# NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
# EDITED ORAL HISTORY 2 TRANSCRIPT

JAMES R. JAAX
INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: Today is October 17th, 2006. This oral history is being conducted with James Jaax in Houston, Texas, as part of the NASA Johnson Space Center Oral History Project. The interviewer is Rebecca Wright, assisted by Jennifer Ross-Nazzal.

Thanks again for coming in again today. We concluded your first interview earlier this month, and we stopped it with your participation in the Apollo-Soyuz Test Project. If you would, start today by sharing with us your thoughts at the end of this mission, since it was the end of the Apollo era, and then tell us how you made that transition into the Shuttle era in your new task.

JAAX: Okay. To me the Apollo was an activity that I came in late as far as the actual Moon landing program, so not very many activities that were directly supporting Apollo 11 through 17 where I hoped to participate. They would have experiments or something where they'd want me to participate a little bit, but more they got me into these advanced studies and that's what gave me the opportunity in the Apollo-Soyuz that I described.

The Apollo-Soyuz was to me a fitting climax. We had proven we could go to the Moon, and now we were actually working with this unknown entity on the other side of the world that we weren't sure what their capabilities were in space versus ours. We knew of the Cold War and all of that, but actually they turned out to be very human just like us. In engineering they were just as qualified as we were to do what we were doing, and that was very rewarding, in that we got to meet them and see their culture, and they got to see our culture, and we got to exchange the way we do things with the way they do things, and I described those the last time.

What was going on during that time was the Skylab Program, and again, Skylab, I guess they had a dry workshop, then a wet workshop type of thing. But they had moved a lot of the activities over to Marshall Space Flight Center [Huntsville, Alabama]. My division, which had the environmental control and life support activity, continued to monitor or manage the Apollo piece of it that would be docking to the Skylab. But the orbital module that had the life support system that would support the crew while they were staying for the duration that they stayed on the Skylab, was really more done out of Marshall at the time. We would sort of help a little bit, but really didn't—only when there was a technical interface issue as to how would this, if you open up the volumes between the Skylab and the Apollo, what could potentially be the problems there; what material problems you'd have there.

I didn't get really involved in that, either, because I again wasn't the technical expert on that stuff, so that left me open to work on a bunch of other things. The nation was trying to figure out where to go, so they didn't know whether they wanted a truck, which is the Shuttle, or they wanted a Space Station, which is the place that you'd be going to. They did a bunch of Phase B studies, as we call them, which is a definition phase of what the systems might look like in the overall structure of the program, and leading to hopefully a Phase C/D contract, which would be the actual design and development one.

My division had me work with the Space Station piece of it, and there was another fellow in my branch, Bill [D. William] Morris [Jr.], who did the Shuttle part of it. So as we're going through Apollo-Soyuz activity, we're also monitoring what, in my case, North American Rockwell was doing with the ECLSS [Environmental Control and Life Support System] design for a Space Station. They went through the Phase B studies, and I think those were in'72, '73. Even prior to that we had done a quick look at what they had produced first versus what McDonnell Douglas had done under the leadership or guidance of Marshall Space Flight Center. I was put on a team to go to Marshall to review what the two contractors had done and come up with a recommendation as to what we think the better solution was.

About that same time was when they finally made the decision as to which way to go, and that would be the Shuttle. I hadn't been prime on that, I had not been in at the base of it, but we shifted our assets to then start helping that, and that's where I got in on the ground floor. Since this other fellow had been working it he took the lead for a while, so that freed me up to work on some of the spacecraft design options that the Center had and looking at other ways that we could utilize our talents in space.

I worked on the Rockwell piece of the Shuttle, a little bit just looking over what they had until probably about '76, '77, when they made me a prime interface for the ECLSS system with Rockwell. We worked out what the system would look like, and I got to then meet the people who I found were the people who had really done the Apollo environmental control and life support system, and found they were excellent engineers and design people.

You have this worry, and if you remember, I said in the Russian program that there had been an engineer who had come over here. He'd been working with their program from day one, and he had looked at me and asked how long have you worked here, and said, "You're green," because I'd only been here three years, and he'd been working probably about 10 years in his program and had a lot of responsibility.

I looked at the Rockwell people, George Laubach and O. T. Stole, in the same manner, as they were very experienced with having gone through the Apollo, and now they were on to the

Shuttle Program. So a lot of the hardware had changed to some degree, but what could I bring to help them do that? We had subsystem managers as the interface, and I was not a subsystem manager. They made me more an analysis manager is what I'd call it.

There was never an official title, but in the division we had a hardware group; that's where the subsystem managers were. Then we had a systems engineering group, and our job was to look at the bigger picture and try to make sure we understood how this system that we were responsible for would interface with all the other systems in the vehicle, and we developed analytical models to do that. So they put me in charge of a couple of contracts—of contractors, which were usually from two to ten people—that were looking at the environmental control system and the active thermal control system.

