NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
ORAL HISTORY TRANSCRIPT

JEFFREY A. HOFFMAN
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is November 3, 2009. This oral history with Dr. Jeff Hoffman is being conducted for the JSC Oral History Project in Cambridge, Massachusetts. The interviewer is Jennifer Ross-Nazzal, assisted by Rebecca Wright. Dr. Hoffman begins today by talking about women in the Astronaut Corps.

HOFFMAN: When you were asking about the effect of having women in the office, the thing that I remember the best was the whole first name business, which we talked about before. It was clear that at that time none of the women were pilots, and so they were all in the same category as the rest of us nonpilots and also nonmilitary. At the time the office was completely run by pilots, as it always had been. That's changed over the years. We got to the point where we had a woman as deputy chief of the Astronaut Office and now I guess we're going to have the first woman who's actually chief of the Astronaut Office, right?

ROSS-NAZZAL: Oh, is there? Who is that?

HOFFMAN: Oh, what's her name, who was up on the Space Station twice now.

WRIGHT: Peggy?

HOFFMAN: Peggy [A.] Whitson. At least I heard that. I can't swear that that's the truth but that's what I heard. Kent [V.] Rominger was going to go and—was it Kent? Who was doing it? Who's the current chief?

ROSS-NAZZAL: I think it is [Steven W. Lindsey] and then he got appointed to the final flight.

HOFFMAN: He assigned himself to be on the final flight, which is a nice deal. He has to leave in order to go train for that. I must have read it somewhere that Peggy is going to take over as chief. It's been a progression from here to there over many years to the point where you have essentially a woman scientist as chief of the Astronaut Office. Al [Alan B.] Shepard would probably turn over in his grave, but that's the way it is.

ROSS-NAZZAL: I thought it was interesting. A lot of people had some very interesting questions for me, one of which I think I sent to you. Did any of the women from that class approach things and say, "Well, I'm a woman and this is the kind of approach that I would use"? I never got that sense from the women I've talked to.

HOFFMAN: No, everybody really wanted to fit in as one of the core. Obviously there were some physical requirements for women. They decided not to have a mixed sauna at the astronaut gym, so they had to build a women's section at the gym. When it came time for getting together the toilet kits for the crews in the Shuttle flights, they give you a selection of things which they've tested for outgassing. One of the first questions was "Where's the hand cream?" Nobody had thought of hand cream, lipstick and whatever. Obviously for the urine collection they had to

develop a whole new setup for the women. Various physical things had to be done. There were women on three of my five flights.

Of course, women have different personalities just like men do. They were all different. I wouldn't say that it changed the nature of the flight for me at least in any fundamental way. [Margaret] Rhea Seddon, she wanted her own private sleeping area in the airlock and that was fine with the rest of us. Other women are more one of the guys type thing. That's just personal. Certainly no difference in the training or what people were expected to be able to do.

ROSS-NAZZAL: Did any of the women you were on a flight with ever take makeup up? Do you remember that?

HOFFMAN: I certainly never saw anybody putting on lipstick. Earrings, yes, they wore earrings. There was a problem with hair at the beginning, because some of the women had pretty long hair. When they realized that the hair is out like this [demonstrates], it's not only an inconvenience to the other crew. If everybody's trying to get a view out the window and somebody's hair is sticking out like this, then it could be a safety hazard. I know there was an incident where Judy [Judith A.] Resnik's hair got caught in the IMAX camera. It then became a requirement to keep your hair either pulled back or put in a net, except for pictures, [where you could let] your hair out. Other than that you have to keep it under control.

ROSS-NAZZAL: What did you think about that quote from Sally [K. Ride] about coming in and becoming one of those first professional women?

HOFFMAN: Let me read it again.

ROSS-NAZZAL: About how it was a very different climate, that they didn't really know how to work with women. That's still an experience today. I was curious, from your perspective.

HOFFMAN: Well, a cultural adjustment in some cases is still going on. I think it's because NASA as an agency was [mostly] engineers. Forty years ago there were far fewer women engineers or pilots, and there were even fewer women test pilots. It was a masculine culture. It was basically white men who put us on the Moon. That changed as American culture changed, it just evolved.

The same thing was true in the Flight Director's Office. It was a long time before there were women flight directors. You need a certain personality, a certain forcefulness. Those were not qualities which traditionally had been encouraged among women, but times have changed and so now there [are] women flight directors just like there [are] women Shuttle commanders and so on.

ROSS-NAZZAL: Somebody also asked an interesting question about whether or not American culture forced NASA to accept women into the corps and flight directors.

HOFFMAN: Oh, I'm sure that's true, absolutely. There's no question. That's why when the Shuttle was designed it had to be designed to accept 95% of the American population, up to the 95th percentile tall six-foot-four northern [European] American male down to the fifth percentile five-foot Asian-American female. That's all-inclusive. The Russians never had to do that,

which is why their Soyuz didn't fit two thirds of the US astronaut corps when we first started flying with the Russians. I had volunteered to go up on Mir. They were having trouble finding volunteers at the beginning. Norm [Norman E.] Thagard had volunteered to do it but not a whole lot of people wanted to go over and live in Russia and fly on the Mir. Then I found out I was too tall, much to my wife's relief. But that's another story.

ROSS-NAZZAL: Well, that would be an interesting story when we get to that.

HOFFMAN: Anyway, yes. They never had the push. There was no question. We knew. I was in the first selection of Shuttle astronauts. Nobody knew whether there [were] any quotas or requirements. I'm sure there are stories of what went on up in [NASA] Headquarters [Washington, DC]. We know that the selection at JSC then had to go up to Headquarters. We were supposed to hear the results in the middle of December, and we didn't hear.

There was all sorts of speculation that they didn't have the right mix of people. I have no idea what really happened. Everybody knew there was going to be women and ethnic minorities. They had so many qualified people. It's not like they had to sacrifice anything to find qualified people. All the people who came in were highly qualified, as much as the white men. So I think it was a good thing all around. There's no question that was driven politically. Organizations generally don't change themselves in that way.

ROSS-NAZZAL: I thought we would start out—unless there was something that we had missed on your first flight [STS 51-D].

HOFFMAN: No, I enjoyed reading it over. One thing I wanted to ask by the way. You sent me a copy of the audio along with the transcript. It'd be nice to get also the electronic version of the transcript; if you could send me the one from that and when you do this.

ROSS-NAZZAL: Oh sure. I'd be happy to send it to you.

HOFFMAN: I found it was a nice record for me. I wanted to share it with my family who's around. It's much easier these days just to send an electronic file.

ROSS-NAZZAL: Absolutely. Yes. Just shoot everybody an email.

HOFFMAN: Yes. It was a pretty long document.

ROSS-NAZZAL: Yes, it's hard to retype all that. It'll take us just a second when we get back to the office.

HOFFMAN: Yes. Obviously you have it in electronic form, so yes, that would be nice. I think having read through that I was quite pleased. That's why I say for me it brought back a lot of nice memories. It was a nice record of the flights. I gave it to my sons to look at. "Do you remember when I was doing this?" Of course for them it was nice. When I did my first flight they were what, five and nine years old. They didn't remember a lot of it.

ROSS-NAZZAL: Sure. Yes, they probably weren't exactly sure what was going on at that point.

HOFFMAN: I guess the only thing that I'll mention—they reminded me of this when I showed it to them. When we got back, there had been some problems. I guess in the previous flight a lot of people are kind of unsteady on their feet. I guess it was Ron [Ronald E.] McNair had two little kids. He'd been on a flight a couple flights before me. After [landing], his kids ran up to jump on him and knocked him over.

All of our kids got a big lecture. "You must not run and jump on your daddy." So what is the first thing that my kids did? They ran up and jumped on me, but I didn't fall down. They remembered that.

ROSS-NAZZAL: That's too funny. You gathered all the kids together from the crew and told them all together?

HOFFMAN: Apparently when they were waiting in the crew quarters or wherever we first met the families after we landed. They were all there. Normally the families would be back in Houston, by which time we would have been recovered. Our flight, if you remember the whole story, was supposed to be a four-day flight. The kids were young enough, it's no big deal to miss school for a few days. So [my wife] decided they would just stay in Florida, because we were supposed to land in Florida as well.

Then when we had the problems with the satellite and did the EVA [Extravehicular Activity] and it got extended eventually to seven days, and there was no family escort there, because that was before the days that they had really formalized the system. She was on her own

for that extra time. In any case, when it came time for the landing, the kids were still there. That's why they all got a lecture on "Don't go jump on your daddy."

ROSS-NAZZAL: Did they fly back with you to JSC or were they on a commercial flight?

HOFFMAN: No. In those days they were not allowed to. After [the Space Shuttle] *Challenger* [accident, STS 51-L] everything changed and [NASA] realized they had to take better care of the families. That actually was a big change, because [in the early days] they offered rides on the NASA plane to the spouses but not to the kids. Everybody was going down. So luckily our neighbors took our kids down. NASA didn't pay. Nowadays, NASA gets the condominiums for [the families], and all the crew stays together. But back then, you were on your own basically. They would take you up to the roof of Launch Control Center on launch day but that was basically it.

Then they started complaining that "We want to know where you are" and "Maybe you should stay here." The spouses basically said, "We're paying for this, not you. We'll stay wherever we want to, and we'll be where we want." The real change came after *Challenger*, when the families of some of the people were just out on their own, and nobody knew what to do about them, and how to protect them from the media. Now what do you do with the kids, and so on and so forth. After that they instituted the whole program that they have now where NASA basically takes care of your family, and you have crew escorts. It really made things a lot better.

ROSS-NAZZAL: I'm sure it was a lot easier to schedule things. Speaking of *Challenger*, where were you when the accident occurred?

HOFFMAN: Well, I would have been on the very next flight after. My second flight was the ASTRO-1 mission, ultraviolet astronomy. Back then flights were getting shifted around a lot. There were a lot of delays. Payloads got shifted around. I told you the story from my first flight. ASTRO-1 being an astronomy payload, they wanted us up there for the passage of Halley's Comet. So we actually held our place in the manifest, and everybody else was shifting downstream of us.

We were going to go in early March of 1986. Of course *Challenger* was the end of January. We were in active training. We were the next flight. I was in the simulator that morning, in the EVA simulator, doing training. At T minus nine [minutes], when they [start] up the [final] countdown, we got out of the simulator, went to look at the launch.

I remember, before going in the simulator, we were looking at pictures of all the ice on the launch tower that morning and I remember thinking to myself, "No way they're going to launch; they can't launch with that much ice." When we heard they were going to launch, we all shook our heads and thought, "Well, they must know something that we don't know." We assumed that it was all safe and that everybody was satisfied. Nobody in the Astronaut Office was monitoring the solid boosters.

It was an interesting situation. It was just, "Solids don't fail!" period. We had people who went to all the meetings about the main engines and the computer systems and the turbopumps and everybody expected that if there was going to be a major failure it would be one of the turbopumps or the main engines, because we had seen failures on the test stands down in Mississippi [Stennis Space Center], and they're pretty dramatic when an engine blows up.

I guess then we saw *Challenger* launch. At a minute-16, when it blew, we knew something terrible had happened. I guess most of us thought it was probably the main engine. What was really strange, we didn't for a while know what the cause was. As horrible as it was, there was always a possibility that they would figure out very quickly what the problem was and it would be easy to fix. They told us we had to continue to train.

