them. But there was no video showing how the arrays moved, so ground wasn't watching at the time, and we didn't have anything to show them in replay.

I say that's fortunate, because I always thought that had they seen it, they might have been so concerned about it, they would never have let us go EVA, but since they didn't get to see it, they didn't have that much data to go on. So it might have scared them if they'd have seen it. But I remember saying to Joe, "Well, you want to tell them, or should I tell them?" I realized he was holding the microphone, so I said, "Well, you tell them." So he called them and said that we had just seen the arrays move, and they probably said, "Stand by." I was convinced that we probably wouldn't be going EVA today.

At the time, we didn't know what had caused it, and as I recall, they drove all the way to the stops. In fact, they probably rebounded off of the stops, and so I was concerned that the ground would be worried there might be damage and they'd have to do all kinds of diagnostics to determine that things were okay or not, so we might delay for a day or be unable to do an EVA. Frankly, I don't know how long it took, but my recollection is they came back fairly quickly and said, "Go ahead and press on." So I don't actually know how much we ended up delaying the start of the EVA for that. I think it was maybe an hour or less. But we ended up getting to do the EVA that day. I always thought it was because the ground didn't get to see it. If they'd have seen it, they'd have probably never let us do it. But that was very startling.

JOHNSON: How did you prevent it from happening for the subsequent EVAs?

HAWLEY: I'm trying to remember what they did. Once they figured out—they may have vented only half of the capacity at a time. There's a couple of vent valves. They also might have taped over the vent valve in a way that cuts down the flow. So it would take longer to vent the airlock, but you wouldn't be putting out as much air per unit time. We did something like that to just

minimize the amount of air flow that was going back there, but I honestly don't remember now what it was exactly. The EVA guys would remember, because it was something they had to do. But those were the steps we took.

I don't know if they knew for a certainty that's what caused it, but by the time we got to the next day's EVA, they were thinking that was a likely candidate; and therefore, to try to mitigate that effect, they had us do some different things with the way we vented the airlock. It would be good to ask Mark or Steve, because I don't remember. Joe may remember, because it was probably his EVA where they had to do it first.

JOHNSON: And during the EVAs, maybe you could describe your role, of course, as the arm operator and what you did.

HAWLEY: I actually think that's a lot of fun. I mean, everybody always wants to know, "Hey, were you one of the EVA guys?" You go, "No, I was the arm guy." But I always thought that was a great job. Primarily, your job is to—let me put it this way. The arm gives you incredible amount of capability to make the EVAs very efficient, either by moving the crewmember to a worksite quickly, compared to how long it would take him to go on his own, or by being able to convey hardware to him. It's really a fabulous tool for supporting EVAs like the Hubble-servicing EVA.

So a lot of the job was moving the EVA crewmember around to the worksite and having the arm operate basically as a platform for him to stand in while he was working. We trained well enough that it really, in most cases, became—we were almost thinking together. We had good enough camera views that I could see what the EVA crewmember was doing. I knew what his next step was going to be, so it was easy for me to put him where he needed to be, could anticipate what he wanted to do next.

One of the things we talked about a lot was the communication between the guy on the end of the arm and the guy operating the arm. It's very important that you do exactly what he

needs and there not be confusion. You don't want to go the wrong direction, particularly if he's close to the telescope. You also don't want to waste a lot of time by having to say, "What did you say? Which way do you want to go?"

One of the things we were concerned about, frankly, was if there was a lot of chatter between the ground and the Orbiter, would that interfere with my ability to talk to him while he was out on the end of the arm? If the ground is talking to the IV [Intravehicular] crewmember about something, we needed to have a way to communicate. So we developed some hand signals that we could use in the event that somebody else was talking on the radio. We didn't want to sit there and wait for that conversation to end before we could do the next task, because time is pretty critical when you're out doing these things.

Those were all things we got to practice in the tank, and they worked very well. Other crews have subsequently used those techniques. We developed a coordinate system to communicate in. He, on the end of the arm, could be in a variety of orientations, and so if he says, "Hey, take me to the right," you need to know if he means his right, or does he mean Orbiter right? There could be some confusion there.

So we had a coordinate system that was based on the Orbiter, and then there was another coordinate system that was based on your body as you stood on the end of the arm. So we spent a lot of time practicing being very disciplined in how we communicated. So you would say, "Take me forward in the bay," which is very clear. It means whatever orientation he's at, he wants to go towards the nose of the Orbiter, or, "Take me port," or, "Take me starboard."

Then he would say, "Okay. I'm going to switch to body coordinates now," and you might do that if you were inside a bay in Hubble. So maybe you're not exactly sure where the nose of the Orbiter is, and then you'd say, "Well, take me head up," or, "feet down," or "left," and my job, then, would be to know with respect to his body which way that meant he wanted to go. Maybe it sounds a little complicated, but if you practice it, it becomes fairly easy. The nice thing about it is it's unambiguous.