The surprise we had when we went to the selection of the Shuttle contractor, and again, at that time I'm still working on these other special studies, so I wasn't on the source board or the source selection group there as a technical thing. I think I went in a couple of times to read a special section of the proposal and then give comments, then you step back out of it. Later I was involved intimately in a lot of the source boards.

The design of the systems that were proposed by McDonnell Douglas in this case were very close to what we had under our Advanced Development and had been looking at as the way to go for the next generation or the next spacecraft that we had. North American Rockwell came up with a design that included in the heat rejections area a flash evaporator. Did I say anything about that the last time?

WRIGHT: No.

JAAX: Okay. We discovered that this was a device we'd never seen before, but it's the heat rejection device that the vehicle uses from liftoff, or above 100,000 feet until you get up on orbit. You can open the doors, and on the inside of the doors we have radiators that are able to radiate heat away. You just run hot fluid through this. They've got a skin on there that gets warm. It looks at deep space, and through radiation it cools the fluid that's gone through there, so it's cool to come back down.

In between when you've got the doors closed, you've got to use some kind of expendable or a heat sink, which could be wax or something, but usually use a liquid like water. Since the fuel cells were providing the power for the spacecraft, then you had excess water, and we could use it to boil the water or evaporate the water or some process. So we had worked with a design on that with Vought, or LTV Corporation, in Dallas [Texas], and Rockwell, when they were chosen to be the lead, had not chosen that design. They had chosen one from Hamilton Standard, who was normally a provider of environmental control systems. We knew that area very well, but this particular device and this particular technical area was something that we'd never had exposure to, didn't know that they could even do.

So the division immediately tried to figure out why Rockwell had chosen this, so I was there when the big question was asked of them, and I can remember George Laubach's reply. He said, "Well, they came in here saying that they knew what the standard was for rejecting heat with something like this. And they said, 'We can do that job for half the weight and half the cost.' When they said that, we had to listen to them." Now, this is Rockwell speaking, of course.

We said, when they said that, "Where's your proof of any of that, that you could do that?"

He said, "Well, we saw what they did,"—now I'm speaking for Rockwell—"and we think that it's got a feasible thing."

"Well, who's the expert that can tell us about this thing?"

"Well, they're all at Hamilton."

"Well, those are the people that are selling to you, so how do you believe this?"

That was our bigger challenge, and the radiator design was something that was pretty much—we understood, and then focusing more on the active thermal control systems, that's the area that I ended up being responsible for. So I'm still in a branch as a working engineer, and after a few months went by there, I literally had my branch chief call me into his office and tell me that, "Hey, we don't understand this device. We don't know what it does. We don't know if it can do what it's supposed to. If somebody in this branch doesn't figure that out, we're in real trouble, and you're the guy I want to do this."

I didn't really know much about the process. I had worked with the advanced development a little bit, but this other fellow, the one that I was referring to who had worked always with the Shuttle during the early seventies had been the guy who had worked on it. The first thing I did was I collected every piece of information I could about this flash evaporator; what is it, what's it do technically, how does the physics work on the thing, and I wrote a book.

I wrote a document so that I could capture all the requirements that we had on it, all of the design data that we had on the thing, and the history of it, so that we would all be speaking in the same voice, and not that you would hear a rumor and say what you think, and then you'd hear another rumor. So my job, I felt, was to try to get an arm around this thing and bring it in closer so we could understand what's it got to do, what's its capability or potential from a theoretical standpoint, and this is going back into the basic physics of it. We had a couple of people in the division, or in the branch, in fact, who could do that kind of analysis, so I worked with them to try to see if theoretically this thing does what it is and can we get twice the capability that they're talking about in this application.

It turned out that technically it was possible to do that, but we couldn't prove it through tests, because they hadn't built one yet. The first thing they do is they try to put it together. Well, the difficulty in building this thing is it's a cylinder shape, and it's probably about 18 inches long and I'd say close to 12 inches diameter. There are three concentric shells that are all pieced together, and in between the three shells are two surrogated, finned areas here that one shell will have one piece in that surrogated area, and the other will mate up against it. And it has to be perfect, because that's where I'm flowing my coolant fluid through, so I can't have a spot that's got no flow or got a lot of flow through it. It's all got to be equally distributed.

That's the second shell, and then I've got another fluid path that's going on through this surrogated web that's on the outside there to a third shell. It's a clever idea, and it technically could work, but can you make one? Well, fortunately, the first time they tried, they made one, and we were able to use it as a development unit.