It was very strange the next morning going into the simulator to do an ascent simulation. I remember we told the sim [simulation] supervisor, "How about just giving us no malfunctions on the first run? Let's just get safely up to orbit," because it was pretty emotional. Of course we had a special relationship with the *Challenger* crew, because the tradition in the office is that the spouses of the next flight put on a prelaunch party for the spouses of the flight that's getting ready to go. Our spouses had all put on a party for the *Challenger* spouses. Of course we had gone too. We knew the families as well as just the astronauts. It was also clear that NASA had not made sufficient contingency plans for, "What do we do if there's an accident." The whole philosophy of the Shuttle was—and people should have known better who were basically saying this—that "Flying in space is now no more dangerous than flying in a 747, and look, we can take teachers on board and politicians," who I had flown with my first time.

Obviously it's not, but because of that I think the system had never stepped up to the possibility of a major catastrophe and didn't really have contingency plans. It was tough.

ROSS-NAZZAL: Did you spend much time with the families once they came back to Houston?

HOFFMAN: Oh yes. We went around one by one and visited everybody. My wife got particularly close with Cheryl McNair, helped them out a lot, because they lived not too far from

us. I guess different people took the responsibility for different families. Ron's parents came there. We got to know them all pretty well. I remember they used to love to go catfishing in the lake, and I'm not a fisherman. My kids thought, "This is great. Somebody can teach us how to fish even if you can't, Dad." They would go catfishing.

Cheryl is still living there. We all thought she was going to go back to South Carolina but she never did. We saw her at our 30th reunion. She was there last spring. That may have been actually after our interview I think. Our class of astronauts, I think, has been unique in that we've had ten-year reunions. The tenth and the 20th reunions were both in Houston. But for the 30th reunion, we decided since we were all Shuttle astronauts, and this would be the last ten-year reunion while the Shuttle was flying, we ought to have it in Florida and organize it when a Shuttle was going to be launched. Amazingly it actually went the day we were there to watch it.

My wife said that was the first launch she had actually ever seen, because she always kept her eyes closed. She got to actually see a Shuttle launch. Our family escort, who was standing behind Barbara and the kids as they were counting down for the liftoff, heard one of my sons turn to Barbara and say, "Mom, this is his last flight. You better keep your eyes open." But she didn't.

ROSS-NAZZAL: I can imagine it's a little nerve-racking. You mentioned that you were in the simulator before *Challenger*.

HOFFMAN: Obviously we didn't go back to the simulator after that. Everybody was in shock.

ROSS-NAZZAL: Did you go to the office and congregate together?

HOFFMAN: Yes. Then the people who were running the office, they were trying to think, "What do we do now?" I went back to the simulator office, and I got all their personal belongings out of [their area], because as prime crew they have a special area. I didn't want people going, taking their nameplates and little books and stuff.

Eventually they assigned people, an astronaut, to work with each of the families, which they now call the CACOs, the casualty assistant [case] officer I think, if I remember, to help them with the government paperwork and all sorts of things. I experienced that actually closer up when Dave [S. David] Griggs got killed in an airplane accident, not Shuttle-related, since they were our close neighbors. Don [Donald E.] Williams, who was his pilot, was actually the official CACO. Because we were such close friends with the family, we helped out a lot with funeral arrangements and just helping with the kids. That was tough.

ROSS-NAZZAL: When did that happen? Was that before or after *Challenger*?

HOFFMAN: That would have been after, around '88, something around that time. He was flying an airplane in an air show. Dave was one of the best pilots. Sometimes your number just comes up. He was flying an old World War II Navy airplane and did an aileron roll. He was not familiar with the plane, I guess. He was too close to the ground, caught a wingtip, and just like that. Like I say, he was one of the best pilots in the corps, there's no question. Everybody respected him for that. It was a real shock.

ROSS-NAZZAL: What sort of impact does that have on the Astronaut Office itself? You lost seven members of the Astronaut Office, and then you lose another member later.

HOFFMAN: Well, it's a reminder of something that we always knew. Probably something that the test pilot community was more used to than we were, because they had seen people get killed and had colleagues [who died]. That had never happened [to me]. Although from my mountain climbing experience—I had never been in any major accidents but I certainly [knew of them]—it's a milieu where people die. It's not like I had never considered the possibility that you could get killed doing this. We recognized it.

I think the thing that was the biggest shock was not the fact that the accident had happened, because we had always recognized that going into space is a difficult business. We're pushing technology. We're dealing to a certain extent with things that haven't been done before. No matter how much you test a system, there are things that you miss. I guess the feeling was "If there's going to be an accident it's going to be some part of the main engine which they missed in the inspection."

[Then] we found out that it was the O-rings for the solid booster, and people had known that this was a problem for many flights. The story started to come out about the discussions the night before, how the engineers had recommended that they not launch because of the cold temperature, and they were overridden and the whole story. That was really like a betrayal, because you're counting on thousands of people to do the right thing to keep you safe. When it turned out that these were people who had other things in mind besides just keeping things safe, that was a real shock.

When we were getting ready for the return to flight, and on numerous occasions people said, "How can these people dare to get into the Shuttle again after seeing it blow up?" Well, frankly, the return to flight was probably the safest flight we've ever had. Everything on the Shuttle had been gone over with a fine-tooth comb. They made hundreds of changes, and everybody was super careful about everything. What I often said then is "This isn't the flight you should be worrying about, STS-26, it's 100 flights in the future," when people get careless. Sure enough, then we get to [the Space Shuttle] *Columbia* [accident, STS-107], and you realize a lot of the same mindset had come back. People were making decisions to go ahead and fly even though the foam was coming off, and there had been instances of fairly severe tile damage that we had gotten away with. It was the same idea that "Well, since we got away with it, the system must be more robust than we thought, and so we'll keep on flying," which was exactly the same mindset with *Challenger*. Once again, people who we thought were doing their best to look after people's safety didn't do it.

Not in the sense that they were—there's nobody out there trying to kill astronauts—everybody recognized that. It's just that the whole safety process had gotten diverted, and people were thinking along different lines.

ROSS-NAZZAL: How long did you continue to simulate your mission, STS-35?

HOFFMAN: I don't remember exactly. It was not too long, because once it became apparent what had happened and that there was going to have to be a major redesign of the solid boosters, that was probably a couple of weeks, but I couldn't swear to it. At that point all the flights were canceled, and we stood down. That was definitely a tough time around the Astronaut Office. It

was around that time I think there were a few people in our group who had made two flights at that point and decided that that was time to leave.

I wanted to make my ASTRO flight, and I had no particular desire to leave. I stayed around. We had been talking a lot about experiments in microgravity and growing crystals, and at that time in the Astronaut Office I think the only person with any sort of a background at all in materials science was Bonnie [J.] Dunbar. I thought, "I have a background in the physical sciences, I can learn about this." I applied to the Astronaut Office management. I said, "Could I take half time off and go to Rice University [Houston, Texas] and get a degree in materials science with a specialization in crystallography? Then maybe, sometime in the future, I'll be able to go on one of those Spacelab flights and help with growing crystals."

There was plenty of work to do around the office. For half time, they assigned me for my astronaut job to the Payload Safety Panel, which was actually quite fascinating work. Then at the same time I was spending—basically full-time—I was sort of working at time and a half—but full-time on getting a master's degree, which was fun going back to school. I was what, 42 years old at the time. I remember some of the students in class would look at me funny. "Who's this old guy in class?" Then by the end of the first semester, it gave me a good feeling because they realized that "Hey, he's getting all As." Before the final exam when they came up and asked if they could copy my notes to use for study, I thought, "Well, that's nice."

I hadn't taken exams since I was a graduate student, so when I went in to take my first exam I remember thinking, "Can I still do this stuff?" It was nice to see that I could still get As in my classes, and it was fun because I always liked school. I like learning new things. Just about the time that I finished up my degree and I was going to start looking around, "What can I

do?" I knew I was going to fly on ASTRO eventually, but since Halley's Comet had come and gone, we no longer had our privileged position. It was still going to be another year or two.

I went looking for what sort of crystal-growing opportunities there might be. At the same time Claude Nicollier, who's a Swiss astronaut who I ended up flying with three times, but we had been friends over the years, was being sent by the European Space Agency to the Empire Test Pilots' School over in the UK [United Kingdom]. At the time the European Space Agency (ESA) was working on the Hermes vehicle. Since Claude was a pilot, it was natural that he ought to go to test pilot school so he could help with the development.

He had been working as the astronaut representative to this strange project called the tethered satellite. He talked to me about it one day. He said, "Jeff, you're a physicist. This is something that might intrigue you." I went with him to one of the technical meetings and I got totally hooked. It was a fascinating project.

I asked the office, "Claude is going off. Can I take over this project?" I did. I ended up flying twice with that system, both times with Claude as it turned out. I actually had quite an unusual flight assignment situation in the sense that, with one exception, every flight I made, I knew what I was going to be doing for my next flight. Because I had been assigned to the ASTRO crew before my first flight, I knew already I was going to have another flight. By the time ASTRO finally flew in 1990, I was already assigned to fly with the tethered satellite.

I got back from the tethered satellite not knowing what I was going to do next. I was hoping to get on the Hubble [Space Telescope] flight, but everybody else in the office was also hoping to get on the Hubble flight. It was only about three weeks. We got back in early August, and I think they assigned the Hubble crew around the end of the month. It was literally only a couple of weeks.

Even before we went on Hubble, once they decided that they were going to refly the tethered satellite, the office management said, "Look, this is such a complicated payload, you guys who did it last time, you go do it this time again." That's how I ended up flying with Claude three times, because he also was assigned to fly with Hubble. First of all they wanted somebody European because of the European involvement in Hubble, and because it was such a critical mission they wanted everybody to have done something that they had done before. I had done an EVA on my first flight, completely by accident, but I had my union card. So I was eligible. Claude had done some fairly complex arm operations with the EURECA [European Retrievable Carrier] payload on STS-46, which was the tethered satellite flight, but we also had the EURECA payload which had to be deployed. He was fully arm-qualified. We did three flights together.

I think at the moment at least we're the only two people who have ever flown together three times. There's a lot of people who've flown together twice. Then there's one Russian pair in the early days. They flew two and a half times, because they had two flights together and then they did another one where they did a rendezvous where they launched separately and then they linked up and they came back together. They exchanged crews. They had two and a half flights together. Anyway, Claude and I had three flights together, and we're still good friends.

ROSS-NAZZAL: That's great.

HOFFMAN: I don't know if you want to go back a little bit more about the ASTRO flight, because that was interesting how I got involved with that. It was actually before I was even assigned to my first flight. There was a lot of controversy about payload specialists at the time.

The Marshall Space Flight Center [Huntsville, Alabama] was running the Spacelab flights, and so they controlled payload specialists. There was always this competition between JSC and Marshall, sometimes more friendly than others. Marshall loved the idea that they had their [own] astronauts, and so they wanted to fly as many payload specialists as possible.

This was strongly resisted at JSC, because they didn't want astronauts that they didn't select. There was a lot of controversy in the early days about what payload specialists should be allowed to do and how should they be selected. Along comes this ASTRO payload, three fairly complicated ultraviolet telescopes. Actually, the program was originally being run up at Goddard [Space Flight Center, Greenbelt, Maryland]. The project said that this was a sufficiently complex payload that "We really want two payload specialists on the flight." George [W.S.] Abbey, who was not fond of payload specialists, decided to see if they were for real or if they were blowing smoke.

Since I was an astronomer and I wasn't assigned to a flight at the time, he asked me to go up to Goddard to one of their meetings, find out about this payload, and because I was still a new guy, he sent Joe [Joseph P.] Kerwin along with me. Joe wasn't an astronomer, but he was a medical doctor, and he knew the ropes and was an old hand around the office.