Again, the thing you worried about, I mean, it's a little bit not elegant if you're way away

from the Hubble, and he says, "Hey, I want to go left," and you take him right, because you were confused. I mean, that doesn't look smooth, but it's not a problem. But if you happen to be right next to the telescope, and you take him the wrong way, you could bang him into the telescope or hit the telescope with the arm or do something like that, and you don't want to do that.

My recollection is that we never made a mistake the whole flight in terms of a bad command or going the wrong direction or anything, because we thought it was very important, and we practiced it a lot.

The other thing I remember is—probably the most challenging task was the insertion of the big instruments. These were the replacement scientific instruments. The point of the Hubble servicing mission that I was on was not to fix Hubble, but to improve it. By then it was working fine, but we were now realizing the original design promise of Hubble, as technology improved on the ground, there'd be a way to incorporate it in the telescope on orbit and keep it state-of-the-art. So we were installing new detectors, and these detectors were basically boxes that were the size of refrigerators. The EVA crewman would grab one of these boxes, and he'd be standing in the arm, so he can't see. All he can see is a face full of instrument. So my job was to maneuver him around. Steve Smith always said he inserted the instrument in the telescope, but I used to tell him, "No, I really did. You were just holding it." [Laughter]

But that was the most challenging task. The tolerances were very, very tight. So that got us to have to realize—one of the techniques that worked in the water, which we knew would work in space, in particular, for example, Steve was on the arm holding one of these big replacement instruments, and now Mark is free-floating in the vicinity, and he's telling Steve how to put this box in the bay and get it properly in the latches, because there's probably about a quarter of an inch or half an inch, at most, tolerance, and so Steve's trying to get this—and he can't really see, so Mark will be saying, "Okay. Take it up a little bit." "Take it right a little bit." If you're the arm operator, you need to make sure that he's not talking to you, because he may be telling Steve to move the box, and he really doesn't want the arm to move, but if you hear, "Hey, go right a little bit," and you go, "Oh, okay," and you move the arm, that might not

be the right thing to do.

So we also had a rule that said only the guy on the end of the arm can command the arm. So if I heard Mark's voice, and he was saying, "Go right," "Go up," then I ignored it. I mean, I didn't ignore it, but I knew he wasn't talking to me about moving the arm.

If Steve said, "Hey, take me to the right," then I would know he wanted to move the arm. That was a nice little technique to keep any misunderstandings from happening. The only command that the guy that wasn't on the arm could give to the arm operator would be, "Stop." If he said, "Stop," then you stopped, because maybe he could see something that nobody else could. But otherwise, if he was saying, "Go right," "Go up," "Go back," he's talking to Steve, not Steve, which was another problem. They'd say, "Hey, Steve." [Laughter] But you worked through all that, and it worked very, very well.

JOHNSON: You say that other crews have used the same—

HAWLEY: Yes. I don't know today how—every crew probably does it a little bit different, but fundamentally those are the principles that are still used. The first servicing mission crew developed a lot of these principles, too. I mean, we probably like to think we refined them a little bit, but the basic principles are kind of common sense. It's just getting a system you're comfortable with, and then developing the discipline to use it.

JOHNSON: I imagine having someone out there on the end of that arm and you're basically responsible not only for the Hubble and the equipment and everything else, but a human life.

HAWLEY: Yes, by then you're probably so insensitive to all that stuff. I mean, by now you've launched and you've grabbed the Hubble. So you're just, you know, "Whatever." [Laughs]

JOHNSON: Just move him around.

HAWLEY: No, you think about that, and you think about—one of the things I wondered, frankly, was, we'd talked about it in training a little bit. The arm moves either in what they call vernier control or course control, and it determines the rates you can command. You like to use course rates if you can, particularly if you're just moving somebody from point A to point B, because you save time, but that might not be comfortable for the guy on the end of the arm, particularly if he's holding something. In training, we weren't too sure how that would work. I found that in flight, in some cases, you could use course rates, and he wouldn't even know. That was kind of interesting.

But yes, your job as the arm operator is to constantly be thinking about, "What can I do to—?" He's the guy out there that's actually in a space suit with his hands on Hubble, and my job is to make his job as easy as possible. One of the things I wanted to do was be able to do that.

Again, the training was so good, and I thought we came together so well as a team. I remember several occasions where I'd be watching out the window, and Greg or Joe or Steve or whoever was on the arm would know I'd be watching, and he'd just do something like give me a signal, like that [gesturing], and I'd take him up, and he'd say, "Stop." And those were the hand signals we had practiced, but it became kind of second nature to just use it and not have to talk if Sox was talking to the ground about something.

I remember one case where Greg was doing some task where he had to do some wiring on a device, and he had to do a series of connectors, and I could tell he was done with these connectors, and I knew he was going to do these next, and it wasn't very far to move him, but I just moved him a little bit, and he didn't even have to ask for it because we were that familiar with it, and that was kind of nice to train to the point where you really felt like you were just all part of, you know, kind of one intelligence that was doing this somehow.

JOHNSON: And there were five EVAs altogether?

HAWLEY: Five EVAs. Right. Almost had a sixth. They talked about some funny signatures I think they had seen in an RWA, which is a Reaction Wheel Assembly. We did have a spare on board, as I recall, and there was some thought we might end up doing a sixth EVA to install it, but they decided that wasn't necessary. I think Joe and Greg might have been disappointed a little bit, because it would've been their third EVA. They got two, and Steve and Mark got three.

JOHNSON: You were able to deploy Hubble, then, again, for a second time. At that time it was the highest orbit.

HAWLEY: I think that's right, yes. I think that's right. We did reboost it, and that was kind of interesting, because as I remember, we ended up doing a reboost, I think as part of a debris-avoidance maneuver. I remember they called us one evening and told us that they were predicting that we were going to have a near miss with some sort of orbital debris, so we did an avoidance maneuver that we ended up turning into a reboost maneuver in addition to the other reboost maneuvers we were doing. I think on STS-82, as I remember, we did eighty-two minutes of reboost and got Hubble, I guess, as high as it had been.

JOHNSON: How long after you redeployed did you get to see the differences with the instrumentation that your crew had installed?

HAWLEY: I don't remember. It was probably about a month. Typically, it's three or four—well, they usually will tell you it's five or six weeks to check out a new instrument. They know it's really three or four. I think it was about a month that we got to see some preliminary results. We had heard, I think, before we saw anything, that they were very pleased with what they were getting out of the new instruments, and that was really neat.

There was some discussion in the community, before the mission, whether it was worth

taking the risk to improve Hubble. Of course, that had always been the plan, and that was what, of course, everyone decided to do. But that was characteristic of some of the thinking that was going on. "Hey, this is working great. Maybe we shouldn't mess with it." But the point was to be able to mess with it so that you could continue to make it a modern telescope. So we were happy to be able to show you could really do that.

The other thing we did during the flight, which I didn't have much to do with, but I do remember it because it was part of my thinking, how would Hubble be different from what I remember? Preferentially, one side of Hubble faces the sun all the time, and that side, we discovered—and the ground could see it, too, on the TV images—looked kind of worn. The silver thermal blankets had cracked, and some of them had peeled up. So we actually—we, the crew; it was really mostly Scott Horowitz that did it—used some materials that we were flying on board and created some not quite replacement thermal blankets, because they didn't really replace the ones that were there, but they went on top of them, to provide additional protection for the telescope. He created those on the mid-deck one day, and then I think it was Mark and Steve went out and installed them on the last EVA. And that was interesting to see how it had actually almost looked weathered over the seven years it had been in orbit on that one side

They actually were concerned enough about it, I think, on the next servicing mission they actually replaced some of the insulation with new insulation, and I think we signed the insulation we installed. I don't know if it's still there, but there's—the STS-82 crew autographs at least at that time were flying on Hubble.

JOHNSON: After this mission, you came back, and did you assume your Deputy Director position again?

HAWLEY: Yes.

JOHNSON: How long was it after you came back before you got the assignment for STS-93?

HAWLEY: Seems like it was about a year. I don't remember exactly, but, yes, it seems like it was about a year. Maybe not quite a year.

JOHNSON: Do you remember why you got this assignment, or why you were chosen for this flight? Or was it because it was another observatory mission?

HAWLEY: I think that was part of it. I think they also were looking for an experienced person for that mission. The pilot was a rookie. One of the other MS's [Mission Specialist] was a rookie. On Shuttle, Michel [Tognini] had flown on Mir previously. I think [Catherine G.] Cady [Coleman] had flown once, and this was Eileen's [M. Collins] first command, so it was a relatively junior crew. I think they were looking for somebody experienced to add to the mix of relatively less experienced people.

Truthfully, I told them "no" when they asked me to do it, merely because I thought I really hadn't been back in my real job that long yet, and I didn't think that it was appropriate for me to step aside and fly again that soon. But they pestered me, and so I did it, finally. But I honestly told them that I didn't think that was the right thing to do.

JOHNSON: What changed your mind?

HAWLEY: My boss told me to do it: [Laughs] He thought it was the right thing to do. So I said, "Yes, sir."

JOHNSON: Do what your boss says. Well, I imagine there was some interest in this flight, mainly because of Eileen Collins, the first time for a female commander.

HAWLEY: Right.

JOHNSON: Did that affect the training at all, or do you have any memories of that?

HAWLEY: Well, it certainly had the potential to affect the training some. She was very good about being very focused on training and protecting the crew as best she could from the publicity associated with her role as the first female commander. She was actually, on that basis, certainly a very good choice to be the first female commander. She was certainly dedicated to not letting that interfere with—and the system was pretty good about protecting us as best it could. Again, we understood it was important, and we also understand that we had a certain obligation to meet some of the demands of the attendant publicity associated with her being the commander, but I think we were also able to kind of keep it in perspective, and I thought she handled it very well.