We went up there. I talked with everybody, learned about the payload. Joe and I talked about this, because we kind of thought, "Well, we know what George would like to hear," but we both came to the conclusion that in fact this was an extremely complex payload. Yes, two [astronaut] astronomers could probably [do the job]—because we had a few astronomers in the Astronaut Office: Bob [Robert A.R.] Parker, Karl [G.] Henize, Sally Ride, Pinky [George D.] Nelson, Steve [Steven A.] Hawley. You could assign a couple of us. We could go and spend two years working at the universities, and we could operate the payload, but we still wouldn't

know it in as much depth as the people who had developed it. We recommended that we accept payload specialists. George went along with it. It obviously didn't destroy my career. Everything worked out okay.

Because of my initial involvement, I went to a few more ASTRO meetings and at one point then [George] decided that Bob Parker and I, both astronomer astronauts, should fly with ASTRO-1. So as I say, I knew before I flew on my first flight that my second flight would be with the ASTRO payload. That was nice.

ROSS-NAZZAL: What was it like to finally be assigned to a mission that related in some way to your field of expertise?

HOFFMAN: Well, I had never gone to NASA with the idea that I was going to work there as an astronomer. It was nice to be able to talk to the scientists. They knew that we understood what they were doing. Yes, it was enjoyable. It was a very complex payload. We spent a lot of time training, did a lot of simulation.

ROSS-NAZZAL: Can you tell us about the training? How did you work with the telescopes?

HOFFMAN: Well, [for] most of the training, they had to basically build computer models. A lot of money went into it, very complex models of the pointing systems and the behavior of the detectors. We really had excellent training. In addition, we went to each of the universities to meet with the people. We would get a chance to try out some of the hardware that they used there for testing.

Then we spent a lot of time at the Cape [Canaveral, Florida]. Not as much as the payload specialists did, but we learned a lot about the hardware. It's not an efficient way to learn about it, because you have to spend a lot of time just going through the drudgery of prelaunch testing. You always learn stuff. We were very well prepared. We had to do it all again, when we resumed our training.

It was a shame in a way. ASTRO was a payload that was developed at the time when people were saying that the Shuttle would be able to fly these payloads once or twice a year. It was a very expensive payload to develop, and in the end it only flew twice. It was not, in the end, cost-effective from a science point of view. It still made some interesting discoveries. It would have been much more cost-effective had the Shuttle been capable of the sort of flight rates that were originally anticipated, and that's what the payload was really developed for.

In any case, it was a very challenging flight. When we finally got ready to go, now we're already in the spring of 1990. We went through our training all over again. We had remembered a lot of it of course from the first time, but you have to brush up and get everything fresh in your mind. They launched Hubble, and we were just starting to find out that "Hey, there may be problems with Hubble, and what's going on here?" We went down for our launch attempt in the spring. We got to about T minus four hours when they start the fast fill of the hydrogen. We had had the party for the launch guests. Everybody comes down, that's a tradition. Then there's another nice tradition where we would go out and stand on one side of the trench out by the launchpad and the buses would come and the families and friends would be on the other side, so we could wave at them.

We'd gone through all that, and we were a two-shift flight. So Vance [D.] Brand, who was the commander, and Guy [S.] Gardner and—let's see. They were the red shift, I guess.

They were all sleeping, because Vance and Guy had to be awake for launch. [My shift] didn't have to sleep-shift, because we were launching like at midnight I think. Our shift, we were supposed to go to sleep shortly after we got to orbit, which was very nice. The red shift, they had to shift their sleep schedule by 12 hours. So while they were still asleep we heard, "Hydrogen leak, launch scrubbed." We had to go and wake them up, say, "There's a leak."

Then [NASA] said, "Well, all right. We'll try again in a few days." A few days later they tried, [but there was] another leak. All right, back to Houston. They'll figure out what the problem was. They do launch leak checks with helium before they ever start filling up with hydrogen, but the problem is that the hydrogen is so cold that everything shrinks. Leaks can show up even if they didn't show up during the helium leak checks where they just fill it with gaseous helium. They did more checks.

I guess about several weeks later we had to go back into training, and that was psychologically really tough. It was much easier for me than the rest of the crew because, as I said, it was already clear that I was going to fly with the tethered satellite flight as my next flight, and we were actively working on that payload. I just went back and I carried on working with the tethered satellite, in addition to the maintenance training that we had to do for ASTRO. I had plenty to do to keep busy. For the rest of the crew it [was tougher]. You're all trained, you're ready to go. You have to keep going in the simulator, doing the same sort of thing over and over again. It can get tough.

We went down a third time. Once again they had a leak. Now there were three flights vying to launch. There was us, there was a military payload, and then there was the Ulysses launch, [which] had to go in September, I guess. Then there was a question, "Who's going to go first?" Then when they decided to launch the military payload and they had a leak, and now this

gets really serious, so they rolled us back to the VAB [Vehicle Assembly Building]. That's where they have these great pictures of the Shuttles passing each other on the launchpad. That was *Columbia*. We were back and forth twice to the launchpad. They put more miles on *Columbia* for that flight, than had ever been done before or since. It wasn't [launched] until I think our sixth trip down. I remember on the fifth trip down—we're already in the fall now—we'd gone through the whole summer waiting for another opportunity while they tried to fix the leaks, and by that time school had started. Our kids went down and again they had a leak, so we scrubbed.

This was getting to be crazy. They kept finding sources of leaks. They would fix it and then think, "All right, now we're ready to go." Now we're ready to go for I think our fifth try or maybe our fourth, I've lost touch. We decided we didn't want the kids to miss so much school so rather than send them down three days ahead of time on the NASA plane or two days, whatever, we left them at home. We said, "We'll pay for their tickets." Our neighbor would take them to the airport. We had arranged the time of flight such that they would have done the fueling before they'd have to get on the airplane. I would be able to tell her is it okay or not, and if there's a leak they don't get in; they just had little handbags so that they didn't have to check their luggage.

Then there was a lightning storm that came through. You can't fuel. So they delayed the fueling. Then they finally started the fueling, but they hadn't gotten to the critical fast fuel part. I get a call from our neighbor [saying], "We're at the gate; they're getting ready to close the door. What should I do? Do they go or not?"

I said, "Well, I guess you better put them on the plane, because we can't not have them go if we're going to launch." That was that. Literally two minutes later, [another] leak. Launch

scrubbed. I said, "Oh, shoot." Quickly I called Continental. Amazingly, I got a human being at the desk. I said, "Can you transfer me to gate such and such?" Again, a human being actually picked up the phone. I said, "Did you just put two little kids on the plane at the last minute?"

She said, "Yes, they're going down to watch a Space Shuttle launch in Florida."

I said, "Well, no, I'm their father, and they're not. Is there any way you can get them off the plane?"

She says, "Well, they've closed the door, but I'll see what we can do." The story as our kids tell it is they were sitting there. At this point they're what, 15 and 11 I guess. One of the engines had started up. All of a sudden things got quiet. The door opened. They said, "And this lady came in and grabbed us and said, 'Get off the plane.' We didn't know what to do, so we followed her. We weren't sure if it was okay, but we figured she seemed really serious, so we got off the plane."

Anyway at that point it was clear we weren't going to go for yet another couple of months. Ulysses went. Then they did a complete teardown, and they found out that they had somehow changed the configuration of the O-rings. The techs were being asked to put them in in a way that they couldn't see [them] properly. They finally sorted out the problem.

On December 2nd, we actually did launch. Then the flight itself was almost like an anticlimax, although it turned out to be quite challenging. There [are] two Spacelab computers which you use to control the telescopes, which are different from the Shuttle computers which control the Shuttle. We got up, and after a few hours of operation, we smelled this burning. One of the computers had basically overheated and burned up.

We operated for several days, and then the second computer burned up. Now we had no Spacelab computers left. It was actually the control unit. The computer itself was out in the

payload bay. It was the interior control unit. It turned out later that it hadn't been cleaned properly, and it had spent so much time on the ground that it had accumulated a bunch of lint. Should have been cleaned, but it wasn't. That impeded the airflow, so it didn't get proper cooling.

I'll tell you. It's a very uncomfortable feeling to wake up in the morning and smell smoke in a spacecraft. It's not fun. But anyway that's the way it was. Then there's a question, "Do we just abort the mission and come home?" No. We still had a limited ability to command, because we had a hand controller. They figured out a way where the ground could send most of the commands that we would have sent from the onboard computers. Then we would do the final positioning with basically the hand controller, which is something that astronomers traditionally have done.

Except I had never used big telescopes, so it was sort of a joke, because the other three astronomers on board were all optical astronomers, whereas I'd been an X-ray astronomer, and I didn't use regular telescopes. They let me, once or twice, use the little paddle. To be honest, I was happy after that. I looked out the window and took lots of pictures.

There was less for us to do than there would have been if we had had to operate the entire system, but the whole thing worked out. It really sorted out a lot of the problems for the ASTRO-2 mission, which ended up being—I think that was like a 16-day mission and was scientifically much more productive because we had to sort out a lot. We knew we were going to have problems with the pointing system. Not the computer problems, but just getting the pointing system to work properly and point at stars. That took a few days to sort out.

That was the ASTRO mission. That was [my] one mission where we landed in California [Edwards Air Force Base]. It was also the mission where the other unique part of that was that

they got a clog in the waste water dump system. We couldn't dump our waste water overboard, which meant we couldn't use the urinal. So they prepare for those contingencies by—there's a huge plastic [bag], it's about the size of a body bag it looks like, and so you hook that up, and you can urinate into that. But, there were seven of us on board, and we filled that up after a couple days.

It's actually a bit of a funny story, because one of the things you do before a flight, they have what they call a bench review where every piece of equipment that's going to be loaded on the Shuttle, it's in Houston because Boeing does all that. Then they pack it all up, and they send it to Florida [Kennedy Space Center] to put on the Shuttle.

Before they do that, they lay it all out on the bench and the crew gets to go and inspect literally everything that's going to go on the Shuttle, just in case you have any last-minute questions. There's a whole bunch of stuff which is used for contingencies. It's stowed way in the bowels of the Shuttle, and usually you never go anywhere near it. There was this whole big boxful of female urine contingency devices, as well as a box of male urine contingency devices. We said, "There's seven men on this flight. Why are we carrying a box of female urine contingency devices?"

"Well," they said, "some flights have women, and some don't, but the paperwork that would be involved to take this thing on and off depending on whether you had women on the flight would be so onerous that it's easier [if] we just leave it on every flight." Okay, seems ludicrous. Now here we are. We need contingency urine collection devices. We had to use all the male ones. Normally you're only supposed to use them once and throw them in the wet trash. But because we knew we were limited, they said, "Would you mind? Just hang them up on the wall and use them as many times as you can."

The problem is that they have little pinholes in them. They were very old. I think they're from the Apollo era. So you get these yellow bubbles coming out. I'm not trying to gross you out. This is history, this is the way it was.

ROSS-NAZZAL: No, it's great. It's just, I'm sure it smelled pretty bad in the cabin.

HOFFMAN: Well, luckily, your sense of smell is very much depressed, probably because of the fluid shift. It's like having stuffed sinuses. We couldn't smell much. Although I have to say when the—well, I'll get to the landing in a minute. We finally were getting towards the end of our male urine contingency devices. Then they went into an Apollo 13 mode and said, "All right, now what are we going to do? We've got these female urine collection devices, and we've got males who want to use it." It's the round hole in a square peg, like in Apollo 13, like I say.

They came up with this plan to do it, but obviously they had not tried it out in weightlessness, because it didn't work very well. They leaked a lot. Anyway it was a mess. We had socks up there to soak up the urine. It was not pretty. It was probably just as well that there weren't any women on that flight. It was pretty gross. When we finally landed, I remember the look on the face of the technician who first crawled on board, because it must have really reeked. We couldn't really smell it that much, because we were kind of inured to it. It was pretty bad, but we survived.