It helped, also, probably, that the flight ended up with some delay. So the time we had to train was longer than we would have had, had we launched on the original schedule, and that was kind of good, because it allowed us to do both more training and more of the PR [public relations] stuff before the launch.

JOHNSON: Can you describe some of the training that you did for this flight?

HAWLEY: This was actually very similar to the way we used to fly back in the early days of Shuttle, and less similar to how we had been flying more recently. That is, we had a satellite to deploy, and it was a Day One deploy. Anymore, including on the Hubble servicing missions we launch and basically go to bed, and then get up the next day and do some checkouts, and then the third day we either grab Hubble or the third day we rendezvous with the Station, and then begin the tasks that are to follow, usually EVAs. In the case of Station, it could be EVAs and transfers.

This was a flight where you launched and you deployed a satellite on the very first day, and then basically the mission was over. That's a different way of thinking, frankly, about how to approach a mission than is typical of how we do it today. In fact, I remember there was some

talk that didn't really go anywhere, about maybe we should move the deploy to Day Two or Day Three since there was really no compelling reason to launch on the first day. We always did that in the early days of the Shuttle, because I think before the Shuttle ever flew when we were designing these missions, there was this concern that the Shuttle could suffer some catastrophic failure and need to come home. So if you were a satellite, you wanted to get out as soon as you reached orbit. Of course, while that's possible, it's not very likely, but what is almost certain is that the crew will become more and more efficient as the mission progresses. I mean, you're least efficient on the first day; and if you're doing the most important task on the first day, you would think you ought to have a good reason for doing it that way.

In the case of STS-93, by the time we were assigned and even began to think of these questions, the mission had pretty much been designed, so it would've been a significant hit to the way the mission had been designed, to some extent the way the satellite had been designed, were we to do it different. So we just accepted it and did it the way it was planned to be. But for me, it was very familiar because, again, my first two flights were just like that. I think for everybody else, it was kind of new and different from how we had been doing business.

We know how to train for that kind of stuff. We've been doing that for a long time. The IUS [Inertial Upper Stage] is a well-understood payload, although interestingly, having said that, we were delayed several months because of an IUS problem that the Air Force had in a satellite they launched prior to our mission, and they needed to understand what happened before NASA was comfortable committing Chandra [X-Ray Observatory] to launch on an IUS. But again, the training for IUS is well established. The models are well established. The drawings have been in place for a long time. So I don't know how many people were left that actually knew how to train us for IUS, but I had trained for IUS myself back in the good old days, so that all felt very familiar.

JOHNSON: The launch itself had a glitch right after—

HAWLEY: Yes, two, actually. One we could see, and one we didn't know about at the time. Right at liftoff, I could see a flash on the caution and warning panel, and a light came on and went off, and I knew what the light was, because even though it wasn't still on, I knew what position in the matrix had illuminated. So it looked like we had an electrical problem of some kind, to me. It was only, it seems like, a few seconds later that the ground called and confirmed that we had an electrical problem.

The other problem we had that we didn't know about was that we had a leak in one of the main engines, so we were leaking fuel through the nozzle. We didn't know about that. I don't know if the ground knew about that right away, either. I could tell something had happened, because when we got to main engine cutoff, the orbit that we were in was not—it comes up on one of the displays that tells you what trajectory the computer thinks the Shuttle's in at this point, and it was different from what it would normally have been. It was off by several miles. Seven miles, I think.

So the two thoughts I had were that that's interesting. But I also knew it was high enough that we could deploy Chandra, because we'd just been, several weeks before, through another exercise, trying to figure out what was the minimum altitude we needed to be at before we could deploy Chandra, and we had come to some number. I don't remember today what it was, but the number I saw on the screen was higher than that. So I knew we were able to go ahead and deploy, without having to subsequently raise the orbit before we could deploy, which would put it in a different kind of contingency deploy scenario.

We found out later that they put pins in some of the main combustion chamber ports as a matter of standard practice when they become old, and one of these pins had been ejected when the engine started, and had hit the nozzle, and it'd broken some of the tubes, and that had led to the leak.

The electrical short turned out to be a real electrical short, and that, of course, put the program basically on hold for a while after we got back, while they went and inspected all the wires and made the repairs that they needed to make.

We knew we were flying with a loss of redundancy on two engines, which meant that a second failure would put us potentially in some sort of an abort with a very heavy payload, the Chandra and the IUS was quite heavy.

I remember thinking, though, that—I know the Orbiter is well built. In the sim [simulation], it'd be a lead-pipe cinch that the next thing that was going to happen is that you're going to lose one of these other main engine controllers, and you're going to end up doing an abort, but in real life I didn't feel that way. In real life, I felt this was going to work. The controllers are well built and the engines are well designed, so I wasn't particularly worried about loss of the next level of capability.