ROSS-NAZZAL: I did want to ask you a few questions about the flight. I was curious, because NASA had promoted this idea of the [payload] specialist, which you had talked about before, with George Abbey and the battles between Marshall [and JSC]. What were your duties on this

flight as a mission specialist, yours and Bob's, compared to the payload specialists? How did that differ?

HOFFMAN: Well, what we did, Bob and I, we were totally responsible for the instrument pointing system, both normal operations and detailed failure modes. We got trained to be completely competent operators of the experiments as well. We didn't go as deeply into all of the failure modes, because Ron [Ronald A.] Parise and Sam [Samuel T.] Durrance and also Ken [Kenneth H.] Nordsieck, who was the alternate payload specialist, they knew those instruments much better than we ever could. We figured that was a good division, and then we had all the rest of the normal mission specialist things that we had to do.

By the way, I think it was a totally unfortunate choice of terminology that NASA made, because the public never could tell the difference between a mission specialist and a payload specialist. It was just totally confusing to everybody. That's neither here nor there. That's the way it was.

We had no problem as far as the crew. We knew very well that they knew the experiments much better than we did. It was perfectly reasonably for them to be on the flight, and they did a great job.

ROSS-NAZZAL: Did the payload specialists remain the same from the time you were assigned in the mid '80s until you flew in 1990?

HOFFMAN: Yes. There were three. There were several candidates, but the actual three were selected by the scientists, not by NASA. They had to pass NASA medical qualifications. Then I

guess in the end, the scientists selected the two of the three who would fly. The deal was that for the second ASTRO flight Ken Nordsieck, who was going to be the alternate for the first flight, he would definitely fly. Then one of the other two would fly. As it turned out, in the interim, Ken had developed other interests, and decided he didn't want to leave his academic interests for two or three years to fly. He basically withdrew. Sam and Ron flew again. They found another alternate payload specialist who was willing to go through the training with the knowledge that he probably would not fly, and that worked out fine.

ROSS-NAZZAL: During this flight you were also working with Huntsville, not just the Mission Control Center in Houston, is that correct?

HOFFMAN: Right. It was the Payload Operations [Control] Center. The POCC was at Huntsville, and the Mission Control Center is at Houston. So yes. Sometimes they had two frequencies so we could have one frequency to talk to Houston, one frequency to talk to Huntsville. Particularly when we started having the trouble with the computers failing and having to work this control, we had to use that loop a lot. We were talking very actively. The people from Houston were very busy as well, because they were dealing with our urine problem and fire on the spacecraft and all these other things. There was a lot of traffic going back and forth, but with the two voice loops you can deal with that.

ROSS-NAZZAL: I read that your mission, the STS-35 mission, would be remembered more for malfunctions than its scientific endeavors.

HOFFMAN: Oh man, yes. Well, as I say, we were just about getting to the point where everything was working right when our second computer failed, and then they had to take another couple of days to develop techniques of operating. It was only a nine-day flight. I think we were going to originally go ten days, but it looked like there was inclement weather coming for the next couple of days. They had us land about a half a day or a day early. I guess we were always planning to come down, maybe it was weather. They must have known pretty well in advance that we were coming to California.

No, that's right, because it was a night landing. Well, they had done night landings by that time in Florida. I don't remember when the decision was made or why, now that I think of it. I'd have to go back and research that. Our wives were all out in California to meet us. It wasn't like one of these situations where they send the family to Florida and then it lands in California. That's always a bummer.

ROSS-NAZZAL: That's got to be. This was a night launch for you. Was that different?

HOFFMAN: Oh yes. It was visually very spectacular. I'm trying to remember. I think I sat upstairs for that launch as MS1 [Mission Specialist 1]. Yes, because I got a chance to look out the overhead window and see the ground light up and the boosters come off. It's pretty spectacular.

ROSS-NAZZAL: That would have been a great seat. One of the other things that I read that I thought was interesting is you had a classroom in space for this mission.

HOFFMAN: Yes. In fact, I pointed out to people when we had our teacher in space that, in fact, we were the first people to actually give a formal classroom lesson from space back in 1990. We had done that. The idea was to put together a lecture about astronomy relating to what we're doing. Things were a bit basic back then. They didn't have a lot of the fancy media things. It was more of a talking heads sort of thing. I thought one way to make it a little bit [funny] for the students, I thought, "Well, all the men teachers that I've had at least in high school, they all wore ties." Nowadays that may not be true anymore. So I thought, "Gee, it would be fun to take a tie into space."

So I did. I had a necktie. There's a nice picture of the necktie floating out like this [demonstrates]. It got the students' attention at least. We actually did quite a few; we did not just that classroom from space, but I ended up working with the educational film people. We did a few educational films about ASTRO, which I was quite pleased with.

As with many things, what's supposed to be an auxiliary add-on event, the classroom in space of course, but it takes a life of its own, and it starts driving the rest of the schedule, because once you've lined up the schools and then public affairs gets involved, and then you've got to do it.

The other thing with public affairs on that flight was—and Aaron Cohen [former JSC Center Director] still talks about this. We had been told that on the next to last day of our mission Eduard Shevardnadze, who at the time was the foreign minister of the Soviet Union, was going to be visiting Johnson Space Center. They were going to arrange for him to talk up to the Shuttle to Vance Brand, who had been on the Apollo-Soyuz [Test Project] mission and had prepared a little speech in Russian that he was going to give to Shevardnadze. Then when it turned out we had to come home a day early, Vance was going to be asleep at that time. They

called up and they said, "Well, we're going to cancel it, because we don't want to wake him up in the middle of the night." Fine. I guess Sam Durrance, Mike [John M.] Lounge, and I were the graveyard shift. We were awake. We got a call from Houston. "*Columbia*, Houston. We'd like to arrange to do a com [communication] check at such and such a time."

We looked and we said, "This is one orbit before they had originally scheduled the Shevardnadze talk. This looks to us like the PAO [Public Affairs Office] is going to override, and they're going to do this talk after all. What are we going to do?" We did the com check.

They said, sure enough, "We're going to set up the talk with Shevardnadze."

We said, "What about Vance?" We looked, and he was sound asleep. We decided, "He's got to land this thing tomorrow. We're going to do this [conference] without him." I had studied a little bit of Russian in college, but that was a long time ago. I went down to the depths of my memory to pull out at least one sentence. "Greetings from space from the Shuttle *Columbia*."

We took the call. Sure enough, Shevardnadze was on there. He said something in Russian. Before they translated it, I answered in Russian the one sentence that I had been able to put together. Then I said, "And now I'd better translate that into English, save your translator some time." We had the rest of it. But anyway when we finally got back from the flight and got back to Houston, Aaron Cohen, who was the Center director at the time, he was just bubbling over.

He said, "Jeff, we had no idea that you were such a Russian scholar. You should have seen Shevardnadze's face when he heard Russian coming down from the Shuttle. It was just great." Literally every time I saw [Aaron] he would remind me about this. What happened was kind of nice, because the month after that, Queen Elizabeth and Prince Philip were visiting the

Center, and my wife is British. So I thought, "If I ever want to ask a favor of Aaron Cohen, now would be a good time to do it, because I'm definitely on his good guys list."

I called for an appointment and I went up and saw him in his office. He said, "Jeff, that was so great what you did with Shevardnadze. What's on your mind? What can I do for you?"

I said, "Well, Queen Elizabeth is coming, and you may remember my wife is British. I'm just wondering if somewhere along her itinerary there would be a place where at least she could get close enough to see her."

He said, "We can do better than that. Why don't you be their guides in Mission Control?" That was great. We have this great picture still of Barbara shaking hands with the Queen. We sent it back. Her father said he got drinks at the pub for months after that for his daughter and the Queen. So it really worked out beautifully.

In 2005, Aaron was up here [lecturing at the Massachusetts Institute of Technology]. What's the first story that he told to the class? He said, "I got to tell you about what Jeff did with Shevardnadze. This was 15 years ago."

He was just up here [again]. We had an Apollo 40 celebration in June [2009]. He and Chris [Christopher C.] Kraft were up here to be on the panel. Same thing, that was the first thing he said to people. "Got to tell you about Jeff and Shevardnadze." That was really something. That actually was when I started learning Russian seriously, because they had started talking about possibly flying with the Russians on Mir.

My wife actually, coming from Europe, had asked me, "Is there any way that you could actually do something over in Europe for NASA?"

I said, "Well, Moscow is in Europe, right?"

She said, "Well, yes, sure." Then I made the mistake. We actually went there for an astronauts' congress.

She decided that she didn't want any part of [it], so when I came back a while later and I said, "Well, it turns out I'm too tall to fit in the Soyuz, so I can't go up to the Mir," she was quite happy. We ended up going to Paris for four years, which was a much nicer part of Europe anyway. Things worked out in the end.

ROSS-NAZZAL: What a great opportunity.

HOFFMAN: Oh yes.

ROSS-NAZZAL: Would you tell us or share with us what you learned from the ASTRO mission scientifically?

HOFFMAN: Boy, it's been a long time. We've learned so much since then from Hubble. It was an ultraviolet telescope. At the time, it was able to make some kinds of observation with greater accuracy and precision than the Hubble instrumentation at the time could do, particularly given that the Hubble optics were not working properly. I think they took advantage of that even for the second flight of ASTRO, after we had fixed Hubble. It had capabilities in the far ultraviolet that Hubble at the time didn't have. I remember there was one example where they were looking for—I guess they were able to determine cosmic helium abundance with a greater precision. As I say, there have been so many astronomical discoveries since that it all blurs.

I suppose had I not been assigned to another flight, I had been invited to go, "Why don't you come spend some time while we're working with the data?" That would have been fun, but I was hard at work on the tethered satellite right after ASTRO finished so I never really had much of a chance to get involved in the data reduction. Yes, I saw the results as they came out, but it's all blended into a continuum with Hubble results and the results from ASTRO-2.

They did a lot of basically determination of chemical abundances and the physical conditions which you can see with far ultraviolet light more clearly than we could see previously.

ROSS-NAZZAL: Any other anecdotes from that flight?

HOFFMAN: Didn't I give you enough?

ROSS-NAZZAL: Sure, but we always ask.

HOFFMAN: I don't know.

ROSS-NAZZAL: I think you were the first astronaut to wear a tie in space. You had mentioned the tie.

HOFFMAN: As far as I know, yes. Yes, actually that was a nice story. My uncle was a New York lawyer, and he represented a lot of foreign firms who did business among them was the Hermès Corporation, which makes fancy silk scarves and silk ties and beautiful things. They were opening a new shop in Houston. He was down there; I don't remember exactly how it

happened. They had a publicity agent who was supposed to be organizing the tour for them. She did something to upset NASA and had given NASA the idea that Hermès was going to use their visit to NASA as an opportunity for publicity, so they said, "No, the visit is off, can't do that. Government property and everything, you can't use it for advertising."

This poor lady was running around pulling her hair out. My uncle just happened to hear this. He said, "Look, my nephew is an astronaut, you got to call him, he'll fix everything up." In fact I was able to do that, so the tour was back on. It was very nice because we ended up getting invited to a lot of the Hermès parties and things.

When I mentioned to them that I wanted to take a tie in space, they said, "Well, it has to be a Hermès tie of course."

I said, "Well, the only problem is your ties are all silk, and all the clothing we take has to be cotton."

They said, "Jeff, for you Hermès will make a cotton tie." Sure enough they made a cotton tie. It was a special pattern with a spaceman figure on it. They gave me actually two copies, so on a subsequent trip to Paris actually we visited the Hermès store, and I presented it back to Jean-Louis Hermès. They put it in their museum. It was really fun. You get a lot of fun things like that which we got to do as astronauts. Anyway that was an Hermès tie in space made of cotton, probably the only Hermès cotton tie that's ever been made.