It surprised me a little bit how much confidence I had, that it really didn't bother me. It was pretty much like a sim, except I knew it wasn't going to be as bad as a sim. Eileen had kind of the same reaction. She always said that it felt just like a sim, so you get into your sim mode and behave accordingly. And that's certainly true, and part of the reason, I think, that we train the way we do—some people say we over-train, but I think it's important to train to the point of saturation. When you really fly, it's a strange environment you're in, and it doesn't take quite as many failures to saturate you as it might sitting in Building 5.

One of the things you develop, I've always thought, is an instinct to do the right thing, and; you know, your instinct needs to be to do the right thing when you have a real problem in flight. Sometimes the right thing might be to do nothing. Sometimes the right thing to do is to throw the switch or know the right procedure to go to. I don't mean by instinctively doing the right thing that you just react, but I mean by having enough training to know what you should do in this case, whether it's to do nothing or to know exactly what procedure to go execute and know what the steps are in that procedure, and you can just do it and have it be very natural rather than see something and suddenly get all confused and wonder what's going on.

So the fact that we get many times more failures in the sim than you'd ever expect to get in real life has a purpose, and the purpose is to teach you how to deal with when your brain is on the edge of calling it quits for the day.

JOHNSON: The actual deployment of the satellite, did you do that?

HAWLEY: I did not do that. Cady, actually, I think, threw the switch that deployed it. Of course, anything like that's a team effort, but she and Michel were primarily responsible for the satellite and throwing the switches that put the stage and the satellite in the proper configuration ultimately for launch.

JOHNSON: And everything went smoothly?

HAWLEY: Everything went very well, yes. Worked just like it was supposed to.

JOHNSON: Quite a powerful satellite to be a part of, I imagine.

HAWLEY: One of the things we talked about was—you play the "what if" game a lot, and we were worried that if we couldn't deploy Chandra for some reason that it couldn't come back, that it would get too cold, and there was some concern on the part of the safety guys that it could break if you'd brought it back and had to land with it. So we began to look at what sort of extreme procedures could we execute to get this thing deployed. You could always jettison it, but if you could get it a mission, you wanted to do that.

The reason I mention it now is, we were talking about, typically, the IUS and the Chandra are launched together just lying in the payload bay, and to launch it, you have to elevate it on a tilt table, and it raises to about 60 degrees above the payload bay, and then you launch it. We had looked at, well, what if we can't get to sixty? What if we only get to fifty? What if we only get to forty? Could we really still get it out? One of the questions was how close would it come to the cabin? Of course, we got it to where it was normally supposed to be, and it seemed like it came pretty close to the cabin. I know that clearance was exactly what people had predicted it

would be, but I remember inside looking up the overhead windows. You had a pretty good view of it as it went over the top, but it really worked just like it was supposed to. Again, it was probably maybe a month or so after the mission that we knew things were working.

It needed to fire the IUS properly to get it in its orbit, which actually takes it a third of the way to the Moon. It didn't go into a geosynchronous orbit like a lot of the satellites we've deployed. Of course, the Air Force had had a problem. So the first thing, the IUS needs to work, and it did.

There's an instrument door cover that failed during testing kind of close to flight, and if that cover didn't open, then the instrument wouldn't work. It needed to be there to protect the instrument during launch, but after that, it needed to get out of the way. If it didn't, the instrument wouldn't work. So we were kind of crossing our fingers to hope that would work, and it did. You know, you get past these hurdles one at a time, and eventually it gets in the right orbit, and everything checks out, and it starts sending back pictures and doing all the things just like Hubble that the scientists had spent basically whole careers preparing for. So it's very rewarding to see them now finally achieve that dream of having a sophisticated imaging x-ray telescope in space.

JOHNSON: I imagine with your background, too, to be a part of two different deploys of that magnitude—

HAWLEY: Yes, for an astronomer, I don't know that it gets any better than that, you know. If I ever actually got to use Hubble or Chandra, maybe that would cap it all off, but to be able to participate in the deployment on orbit of two of the four great observatories, I mean, that's really special.

JOHNSON: Were there any other experiments on that flight that you have any memories of?

HAWLEY: Yes. The one that I spent a lot of time on, it was actually a second telescope. It was an ultraviolet telescope that attached to the side hatch window, which is an ultraviolet transmitting window. We used it to examine some of the solar system planets, which was kind of fun. It was almost like doing real astronomy.

That was a very time-consuming experiment. I worked on it for, I think, four days after we launched Chandra. Eileen used to joke that—the window is right by the WCS [Waste Collection System], right by the toilet, so she would joke that for four days she never saw me leave the toilet, because that's where I was. I was stationed by the window with this telescope in the rat's nest of cables.

But it was fun to do some almost real observing and see what the planets looked like through a little telescope from space. So that was kind of memorable. I remember that being challenging. It was very, very time-consuming, but it was also kind of fun because it was real astronomy.

JOHNSON: Did you have anything to do with SAREX-II [Space Amateur Radio Experiment], the ham radio?