ROSS-NAZZAL: I'll have to go check that out. So immediately after this flight landed you just —

HOFFMAN: I just carried right on. We had a little bit of postflight activity. There was a little bit of international involvement now that I think of it, because the instrument pointing system was

made in Germany, and it was a European Space Agency thing. In contrast to my other three flights, when we had European astronauts on board, and we all took European trips, but we didn't do that.

I guess the best trip there was the trip to the White House where President [George H.W.] Bush I was there. We've been to the White House three times, with [Ronald] Reagan, with Bush, and with [William J.] Clinton. Bush, he was really enthusiastic about space, he kept us there for about an hour, and then Barbara Bush invited us all back the next day. She said, "You got to come back for tea." She was just a lovely woman; we had a great time. She entertained us for an hour or hour and a half. That was really a lovely experience at the White House.

I went to the American Astronomical Society to give them a talk about the ASTRO mission. I'm sure I did a bunch of other things. Basically the work on the tethered satellite was in full swing, so I just got right back into it. That was an absolutely fascinating project because it was something that nobody had ever done before. It was like learning how to go to the Moon, how do you do it. Nobody knew how to control a tethered satellite.

In fact, the way that it had originally been designed, they had thought that this was going to be an easy thing to do. It was going to be completely automatic, and all you would do is push a button. It would go up, and then you'd push a button and it would come back. There wasn't any sort of manual control. It had an attitude control system [so] that it could yaw back and forth, but it had no control over pitch and roll, and this is just typical of the design philosophy when it was first done.

I asked the question. "Well, pitch and roll are controlled when the tether is pulling on it, but suppose the tether goes slack at some point. The satellite is going to go out of control."

The answer was "Well, why should the tether ever go slack?" They just never designed for any sorts of contingencies.

We said, "Suppose something is going wrong, and we want to stop the deployment in the middle."

They said, "Well, the only thing you can do is put the brakes on."

The problem is when the thing really gets going, it's coming out at several meters per second. That's pretty fast. If you just slam the brakes on, it's going to go wildly unstable. They basically had never designed for all these contingencies. As we did more and more simulations, and we learned more and more about the system, we came up with more and more scenarios where you need these manual capabilities. Of course money was tight, and the project manager was very reluctant to spend any more money to put in these extra capabilities.

I don't blame him for it. His job is to get the thing done on budget, on time. To his credit, when we could present good reasons why we need these capabilities, he went ahead and got the money and did it. In the end, as things turned out, every single manual capability which we finally had them build in, we ended up using, including an attitude control system, which they put in very late in the game. I think it was later than a year before launch, so there was no time to build in an automatic control system, so we basically had to control the attitude just by looking up at the satellite. We practiced this a lot in the simulator. The satellite would be pitching and rolling, and you'd look up and try to time exactly when it would get to the end of its pitch. Then you'd say, "Right roll, now." Somebody else would be on the computer and would have to [enter the command].

We got pretty good at it. It was a ludicrously primitive way of trying to control a satellite. We were basically in what should have been an automatic attitude control loop, but they didn't have time to build it, so we were doing it all manually.

Of course the idea was we wanted to get this satellite out to 20 kilometers. We could control the amount of current that flowed through the tether, because it had a copper core, so it was electrically conductive. As it moved through the Earth's magnetic field it generated a voltage, several thousand volts actually, that we could use to pump this current.

Then there was all sorts of plasma diagnostic equipment on the satellite itself, so it was an absolutely fascinating project, because we had the whole plasma physics idea. Studying environmental physics in an active experiment, and all the dynamics of learning how to control the tether, particularly when you try to reel the thing back and all sorts of instabilities can occur. As the tether gets shorter the instabilities grow, so we had to develop methods of damping them out, including using the Shuttle as an active control element, moving the Shuttle around to damp [them] out. Sort of like playing with a jump rope, you can get the jump rope going, and then if you shake it out of phase you can damp out the vibrations.

That's basically what we were prepared to do with the Shuttle, so we were using the Shuttle to do things that it had never been designed to do. It was really fascinating from all points of view: scientifically, engineering, space operations. They all came together, and [also] a lot of good opportunities for interesting photography, because we were expecting the thing to be glowing in the dark.

At the beginning of the flight first we had to deploy a EURECA payload and that went smoothly. Of course we had spent a lot of time in Europe; the EURECA was made up in Bremen, so we had been up there, particularly the payload crew. Claude, Franklin [R.] Chang-

Diaz and myself spent a lot of time in Italy. We had two Italian payload specialists, one of whom would be the first Italian in space, so there was a lot of excitement about that. It was a lot of fun preparing for that flight as well.

Then we finally launched; we actually launched on time. Actually I think we were, yes, [42] seconds late, because there was something where Andy [Andrew M.] Allen, I forget the details, but for some reason he was [42] seconds late turning on the APU [Auxiliary Power Unit]. He got a lot of grief from his pilot friends about that. He convinced us all that there was a good reason why he had had to do that, but I don't remember the details at this point. Anyway when we went for the second tether launch, he was commander, and he made sure that Scott [J.] Horowitz did the APU on time.

There were three parts to the flight: we were going to deploy EURECA, then we were going to do the tethered satellite, then we were going to take the Shuttle down as low as we could safely go so that we could study the airglow, the oxygen glow on the Shuttle. EURECA went fine, then we started to deploy the satellite. We extended the boom, and there's an umbilical up on top of the boom. It would not pull out, so this was the first of just a whole series of unbelievable problems.

They thought, "Maybe it's a thermal problem." We turned the Shuttle upside down so that it was facing the Earth. This was interesting, because at the time they had thought that after a successful TSS [Tethered Satellite System]-1 mission they would do a downward tether and actually drop something down into the atmosphere on a 100-kilometer tether, which would be quite fascinating. We actually had pictures of the tether boom pointing down at the Earth, which was something that was never planned for TSS-1, but there we were. Then I think we had to

shake it with the primary jets and finally got the umbilical pulled off. Then we went to start the deployment and it didn't start, and it didn't start, so we had to nudge that up.

We had lost a couple of orbits now. Finally it started going up okay. It's a spectacular sight, the satellite and then this tether linking it [to the Shuttle]. When the Sun set and everything turned red, it was just glorious. I thought, "Well, when the Sun rises, I'm going to be there with the movie camera and take a picture of the tether turning bright red and then gradually turning white, and that'll be a great shot."

I remember clearly looking through the camera. I saw the tether, it turned red, it turned white, then all of a sudden it started to get all these wiggles in it. Wiggles mean that there's no longer tension in the tether, that it's gone slack for some reason. There [are] various reasons that can happen. Either the tether has broken or it gets jammed and the satellite is coming back down at us.

Well, the tether wasn't broken, we could see that. The tether had jammed, in fact. The satellite had a jet of nitrogen gas to pull it away, so that was still on. But now, and here's where we get into the attitude control, it had bounced back. Now it was starting to tilt over. The jet that was coming out, instead of pushing it away from us, was now pushing it over to the side, so we, Claude and I, were trying to get control of the attitude to get it turned around.

Meanwhile Loren [J.] Shriver, who was the commander, was trying to [get the Shuttle under the satellite], because the thing was going over to the side. If it gets to a 45-degree angle, that's our red line. We would have to cut the tether, which we didn't want to do, so he was madly trying to fly the Shuttle to get back underneath it. We were trying to control it. Every once in a while I listen to the audio from that. It was certainly the wildest time that I've ever had in space, we were really up against the wall. We got very close to the red line, where we would

have had to cut the tether, but we managed to get it back under control and finally brought everything to a halt.

The thing was just resting calmly, about 150 meters above the payload bay. Everybody caught their breaths. Then we start, "What could happen? There's probably—" the tether went over a lot of pulley wheels and things. "There's a possibility that there's a little kink in the tether, so what we really want to do is let's pull the tether back. Instead of starting it up slowly let's start it up really fast and maybe the kink will work its way through this time."

Of course we couldn't have done any of these things without the manual capabilities that we had requested to be built in, so we did that. Of course, starting up the tether fast means the whole thing goes unstable again, so once again we're fighting to control the attitude of the satellite and to get it back. It went out another maybe 20 meters or so and then it stopped again.

Then we thought about it a little more. Mission Control said, "Well, that pretty much worked. We got another 20 meters, so let's try it again. Pull in ten meters, and then let's run it out fast." I don't remember how much time there was between these different attempts.

We did that, once again it went out a little bit further, but then it stopped again, so then they decided, "Well, let's try it one final time, and we'll see what happens." So we went to pull it in, and it wouldn't pull in. At this point there really was a jam in the gear. Now we're in a situation where we can't let the tether out; we've got about 200 meters of tether out there, we couldn't let it out, and we couldn't pull it in. Either you're going to cut the tether or what they decided to do was "Well, maybe we'll do another contingency EVA."

I thought, "What's going on here?" Franklin and I were the EVA crew, and we actually went through a prebreathe. We were going to do it, but then fortunately or unfortunately they came up with one final plan before. I was going to climb up the tower and basically pull it in

hand over hand, and Franklin was going to wrap up the tether. That way we'd be able to get the satellite back and at least have another try, maybe.

They came up with the idea that we would collapse the boom a little bit and then set the brake again. The motor that extends the boom was actually more powerful than the motor which reels in the tether, so maybe if there was a kink in there, by extending the boom, that would be able to pull the kink free. Sure enough, that worked.

At that point they decided, "We don't know what's going on, let's just retrieve the tether, bring it back, and we'll call it a day," so that was the end of TSS-1.

We did go down to the low altitude, which was visually the most spectacular thing I've ever done in the Shuttle, because you're down where the atomic oxygen is rather thick. The entire Shuttle was just glowing bright orange, just spectacularly beautiful. I don't know if you've ever seen Saint Elmo's fire on a boat. Saint Elmo's fire is more bluish, this was kind of an orange-white just an ethereal glow. It was so bright, you could see it with your naked eyes. It was just spectacular, so we did that for a day or so and then we came back and landed.

Then we went on a really very nice European tour because Claude was ESA's first mission specialist astronaut, and so they wanted to do this big, so it was a great tour. Then after the ESA part of the tour was over, Claude's Swiss friends invited us to Switzerland for a week, so it was great. We were being driven around in Mercedeses and Rolls-Royces and staying at five-star hotels.

That's not my lifestyle, but I was not completely unfamiliar with that. I remember a couple of the wives, they had never even been out of the country, and they were just totally blown away. I remember the watchword that I was always telling them. I said, "Enjoy it, just don't get used to it, because we're going to get back to Houston, and it's going to be life as

usual," because that's what always happens after a flight. You're prime crew. You're on the flight, do these great postflight things. Then you're back in Houston. "All right, back to work." That's just the way life is, so anyway, "Enjoy it, don't get used to it." We really did have a spectacular time.

That was August of '92. I remember before that flight Don [Donald R.] Puddy, who was head of Flight Crew Operations at the time, when we were in quarantine waiting for launch, he had said what was I interested in doing afterwards. Was I interested in Russia? Well, I'm too tall. Maybe another Spacelab flight, and I said, "What I'd really love of course, being an astronomer, I'd love to go on this Hubble mission," because already people were working on it.

He said, "Oh yes, you and all the rest of the office." I never thought much more about it, because I didn't think there was that much of a chance. When I got back, I think Story Musgrave had already been named as payload commander, but the rest of the crew hadn't been named yet. I guess I heard Dave [David C.] Leestma was either deputy astronaut chief or deputy Flight Crew Operations. I don't remember, but in any case I got a call from him saying that Headquarters had decided that, given the importance of the Hubble mission, they had put some requirements down on crew selection. Whoever was going to be doing something on the Hubble mission had to have done that before. You had to have somebody who had already been a commander, somebody who had already been a pilot, four people who had already done EVAs, and somebody who had already done a significant arm operation.

He said, "And the word that's coming back is that your name is on the short list." I started to get a little bit excited. I thought, "Could this really happen?" He came back, I don't remember exactly whether it was the next day or—anyway he said, "Well, I got to congratulate you. You're going to be on the crew." I think this was on a Thursday or Friday, it was towards

the end of the week. He said, "But they're not going to make the announcement until the end of the weekend," so I thought, "Oh, well, that's good, I'll have time to get home and tell my wife." I think she had kind of thought that after my third flight, since I didn't have another flight assigned and our oldest son was graduating from high school at the end of that year, if we were going to go somewhere else, that would have been a reasonable time to do it. I had made a few inquiries just to see what—I hadn't made any decision one way or the other, but I was testing the waters in a few situations. I think she had basically figured that meant, "We're out of here."

Then a little later I got a call from Dave Leestma saying, "Well, NASA PAO can't keep a secret, so it's out." I thought, "Well, I better get home before she hears about this on the radio." She was pretty upset. I won't go into the details, but we've made up since then, so it all worked out for the best.

Obviously I was really excited. The story that Barbara tells is that when we went to the next astronaut party all the astronauts were coming up to me and the rest of the crew congratulating. "Oh, this is great. You guys are so lucky." The wives were coming up saying, "Sorry, Barbara, you have our sympathies," because they all knew that she wanted out of there.

That was really exciting because we knew how important the mission was to NASA. It was a very different sort of mission than the training for the tethered satellite, because the [TSS] crew and the flight director and the flight control team, we basically figured everything out. We did the whole thing. [In contrast], a lot of people had been working on Hubble over many many years, so there was a whole set of tools and procedures, but it was our responsibility to do it. As often happens, when you're the person who actually is responsible, you start to see things in the procedures that other people didn't see. After a few months in the simulators, and particularly

underwater, we came to figure out that there were some things we could do faster by using different techniques.

It wasn't just our choice, because we were responsible to the whole Hubble organization. We basically had to convince the Hubble team. We had people from Lockheed and people from Goddard at all our training sessions. In particular, for instance, on the very first day of activity Story and I were going to go out to replace the gyroscopes. They had developed an elaborate procedure. In order to get easy access to the gyroscope you had to take the star trackers out. They were rather big. When we were in there working, we thought, "Well, if one of us could actually slide in underneath these we could avoid having to do all that rest of the work." Story is a little bit smaller, so we worked out the procedure where I would position him underneath the gyroscope and then I would use the power tool to undo the bolts. He would pull out the old gyroscope, hand it to me. I would stow it, hand him the new gyroscope. He'd put it in place and hold it there, then I'd drive the bolts home, then we would hook up the electrical connectors.

We could do it probably 30, 45 minutes faster than the original procedure, but there was always the danger that since we were shoving him underneath the gyros that he might damage something, because you can't really see what's behind you. We were working very close to a lot of very delicate equipment, so we rehearsed and we rehearsed. We finally said, "All right, we're ready for our final exam, get in the water with us. We want you to look really closely at what we're doing. You tell us if you're happy that we can do it safely." Sure enough they bought off on it, and we did. It turns out that that was actually a lucky thing, because we had problems on the first day and ended up staying out over eight hours. Had we had that extra half hour, 45 minutes tacked onto it, we never would have gotten the doors closed.

NASA was looking for any possible way to reduce risk and to increase the success possibility, so all of us had done EVAs before. We knew that often people get fatigue in their wrists, their fingers, and their upper bodies, so we thought, "Well, we owe it to the program that we're in as good a shape physically as possible."

I keep in shape aerobically, but I'd never pumped iron and tried to really work upper body muscles. We decided that we didn't really know the best way of doing the training, so could NASA get us a trainer to show us what exercises would be reasonable? I don't know how they got in touch, but they came up with the trainer for the Rice University football team. I remember I met her once when she came down to JSC; she was only coming down I think two afternoons a week.

She said, "Look. Why don't you come," since I lived right near Rice University she said, "come [to Rice] in the afternoon and I'll show you a few exercises that you can do." I remember going up to the entrance where the football team's lockers are. Big signs, "Football team only, nobody else permitted." I walk in, and I was two steps inside when this big hulking center comes up.

Says, "May I help you?"

I said, "Yes, I'm looking for Beth [Stringham]."

"Oh, yes, Beth." They all know Beth. She's a really tough lady; she was like the middleweight weightlifting champion for the country or something. A very husky, husky lady. Very nice, so she really did work with us. That actually set the stage, they've had physical trainers ever since. Actually playing a much bigger role now I think, in rehabilitation after the long duration flights even than in preflight preparation.

In fact Beth ended up marrying Bill [William M.] Shepherd. Bill is also a very husky guy. I don't know if they've ever had kids, but these kids would be like gorillas if they ever had kids. So that was just an example of the lengths to which NASA would go.

It was a wonderful mission from that point of view, because everybody was pulling in the same direction. I talked a little bit about intercenter rivalry between Marshall and JSC, which had existed, but none of that. Everybody was "Got to fix Hubble, and whatever it takes, we'll do it."

The only potential problem was that everybody wanted to form a study committee to make sure that we were doing it right. What's the first thing? You put together a new committee, they want to come down and talk to the crew. I think we had a total of like 13 different study committees that were looking to make sure that we were doing this right, some internal to NASA, some external.

I don't remember all of them, but in any case what management did again was a very good call. They appointed a mission manager, Randy [H.] Brinkley, who came down. He basically intercepted all this. It was, "You talk to me, not to the crew, and then if there's anything specifically that only the crew can answer we'll get them involved."

That worked out quite well. In fact a couple of the committees were quite useful. In one case for instance, the original plan for doing the repair was that all our tools would be in a toolbox out at the aft end of the payload bay, so every day we'd have to go out and load up the tools. That would take 15 or 20 minutes. We realized that the limiting consumable—on every flight you have a limiting consumable in terms of what you can accomplish in the mission, maybe the amount of oxygen you have or whatever. In our case the limiting consumable was useful EVA time outside.

We wanted to eliminate any EVA time that was devoted to things that were not necessary, including preparing our tools. We suggested to one of the visiting committees that if we could bring those tools inside we could save a half hour, and we would get them all ready to go before we ever went out. On a normal flight, just out of the question. We were several months from launch. They had done all the weight and balance. Just because the crew asks for it doesn't mean you're going to get it, but this was Hubble, and so sure enough, the tools were inside. Again that saved us a lot of time every day. It's just typical of the way NASA was working.

We were concerned. I know on my first spacewalk at night, the last nighttime one, when we had to stay out. I think I told this story where we had put the flyswatters on the end of the arm, and now they had to see whether the arm could cradle itself and whether the flyswatters would interfere with the payload bay door closing. Just when Rhea got the arm cradled the Sun set, and they didn't have the right lighting. That's when they asked us, "Would you mind staying out for another 45 minutes or so?" No-brainer.

While I was out there during the night my hands got really really cold, because you're radiating all your heat away into space. We weren't working very hard physically. I knew that would be the situation for Hubble. There was a lot of very intricate work, you're not really exerting a lot of muscles. In fact we never got particularly tired out working on Hubble because of that. All the tasks were very well designed, very suited for EVA. The thing about Hubble was when the doors to the telescope were open, they never wanted direct sunlight to come into the telescope, because it could evaporate some organic contaminants from the inside, which would pollute the ultraviolet optics. Ultraviolet optics are very sensitive to organic contaminants.

In fact the first of the WFPC [Wide Field Planetary Camera] instruments never worked very well in the ultraviolet. They think it was because of contamination, so we were very careful. In fact when we were preparing the tools inside, we always wore gloves on our hands so that we didn't get finger grease which would then outgas and could contaminate the optics. We were very careful about that.

The idea was that they would do the mission with the Shuttle's belly always pointed towards the Sun, that way the Sun could never shine into the telescope, so during the day the telescope would be pointed down to the Earth. We would be warm enough because the radiation back from the Earth would warm us up, but at night if this is the Sun now you're moving around and here's the Earth. [Demonstrates] This is during the day. Now at night we're pointing out to deep space. We knew we were going to get very cold, so we spoke to the mission planners about this. They got the thermal people to sharpen their pencils a little bit and figured that yes, some of the metallic equipment was going to get down to about 150 below zero. I was more concerned with my hands, but there was also some concern. "What's going to happen? We don't normally fly cold attitudes like that during EVA. What's going to happen to the equipment?"

So again this was Hubble, so they organized a thermal vacuum test, which is not cheap. Because of the stakes, they didn't want to take any risk that they could avoid, so I went in for the first test. We go in Chamber B, which you can run liquid nitrogen through the walls and make it very cold, so they cooled it down to the expected low temperature. This was when the tools were going to be in the toolbox.

I went in the spacesuit; I opened up the toolbox to take the tools out. Most of the tools I couldn't even get out of the toolbox. The little PIP pin, which is these little devices you have to press, and there's a little ball bearing which moves up and down. Everything was just frozen up

so it would have been a disaster. We would have been out there; we couldn't have gotten half the tools out that we needed.

So, that got people's attention. The engineers went to work; they took out all the residual grease. I guess they filed away, increased some of the clearances. It was Story's turn to go in to do basically the same test that I was supposed to do but that I couldn't do because I couldn't get the tools out, because we wanted to see did the tools actually work.

Story went in, and sure enough what the engineers had done was okay. He was able to get the tools out, and then he was exercising the tools. He was complaining that his hands were really really cold. No surprise, he was holding on to the cold metal. I guess a little while later the flight doctor who was in attendance just asked, "How are your hands, Story?"

He said, "It's okay. They must have warmed up, because they don't hurt anymore."

Bad sign for someone, but Story is a Southern boy, so I don't know, maybe he just didn't think of it. We think, "If your hands are cold and then you can't feel them after a while that's a bad sign." Sure enough, when he came out and pulled his glove off, his fingers were purple and black, and he had really severe frostbite. I don't know if you've interviewed him about this.

ROSS-NAZZAL: We haven't, but we talked to Dick [Richard O.] Covey, who told us a little bit about this.

HOFFMAN: That was really serious, because he might not be able to fly, so they sent him up to Alaska, where they have the world's frostbite experts. I don't know exactly what they did to him, but they managed to save his fingers, and he flew, but that definitely got management's attention. Essentially they said, "We can't fly this thermal profile because it's too cold."

Instead they had to do an attitude where we had to do two attitude maneuvers every orbit in order to make sure that the Sun wouldn't come in, but that had never been planned as part of our fuel load. We didn't have enough propellant to do that, so they had to come up with a new way of working the reaction control system jets so that they could do the maneuvers with less propellant. I sometimes use that as a story for my students here about how all these systems are interrelated, and who would have thought that the thermal system could force you to develop a different reaction control scheme, but that's the way it happened. Story did recover.

We did most of our underwater training at Marshall, because they had at the time the biggest water tank. That was before they built the new facility at JSC. It meant spending a lot more time away from home. It's more pleasant now. You go, you train in the tank, and then you go home in the evening; on the other hand it was nice because we were totally concentrated on what we were doing. We'd go down there for a week or so, and it was basically a routine which we'd get right back into the next time we went down. You get up early in the morning. We'd all gather around the table. There'd be a model of the Shuttle, Hubble, the arm, and the little toy astronauts. We'd go through the entire, "This is what we're going to do," because we were really trying to choreograph to try to eliminate any wasted motion, because that was the whole [mantra], "No, just keep doing useful work."