HAWLEY: No, I really didn't. I believe that I did talk to my wife once on it. As a happy consequence of flying the hardware, they'll generally try to set up an opportunity for you to talk to your family, and that actually worked out. So we got to do that. That was kind of neat.

But I think Eileen and Michel were the two that were primarily responsible for SAREX. SAREX is kind of a neat capability, though, because one of the things we use it for is to get to talk to schools. It has a capability to get tied in, and I think that's kind of fun for the students to actually get to talk to some astronauts who are at that moment flying in the Shuttle. But I didn't get to do that myself.

JOHNSON: Are there any other memories about that flight that you'd like to share?

HAWLEY: Well, nothing that is really major. We did have the treadmill that is actually on the Station as a demonstration. That was kind of fun, because several of us on the crew like to run. So to get to try out the treadmill was interesting.

The thing I remember about it, though, is that the way they had it stored, they had it stored below the mid-deck floor in a stowage volume that's kind of back in under the forward lockers. And I was absolutely convinced that we would never, ever be able to get it back in there. And [Jeffrey S.] Jeff Ashby did it. I don't know how, but he did it. I remember even telling the ground, "Hey, when we disassemble it, there is no way we're going to be able to get it stowed back in here." And he did. Somehow he managed to get it in there. So that was kind of interesting.

JOHNSON: After this flight, you resumed your duties as the Deputy Director, and then were promoted to Director in October of 2001. Is that correct?

HAWLEY: Yes. [James D.] Jim Wetherbee got to go fly again, and so Mr. [Roy S.] Estess asked me if I'd be Director.

JOHNSON: Anything about that position that you'd like to share?

HAWLEY: Seemed like it was about the same job I'd been doing. Actually, when I was Deputy, I don't remember exactly, it may've been [19]'98 when Dave left and Jim came in and took over. He flew once or twice, anyway, while he and I were working together, so I felt I had a lot of experience being the Director. So it really wasn't that big a thing to have the title officially.

JOHNSON: What were some of the duties or responsibilities that you had during that position?

HAWLEY: Well, I suppose they divide themselves into a couple of different categories. One is, in that role you're really the chief spokesman for the crew as appropriate for all the technical issues that come up and all the programs, whether Station or Shuttle or SLI [Spacelab Integration and Test] or whatever that's interesting and challenging. There were some difficult issues about crew size, increment duration, crew workloads that we had to deal with.

As the Director, you're really responsible for the budget. Although I had a lot of experience with that as the Deputy, that was something that I kind of took that role with me when I became the Director because the Deputy that came in to work with me, Kent [V.] Rominger, was new to the world of budgets and things like that. So I kept that.

I suppose that if there was one thing that occupies the majority of your time, it's probably resources and dealing with resources and acquiring resources and trying to defend your resources or your need for your resources, and how the resources are being managed by your organization. It wasn't something that I thought was the most fun part of the job, but it is necessary, and I thought we did a good job of trying to be good stewards of the taxpayer dollar. Everybody's got tight budgets these days, and so it's a real struggle to figure out how to do what you need to do. Nobody wants to be told, "I'm sorry. You can't do that because we don't have any money."

You also get to recommend crews for assignment. During my tenure, we didn't select any new astronauts, but if we were, that would be something for which the Director would be responsible also.

JOHNSON: Well, during your time there as Deputy Director, Phase I of Shuttle-Mir was going on.

HAWLEY: Right.

JOHNSON: Did you have anything to do with any of the flight crews that were chosen for those missions or that residence?

HAWLEY: I certainly consulted in some of the selections. I was also part of the Phase I Program Mission Management Team, so as there were technical issues, the Director or I would be involved in trying to resolve them.

I remember when [Norman E.] Norm [Thagard] was selected to be the first Shuttle-Mir crewmember. I had argued that I thought that would be a good choice, first of all, because he was a doctor, but secondly, because, frankly, he really wanted to do it, and I felt that one of the most important qualities of someone in a position like that is that they really want to go do it. He really wanted to go do that. He really wanted to become part of their program, not just be an astronaut flying with the Russians, but he wanted to go over and be cosmonaut-trained and be part of their program. I thought that was a good trait. So I remember arguing for his selection, and was glad that that worked out.

JOHNSON: Did you have any dealings with the other astronauts that came here and did training, some of the Russian astronauts?

HAWLEY: Some, but actually, not a lot. We didn't have anything to do with selecting them. Typically they were selected by either Energia or GCTC [Gagarin Cosmonaut Training Center]. We would track their progress, but in that job you're not directly involved in the actual training activities. I got to know some of them on an individual cosmonaut-to-astronaut level. We're all very similar, kind of similar types of backgrounds and similar types of interests and similar kinds of challenges and meeting the training objectives and getting the mission done and all that.

I suppose the first time I saw that, it was kind of an interesting surprise to realize that, hey, fundamentally cosmonauts and astronauts are kind of the same people. Maybe that shouldn't be surprising.

JOHNSON: You've recently moved into another position, also, Associate Director of AstroMaterials Research and Exploration Science.