We fully expected there were going to be surprises. We could choreograph it as well as we wanted, but at some point we would have to improvise. At least the planned activities, we didn't want to waste any time, so we would go through that, then we'd go through the predive, and then we'd get suited up. We'd do the dive. Two people would be in the tank, the other two would go in in scuba gear, then we'd finish. We'd have our debrief, then we'd go to the gym and we'd work out, then we'd go and have dinner. Then we'd go back to the hotel and sit in a

hot tub and talk about what we were going to do the next day and "What did we learn from today?" It was total immersion in a way that you can't get when you're going home every night, so it was valuable. I didn't like being away from home that long but that's just part of getting ready for spaceflight.

We also spent large amounts of time up at Goddard, because they had the real hardware in their clean room. Two incidents up there. The two main instruments that we were going to install, the WFPC 2 (Wide Field Planetary Camera), which had the corrective optics built in, and then the COSTAR [Corrective Optics Space Telescope Axial Replacement], which had the rest of the corrective optics. They had a high-fidelity mechanical simulator in the Goddard clean room, built to the same specs [specifications] as Hubble itself. They actually brought the real WFPC 2, the actual flight hardware, so that we could look at it and get familiar with it. Then for one of the exercises, we were going to [put WFPC 2 into the mechanical simulator. It was] suspended by a crane, then we were going to actually insert it into the telescope.

We had brought our space helmets and the lights. We had gotten permission from safety to turn out all the lights in the clean room and that took a lot of doing, but again, it was Hubble, so they did it. We wanted to see exactly what we would be able to see, because we were very concerned that things could get hung up as you're trying to put this in. We didn't want to break anything, so we wanted to know beforehand, "How good a view are we going to have during the day? During the night?" We got WFPC inserted about halfway, and it hung up. "Stop. What's going on? Let's take a look."

We pulled it out, and it turned out that the thermal shielding on the outside had been installed in such a way that there was like a right angle piece, and it goes into a right angle, but

they had installed the thermal covering on the hypotenuse of the triangle so it interfered with the ledge that it went in. There was no way it was going to go in.

They went back to talk to the people out at JPL [Jet Propulsion Laboratory, Pasadena, California] where they had put WFPC together. The technician said, "We had a problem getting WFPC 1 into the telescope before we launched it. It was the same problem, because that's the way the drawings had been done, and the drawings were wrong." They had had to modify the thermal covering on WFPC 1 before they could get it into the telescope before launch, but nobody had changed the drawing, so WFPC 2 had been made the same way. Luckily, we had gone through this process. Again a very expensive operation to go through all this, but any way that they could reduce risk they were going to do, and that's why we went through this whole procedure. Then we got WFPC properly inserted.

A while later, it may have been another visit, I don't remember, but we went back to install COSTAR. COSTAR went in until about the last two inches, and it hung up. This doesn't build up a lot of confidence when neither of your two main instruments go in properly, so we pulled out COSTAR. Sure enough, there was a little bolt sticking down.

Now the high-speed photometer, which we had removed to make way for COSTAR, was slightly smaller than COSTAR. The fact that it was in there is no guarantee that COSTAR would get in there, so they looked at the drawings for the telescope. "What's this bolt doing here?" The drawing showed that the bolt was actually supposed to be flush, but it wasn't. Then the question was "Well, but what about the real telescope? Is the bolt flush or does it come through like this one?" Because again the fact that the high-speed photometer was in there, it could have gotten in with this bolt, but COSTAR couldn't.

We had lots of contingency tools. We had hacksaws and Vise-Grip pliers. We were going to do whatever it took, but as it turned out when we got up there, we pulled out the high-speed photometer and Kathy [Kathryn C. Thornton] and Tom [Thomas D. Akers] looked in. Sure enough the bolt was flat, but just an example of how things can really get messed up.

Which reminds me about things getting messed up, I never told you the final story about the tethered satellite. Why it got hung up. Remind me to get back to later, but I'll finish the preparation for Hubble, then I can tell you that and then take a little break as well, give my voice a rest.

We got the COSTAR installed, and everything got shipped down to the Cape. Anything that we could think of that could go wrong we tried to come up with, "Here's what we would do." I remember when we went down for the TCDT, the terminal count[down demonstration test], we were thinking, "What more can we do to get ready?" Of course we had the final few integrated simulations, and we went through them in the last few weeks, then we went into quarantine in Houston.

Oh, the other story I didn't tell you was the lights in quarantine. This is going back to ASTRO. I'm going to skip back and when we put it together maybe we can switch it back where it belongs, but in any case with all the hydrogen leaks we ended up spending a lot of time in quarantine. Normally you have six meals in quarantine. The people who cook for us, they're basically dieticians, they're not chefs. They want to be sure that we get properly nourished.

So they have their six meals, and those are the six meals you get. All the food has to be properly sterilized; every lettuce leaf has to be washed off with soap and water. They don't want us to get sick. If food isn't eaten within two hours, they put a big sign saying, "Not for prime

crew." It's a standard joke in the crew quarters, "All this food says, 'Not for prime crew,' what am I going to eat?"

"We'll fix you something healthy, and you can eat that."

We were getting thoroughly tired of this food. Quite a few of the people knew how to cook. Ron Parise said, "Why can't I cook some nice Italian food?" I don't know. Bob Parker wanted to cook something. We asked, "Could we do our own cooking?"

"No, out of the question. You can't do it, because only we can go buy the food, because it has to be special."

[We] said, "Well, look. If we give you the list of ingredients, will you buy the food? Then we can cook it."

"Well, okay." So we started doing that. Actually it became a tradition on all our crews; like the next flight, Claude did a cheese fondue from Switzerland, and Franklin did a Chinese food, and Franco Malerba's wife did some nice Italian thing. I don't remember what it was, but anyway it was kind of fun. It helps quarantine go by.

The other thing though was that when you have to do a sleep shift you try to stay up all night and then it's like working third shift. I was on the blue shift, so we didn't have to do that, but the other guys, Vance, Guy, Bob, and Ron, after a month in quarantine they said they still didn't really feel like they were awake at 2:00 in the morning. Somebody had heard about this research being done by Dr. [Charles A.] Czeisler over at Harvard [University, Cambridge, Massachusetts] in the sleep laboratory about the use of lights for changing circadian rhythm. They invited him to come down. He basically set up the crew quarters. They painted everything white, put white butcher paper on all the tables, fluorescent lights covered the entire ceiling wall to wall. It was so bright that when they first turned it on you needed sunglasses.

Then he had a special program; you turn it on at a certain rate to simulate twilight and so we were basically the first crew who used this. The difference was astounding. Again it's the sort of thing that the doctors would have liked to have done controlled experiments, have one crew do it and another crew not do it. It was just like black and white, so we just said, "This is the way it's got to be done." They've been doing it that way ever since. The new crew quarters has that light built in.

But my wife told me that—you get a little bit crazy, you run out of things to do in quarantine. She came in one day, I think she said she was glad that the news media wasn't in there because she said one of the crew was doing needlepoint, and another one was in the kitchen cooking, and I forget what [else]—not the sort of thing she thought astronauts normally would be doing, but we spent several months in quarantine.

I think in the fall when we were in quarantine for another one of the launch attempts, Dr. Czeisler came and visited us. He said, "I'm going to go through this procedure with you, and I'll stay up at night." We thought, "Gee, this is great. This scientist, he's actually testing out his own thing."

After two days he went on his way. We said, "You're going back to Harvard now to confirm that all this worked?"

He said, "Oh, no, I'm on my way to a conference in Japan, I just thought this would be a good way to get used to the time change." It really does work, so anyway yes, that was something.

So now going back to Hubble, we went in. Now we're all on the same shift, so we all have to stay up. It's so bright in there you can't even see your computer screen. At least in those days they didn't have daylight computer screens. You could watch television; somebody had

gotten ahold of a Tim Allen, you know from *Tool Time*—comedy routine. We watched that over and over again. We kept laughing about it and got into some of his "More power, uh," that sort of thing. The reason I mention that is because eventually we were on *Tool Time*, which came out of all of that, because during the flight at one point I think one of the batteries on one of our power tools was running down, and so I said, "Oh, need a battery."

[Kenneth D.] Bowersox said, "Yes, more power."

Then someone else, I don't even remember who now, said, "Uh, uh."

Someone on Tim Allen's show picked up on that and said, "What are these guys up in space doing?" They invited us to come and be on *Home Improvement*. Because they wanted us to come out to Hollywood, I remember thinking, "No way is NASA going to let us do this."

But actually I think someone in PAO was clever enough to realize that at the time *Home Improvement* was the most popular show on television, which is a bit scary, and they said, "This would be great publicity."

So we went out, we had this great week in Hollywood. We had to go and rehearse in the afternoon, and the rest of the time we were on our own. We were on the show. It was great fun. Every year they keep running reruns. Every year a student [says to me], "Professor Hoffman, did I really see you on *Home Improvement*? Was that you?" So that's been with us ever since. Yes, it was fun.

We're getting towards the end of the training with Hubble. We had gone through all the integrated sims; we went through quarantine. When we finally flew down to the Cape, I remember we were standing on the pad, looking up at *Endeavour*, and thinking, "I hope this goes in time, because if we have to go back in Houston, there's nothing more we can do." Basically if someone had said, "Take another six months, get yourself a little bit more ready for flight," we

realized we didn't know what we could do. Everything that anybody had thought of we had done.

We were about as ready as you could be. In fact, we did have a launch delay, because we were originally going to go on the 1st of December. I remember thinking to myself, "My ASTRO flight was on the 2nd of December, that's the right time to fly." The crosswinds were predicted to be above limits on the 1st, but they had us get in anyway. We were sitting in there, and the Shuttle was rocking back and forth with the wind. I was convinced, "We're going on December 2nd, because that's the right day to launch," but we waited for the entire time.

Sure enough we had to get out. The next day I remember Barbara, she said, "I can't say goodbye to you again." So she sent our oldest son, who had just turned 18. You have to be 18 to come in quarantine, so I spent the day with him. That was nice, and then we went. Sure enough, December 2nd 4:00 a.m. we launched. Let me take a quick break, and I'll be right back.

[Break in audio]

ROSS-NAZZAL: You'll also have to check out also some of your colleagues. We've got their transcripts online. See what their recollections are of their time on those flights. I think it's interesting to hear the different stories.

HOFFMAN: Yes. I know enough about human memory to know that it changes. Particularly when you get older people doing their recollections of what happened. What you would like to remember sometimes mixes in, and then some things you just forget, or you remember things that other people told you as having actually happened. That's one of the problems that

historians have trying to put together what actually happened on the basis of what people said happened.

ROSS-NAZZAL: Yes, absolutely. That's where documents come in handy.

HOFFMAN: But not all documents agree either.

ROSS-NAZZAL: Yes, that's true. Yes, so you were going to tell us about the TSS.

HOFFMAN: What happened was obviously there had to be a major investigation for what went wrong. This was very embarrassing to NASA. The Italians did the satellite. It was the early days of the Agenzia Spaziale Italiana, which is the Italian Space Agency. This was their first big mission, a lot of publicity. The satellite worked fine; in fact the satellite was brilliant. We were able to use the jets to control it in a way that had never originally been imagined.

It was really the part that NASA had built, which was the whole deployment mechanism, which for some reason didn't work properly. In fact, we had had multiple failures. We had had the failure of the upper umbilical too. We had the failure of the initial deployment attempt, then we had had the getting stuck on the way out and then getting stuck on the way in. There were multiple problems. So a major investigation was launched. Here's what they came up with for why the tether got stuck; I won't go into the umbilicals. When they redesigned it in fact they removed that upper umbilical, and they made a few other changes in the mechanisms.

We had 20 kilometers of two-millimeter tether—so that's about a tenth of an inch—wound around this big drum. It was essentially like a big spinning reel, a fishing reel. Like a

spinning reel, as the tether is wound on you need a mechanism to make it go back and forth and back and forth evenly. It's called a level wind device. On a fishing reel they have a little catch that holds the line; it moves first to the left, then it gets all the way to the left and moves back to the right and then to the left and so on.

It's geared together with the reel so that as the reel turns the little level wind mechanism moves back and forth. There was exactly a similar sort of mechanism on this big reel of the tethered satellite. The level wind moved back and forth. It was geared together with the big drum. After the payload tests had all been completed, and we had had our final integrated test of the payload, I'm not sure I get the exact sequence right, but they always have to do a structural loads analysis for all payloads that fly in the Shuttle.

Somewhere late in the game, I think it was Lockheed who was responsible for that, but they changed the model for some reason. I don't remember the details, but the upshot of whatever was done was that there was a negative margin holding this whole big tether reel assembly onto the underlying pallet. No big deal. The normal way you would fix that is you would just take it off, put in some reinforcement, and put it back together again.

The problem was everything had been integrated, so we would have had to tear this apart. It would have been a several-month delay in launch, and they didn't want to do that. One of the engineers came up with what was really quite a brilliant idea, which under other circumstances he probably would have gotten a medal for it. Said, "Rather than take the whole thing apart we have some structural pieces which are coming up which we could actually put some bolts through those and bolt that to the tether reel assembly. That will give us the extra structural margin we need, and we won't have to take anything apart." It was brilliant.

Now I use this often when I lecture to my students about systems engineering. They unfortunately did not go through the entire systems engineering process as it should have been done. One of the fundamental rules that we always try to follow is when you're doing testing and preparation for flight, test it like you're going to fly it, then once you finish the tests don't change anything. If for some reason you have to change anything, it should be a major undertaking. Everybody needs to be informed, so that everybody knows what's going on. If anyone can think of problems, you've got to just keep your hands off.

Well, they didn't do that. They got a drawing to confirm that everything was going to be okay. It turned out afterwards that they were using an out-of-date drawing, so another failure of systems engineering, but they didn't do all that should have been done to make sure that there wasn't going to be a problem.

In fact, what had happened was one of the bolts had come through in a position where it was interfering with the level wind. So the first 150 meters—the level wind started over here on the left side. It came over 150 meters, it hit the bolt, and everything came to a stop. That's what caused the first jam. Because the people on the ground thought that it was a kink in the tether, we wound it back, then "Now let's take a running start." Now we came smashing in and actually bent the bolt. That's why we were able to get out another ten or 20 meters, because when they took the whole thing apart this bolt was bent way over.

Then when we did it, I think the third and final time, we were letting it go so far out so fast that a kink actually did develop in the tether. That's the kink that got stuck in the gear mechanism up at the top of the tether boom, and that's what prevented us from pulling the tether back in. It was basically this bolt which was interfering with the level wind. When we heard that it was like misgrinding the Hubble mirror. It was just one of these incredible blunders.

"How could anybody have done that? Whose head is going to fall?" We were basically out of it by that time. Of course, given what happened on the second tether mission, we may well have had problems. Or, we may not have. You never know, because the short circuit there may or may not have been in existence four years previously, but that was a horrendous discovery when we finally found out how the whole thing had failed.

At that point the project office at Marshall started making plans for a reflight. It was a question whether NASA really wanted to do that, but I think partly because of the Italian involvement they felt that we had a responsibility. Then we had one of these nonadvocate reviews, which I was taking part in. I don't remember whether that would have been before or after, probably after the Hubble mission I think. I got fully involved again with tether. That's '94, we flew in '96. Yes, that was probably a couple years before flight. We had the nonadvocate review, and a lot of people talked about the interesting science and engineering that could be done with this, so NASA did decide to go ahead and have the reflight, at which point we were told as the payload crew that we should plan on flying with that.

Surprisingly, Barbara was not upset that time. Hubble took her by surprise, but just by the way we had always talked, she and also Claude's wife—they're close friends, and Franklin, they always knew that if they were going to fly tether again that we were going to be on it. We were all good friends at that point, so they were happy. That was a lot easier.

So that was the sad ending of the first tethered satellite. I guess the other thing we were talking about, during the return to flight period when I was doing my master's degree at Rice, I also started working on the Payload Safety Panel, which was a very interesting activity, because it really gave me my first exposure to the whole safety process. I really learned a lot, which has been very useful over the years. It gave me a lot of respect for how carefully people look after

the safety of things, but at the same time, it also showed me how difficult NASA makes it for people who want to use the Shuttle. The amount of paperwork that you have to do to get a simple university experiment flown on the Shuttle—piles and piles of paper such that you have to basically hire a contractor to do it for you, because academics just can't handle that amount of paper.

It's a process which ensures safety, but it does not make it easy to do good research. It's a problem which we still face with the Space Station. I don't know if NASA is going to figure out how to really turn the Space Station into a usable scientific laboratory until they figure out how to make it easier for researchers to get access to it, but that's another story.

Given that I was now an experienced EVA crew member because of my first flight, I got assigned to work in the EVA Division as one of my jobs. One of the things that they were doing back then was to try to develop what they call an eight-psi [pounds per square inch] suit or a zero-prebreathe suit, ZPS so to speak. The idea is that when you go from atmospheric pressure to the spacesuit operating pressure of four pounds per square inch, you'll get the bends. For instance on the ground before we go into a vacuum chamber I have to spend four hours in the suit breathing pure oxygen to denitrogenate my blood, to make it safe to depressurize the suit. Four hours in space is unacceptable.

We get around that with the Shuttle by depressing the Shuttle to 10.2 psi when we know we're going to be doing an EVA. We actually did that on the first tether mission when Franklin and I were prebreathing. We had started a prebreathe on the oxygen masks, and at the same time we were letting air go out of the cabin. That was another interesting thing; it had not occurred to anybody that the air that was coming out of the cabin was all going out in one direction, so it was

actually propulsive. Under most circumstances you'd never know it, but we had a tether sitting up there.

After we'd been letting air out of the cabin for 20 minutes we looked out, and the tether was way over to the side, because the Shuttle had been pushed over to the side, only by ten or 20 yards. Without the tether it wouldn't have made any difference, but again that was an instability. We knew how to correct it so when the tether swung back we took out the velocity, but it was interesting that nobody had thought of it when they told us to start the cabin depress.

On Space Station there had been a big argument between the operations people and the life scientists. The operations people wanted to be able to run Space Station at ten psi, because they knew that we were going to be doing a lot of EVAs, and they wanted to be able to do the normal 40-minute prebreathe, like we do out of the Shuttle. Life scientists said no; the purpose of Space Station at the time was to do life science research. They said, "All of our baseline data is at one atmosphere, and if you work at other than one atmosphere, none of our data is going to be valid."

Now a lot of us in the operations world said, "But look. When we talk about doing the life science research it's supposed to be to support future exploration. Future exploration, we're not going to have one-atmospheric cabins. So why don't we pressurize the Space Station the way we think that future exploration vehicles [will operate]?" The operations people lost and the life scientists won out. So Station was only designed for one atmosphere; you can't reduce the pressure.

As a result, if you're going to use a four-psi spacesuit, you're going to have to prebreathe for four hours, which is essentially what we're doing now. There's various ways of doing that, but it's a fairly involved and time-consuming activity. If you could develop a spacesuit that

operated at eight psi, then you wouldn't have to prebreathe, because if the change in pressure is less than a factor of two, experience shows us that people don't develop the bends, so that was the motivation behind the eight-psi suit.

The problem with the spacesuit at higher pressure is it becomes stiffer. It's harder to move. This is a particular problem with the gloves. We weren't testing eight-psi gloves; we just used the regular gloves. We had two different kinds of suits, one developed at JSC and one developed at Ames [Research Center, Moffett Field, California, which] used to have a big EVA group. Theirs was a hard suit, looked very much like a robot with a lot of articulated robotic type circular joints.

It was very easy to move around in, although it was very bulky and heavy. We had to test these suits by doing a lot of construction jobs using the old [EASE/ACCESS (Experimental Assembly of Structures in Extravehicular Activity/Assembly Concept for Construction of Erectable Space Structure)] payload. It was a big construction project that had been done on one of the early Shuttle flights. It was actually designed here at MIT [Massachusetts Institute of Technology, Cambridge, Massachusetts].

That was something that had been done in space, and they thought that would be a good test. So we had to do that, both in a regular spacesuit and in each of the eight-psi suits, and then we had a whole bunch of other mobility tests and reach. It was a very thorough evaluation. It was quite interesting for me, because it got me much deeper into the EVA community than I had been before, and I learned a lot about spacesuit construction. Also learned more about the intercenter politics between the EVA group at Ames and the EVA group at JSC. That's another story.

In the end, our recommendation was that neither of the suits were adequate. This was on top of the fact that nobody had been able to develop eight-psi gloves in any case. I know at Ames they were not at all happy to hear that. At one point the deputy chief of the Astronaut Office came to me, and he said, "Jeff, we've got a congressional demand from the California congressional delegation knowing why we're not adapting the Ames suit. What can you tell me?" These things happen. So I explained that "We're not recommending adapting it because it didn't work. There were numerous things about it that we didn't like." That was probably the end of it, but I was amazed in my naivete. Why would Congress get involved in something like this? But I know better now.

ROSS-NAZZAL: Tell us about your work with the Astronaut Office Science Support Group that you helped form.

HOFFMAN: Well, as scientist astronauts several of us were often asked to work with scientists who were preparing experiments for space. For instance, I got assigned at one point—there was a combustion science working group at the Glenn [Research Center, Cleveland, Ohio] at that point it was the Lewis Research Center, so I was basically their astronaut contact.

I went up there periodically when they would have their investigators' meetings and tried to give them advice. "You're trying to design this, but you're asking the crew to do this. In weightlessness that's going to be very difficult. We should change things around and so on." It was nice, actually. On my last spaceflight we had a glove box, and we actually performed some of the combustion experiments that I had been working on. This was early on, this may have

even been in the early ’80s while I was still getting ready in the early days of my training. I don’t exactly remember, but it was kind of typical.

All of us would have similar experiences where we would be presented with experiments that people thought were ready for flight, but clearly there were aspects of the space environment that they didn’t understand. We could often see ways in which things could fail or just ways to make them more efficient, so we came up with the idea of “Maybe the scientists in the [Astronaut] Office should form an advisory group so that we could work with people who were designing experiments.” At the same time we thought, “They’re always having lectures to the Astronaut Office about various aspects of aircraft safety and space operations. Maybe we can invite some science people in to give maybe a monthly lecture to the office about something of interest.” So those were the two motivations.

Franklin, Bonnie Dunbar, I, Rhea Seddon, a couple of other people were the founding members. Actually we had a fair bit of success in the first few years, but as often happens then we all got assigned to flights. You get so busy that we couldn’t really continue it, but I think some of the payload people took over that kind of philosophy with the idea that we really have to look at these experiments from a user’s point of view. The only difficulty is that when it’s not the users or people who are really scientifically knowledgeable, but instead they tend to be the engineering contractors who do this, they tend to go very strictly by the book. That again often ends up making life more difficult for the experimenters rather than less difficult, but that’s the way things evolved. We were active for a couple of years. Then after return to flight, and everybody got busy doing lots of different things, and we really couldn’t keep it up just as astronaut scientists.

ROSS-NAZZAL: You made a film: *Shuttle Science Operations, Lessons Learned*. Is that something that you all participated in?

HOFFMAN: Yes, I still have a copy of it. We look very young. Have you ever seen a copy?

ROSS-NAZZAL: No I haven't.

HOFFMAN: I'm in the process of transferring a lot of my tapes to disc. I'll transfer it to disc and I'll bring a copy and I'll give it to you and you can take a look at it.

ROSS-NAZZAL: Great. Well, I think that's all the questions I had for today. We can pick up next Thursday when you're in Houston.

[End of interview]