HAWLEY: Yes. It's kind of, you know, the circle is now complete. I'm sort of back to doing real science things.

JOHNSON: Can you describe some of your duties and what you expect to be doing in this position?

HAWLEY: Well, I'm still relatively new at it. I'm trying to figure out exactly what my duties are. For JSC, it's all of the science that isn't a life science. For us, the centerpiece of that, frankly, is the curatorial facility and the contents therein, the Moon rocks, and then the associated science that's done on Moon rocks, on meteors. We also have a unique niche, I think, because we are really the experts on the role of humans in exploration, how you do space exploration with humans. If we're to go back to the Moon or on to Mars or go anywhere with humans, we're the people that have the expertise in how you might do that.

So in a very real sense, this is perhaps a look at our future, particularly in today's environment where science is now a new priority within NASA, we're the people [that] do that. So I'm hopeful that we may see this area grow a little bit and build up JSC's science capability, and in particular, if we can find a way to push out beyond low Earth orbit, then we'll be among the folks that are kind of helping to chart that course, which will be kind of fascinating.

JOHNSON: Looking back over your career with NASA, is there anything that you would say was the most challenging aspect of your career, or anything that you were involved in that was most challenging for you personally and professionally?

HAWLEY: Boy, that's really hard to say. Well, I suppose that maybe trying to learn how to—it

wasn't as big a leap, I don't think, to go from being a scientist to being an operator as perhaps it was to go from being an operator to being a manager, and having to learn how to be successful in the world of people that do business-type things for a living. At least I hope I was successful. That was pretty challenging.

I've had a few people say, in particular recently now that I've moved on from FCOD, that I was one of the few people they dealt with that had any business sense. Part of that, frankly, I think, is we have a little bit of a history of people in those jobs who are there for a short period of time and then rotate back into flight assignment. I was maybe one of the first to come out of the Astronaut Office that actually did it for a prolonged period of time, where I was able to actually develop some experience in how to do business with the world of resources and procurement and all of that.

Maybe if I was able to develop something of a reputation as being pretty good at that part of the business where I really had no training at all going into it, then that may have been among the most challenging things to do.

JOHNSON: What about your most significant accomplishment?

HAWLEY: Well, that's another hard one. There's so little that you really get to do yourself. Everything you do is as part of a team, I think. I mean, obviously, the things we did with Hubble are things that I'll remember forever, but they're not things that I did uniquely. I did them as part of a team. And if it hadn't been me, it would have been somebody else that would have done it just as well.

I guess every once in a while I had a good idea that somebody incorporated. I suppose, in general, particularly as I got into management jobs, the thing that gave me satisfaction on a day-to-day basis was, did I do something today for somebody that actually helped them? My experience, which I guess is not unique, is you go do battle on a hundred different fronts, and you're going to lose ninety-five of them, but you may win a few. And you have to be satisfied,

I've always thought, with the knowledge that you're not going to win all of them, you may not even win most of them, but you may win some. And the ones you win are going to help somebody do the right thing, or they're going to help the program do the right thing. If you can take satisfaction in the few that you win, knowing that you really did some good for somebody or some program, then I think you do get job satisfaction in that.

So, sitting here right now, I'm not sure I could tell you what any of those are, but I do feel like I won a few over the years that probably gave me a lot of satisfaction at the time that we were able to win this point or successfully fight for funding in some area that we thought was important, where they had cut our budget, or win some technical point that was going to make the program better.

JOHNSON: Before we close, I'm going to see if Rebecca and Jennifer have any questions.

HAWLEY: Sure.

WRIGHT: I don't today.

ROSS-NAZZAL: I actually had a couple.

HAWLEY: Okay.

ROSS-NAZZAL: In your earlier interviews, you did a really nice job of describing the importance of the astronauts to the Space Shuttle Program, especially early on in the 1978 and the1980 astronauts. I'm wondering if you could give us a timeline of when astronauts began to play a less important role, once the Space Shuttle Program got started and things became more routine.

HAWLEY: I wouldn't maybe characterize it as a less important role as I would maybe say less

pervasive, but I think it probably happened not by making some strategic decision that says, "Okay. The program is mature enough now that you don't need the involvement to the extent we've been providing it." It was probably, rather, that priorities said, "Hey, we need to devote more resources to Station now, because Station's in development, and we don't have the people to devote to Shuttle. We'd like to, but we can't." So it was probably more circumstance-driven. That would have been probably in the mid-eighties and then subsequently in the early nineties after [Space Station] Freedom was replaced with what became International Space Station, and we had to devote more people to doing exactly the same kind of things that we did early in Shuttle for Station.

But the difference in the early nineties compared to the seventies was, in the seventies you developed Shuttle and then you flew Shuttle. In the nineties, we're developing Station and then we're going to fly Station, but we're also still flying Shuttle. So we have an ongoing operational program plus now a new development program, and it just probably became a matter of resources that we had to cut them from Shuttle and put them on Station because that was the more pressing need.

So again, it wasn't so much that we said, "Hey, we've reached the point in time where we can get out of this now." I mean, that was part of how you make those priority decisions, but it was just probably resource-driven.

ROSS-NAZZAL: You just answered one of my other questions, but I'm wondering if you could tell us how the position of astronaut has changed since you joined the corps in 1978 until present.

HAWLEY: Oh, it's probably changed in a lot of ways, some of which I can think of, and others I'll probably think of after I leave here. In the spirit of random thoughts, I would say that we ended up, because we were involved in the early development of Shuttle, we developed a lot of procedures. We developed a lot of training techniques that subsequent classes of astronauts just basically inherited. A consequence of that is that I think there's a tendency maybe for people to

know how to execute a procedure without really knowing where the procedure came from. I don't mean that to sound like a value judgment. I mean, it may be that that's just a different way of training, that given where we are in the program, the resources we have to spend on training, and the maturity of the system, that that's appropriate.

[But,] our class, I thought, really understood more of the details of how the system worked because we had to develop it along with engineers and controllers before Shuttle ever flew. So maybe in that sense people aren't quite as well prepared when they fly as we were when we flew. Now, that doesn't mean they're not adequately prepared; it just means that we probably knew more details because we lived it.

Another thought I have is that I think people that we hire, as time goes on, are better prepared to be astronauts than we were, partly because there's a real model of what a Shuttle or Station astronaut is now. There wasn't when I applied. So if you want to prepare yourself to do that job, you have something you can actually use as a template, and you know how to go about it, you know what kinds of things to prepare, or you know what the job is going to be. So I do think that the people we interview and accept are better prepared, better qualified. I've told people on the selection board, "We probably wouldn't be competitive anymore if we were applying with what we brought in 1977," just because people are more qualified today.

There's probably a little more anonymity with astronauts today than there were—our class was a little bit unique, in we were the first Shuttle class and we were the first class with women and minorities, so the women and the minorities got a lot of the attention, which was fine with us. Eileen Collins always said something which I thought was kind of cute, but also kind of telling. Somebody asked her once, "How does your daughter feel when she's at school and somebody points out that her mommy flies the Space Shuttle?"

And Eileen said, "Oh, heck," she says, "my daughter thinks everybody's mommy flies the Space Shuttle." [Laughs] So in many ways it's not as big a deal anymore as it was.

I think one of the things that's clearly different today than it was back then is the international nature of the program. You are called upon to be, I think, more culturally aware,

more language-skilled, and the training is more difficult if you're going to participate in the Station Program, because you're going to spend a lot of time training overseas, and in particular in Russia. I mean, that wasn't something we signed up for when we came on board.

So, in many ways, the hardships are still there. They're different than the hardships we went through. They may even be greater today for the people that have to experience the separation from their families because they're training for a couple of years in Russia. So that's different.

I guess those are the things that come to mind right now.

ROSS-NAZZAL: Okay. Thank you.

JOHNSON: Thank you again for being here and joining us and for participating in the project.

HAWLEY: You bet. I think this is an important project. Thank you for doing it.

JOHNSON: Thank you for coming.

HAWLEY: Eileen [Hawley] and I, my wife and I were talking the other day about the notion that people are leaving that had a lot of this expertise. In fact, I was talking with somebody in my new work group just yesterday that we've had this problem in the Shuttle over the last several weeks about the ball strut tie rod assembly. It's a piece of hardware in the plumbing for the main engines that they discovered cracks in one of the vehicles, and so they're trying to figure out how much cracking it can sustain and what causes the cracking, and is it going to produce debris which could be a threat to the engines during operation. This colleague of mine that I work with in Building 31 was telling me, actually, that she got a call asking, "Hey, do you know so-and-so?"

She said, "Yeah, I know so-and-so."

He said, "Well, we're really looking for so-and-so's dad. Do you know if so-and-so's dad is still around?" He had retired, but, "Could you get to so-and-so and find out where her dad lives?" Because he was a guy that thirty years ago worked on this stuff, and he was the only guy that anybody could think of that actually knew how the certification testing had been done originally.

That's, in a nutshell, the sort of problems we're going to begin to face as we operate this program. If we go to 2020, this thing will fly for forty years and probably have been in development for fifty years, and we have to have a way to figure out how to capture the knowledge and experience of the people that were there in the beginning that aren't there now. I mean, in the same sense that the astronauts today probably don't know why this procedure is written the way it is. They just know when this happens, this is what you do, because they weren't involved in developing it. In the beginning, we didn't know what to do when this happened, so we had to figure it out. Now it's written down, so you just learn to do it. What happens when things begin to break thirty years later that you didn't really think about, and now you don't have the expertise anymore, you don't remember why they built it that way, you don't remember why you rendezvous with Hubble at night, that sort of thing.

JOHNSON: And now we know.

HAWLEY: Now you know.

JOHNSON: Hopefully, we can continue to provide those kinds of details for people.

[End of interview]