Another unique feature was that what you're doing is taking water and literally squirting it into this cylinder. It's got a vacuum in there, so the water will sublimate real quickly, and in the process sublimation is going to have heat, so it collects that from the fluid that's hot, and that's how it cools it down as you go through this thing. But it's then got to get out to space, so they had put a hole at the bottom, which was a pretty good-sized, six-inch hole. But you don't want the liquid to just go immediately out there, it's got to splatter it against the wall. So they put something they call an ACOD [anti-carryover device], which is just a cover, you might say, over the top of that had an opening at the bottom of the thing that the water or liquid that's already sublimated could get its way out. So it was sort of a torturous path to get through there.

The important thing was that you had this cylinder, all of the things were welded so that there was no hot spot or cold spot or anything else. We got the first device; brought it. They tested it some up there, and it seemed to do pretty good, but we told them that, "The chamber you've got up there is too small, because the feedback you get because you're blowing gas out into the chamber, it raises the pressure in there so that you don't get the same response as far as what the device is doing as you would out in space. So we have a chamber down here in Houston that does that." We convinced the program that it would be best to test this thing down here and see how it responds.

When they got down here and we put it in the chamber, we found that there were some modifications that had to be made to get the thing to work. But the bigger problem was that while we're doing this, they're trying to make a second one; a third one. You know, trying to make the second one. They went through 61 bills and I think over a lengthy period of time, where we've got one device, and we're just trying to get a qual [qualification] device, another one, to do this while we're doing this testing on this thing.

I think around the 61 or 63, they got the second one to work fine. And what you've got is this flux, which is the material that's used to give you the weld, you might say, on there, they had to put wooden pieces—I believe it was wood—inside of this inner shell so that it would equally expand or contract as you go through this process here. It's not only magic, but it was black magic, as far as doing it, and it's like many processes you discover, it's the guy or the technician who does it who makes it happen, and if he's not there, nobody else can replicate what he did or how he did it.

So they went through a long period, and we're down here testing the device. The device down here, the biggest problem we had was that it kept making ice balls, which was not good, because that meant it can't do its thing. It's got this liquid that's supposed to sublimate to a gas, and it's supposed to go on out, but instead it's got someplace in here—we call them nucleation sites—where it would get a drop of water, and as soon as you'd throw another piece of water on it, then it would make snow, like a snow cone. It would just grow into this snowball as such.

We'd set up this test, and we were trying to see if we can get the device to work. We'd do a pump-down on the chamber, run a few tests there, and discover we couldn't get anything done, so we'd raise it back to sea-level pressure. We'd have one of the Ham[ilton] Standard technicians like Milt Garrison [phonetic] go in there and literally shave off or put a shim in with a borescope—that's a little eyesight thing that you have—to try to make sure that there was no sharp edges, no ledges, no anything in there. Finally he got it so it reasonably worked.

My job during that time was to do the analysis and to see if it was working with these analytical programs we had and also trying to get performance out of it so we could verify with the power people that the power profiles that we were planning for ascent and for entry and that would all work. So I'm interested in every one of the test points that they've got there, but there's somebody else that's in charge of actually running the tests and managing that. I'm looking and concurring with him on here's the test points we need to run.

Well, about a week into the tests, we have daily meetings at seven in the morning or so to say here's what we're going to do today, and this is when we're going to do this activity. The division chief, Walt [Walter W.] Guy, comes into the meeting there, and we're looking at the test matrix that we've done here, and what the guy had was a sheet of paper on which he had filled up columns of conditions as we go through this; go through test point one, two, three, four.

Well, after two, it failed. So he went on to three, and it failed again. All of those are successively harder test conditions, so you know after the second one, there isn't any way it's going to pass four, five, six, or whatever it is. But he had designed it this way, and he was going to follow it this way.

I'm sitting here like we're doing, listening to this, and the division chief is telling him, "We don't need to do that anymore, because we know it's already going to fail. Let's go over here and try this. We need to find out how it works."

"No, I designed it like this. This is the way I want to do it."

"No, you need to move it like here."

Then I'm asked, "Are you getting any good data?"

I said, "No, I know it's going to fail, too, because I've seen it. I'd like to see this other stuff."

So then, "Are you going to move it to this other thing?"

The guy says, "No. In fact, I haven't had vacation in two years. I think I'm going to go on vacation. I'm going to leave."

So Walt turns to me and says, "Well, you're in charge of this test. You get to run this." I agreed with Walt that we needed to look at where this thing does work and see if we can characterize it and to try to minimize the number of down times.

Our biggest problem during that whole test was we were using the large—I think it was Chamber B in Building [32]. It's a huge thermal vacuum chamber in there. They used to have this dial of gauges as the way you control the systems in there, so they had just automated it. We're talking back in '78, so it's not a today-type automation; it's going to the computer, but the biggest problem for those computers in those days was the amount of data you get.

It's the same thing we have on spacecraft. Engineers would like to have data on every instrument on every surface they can get ahold of so that they can see how this thing responds and get the full effects and have every piece of data they could possibly think of. Back then, as even today, the computers can only swallow so much information every millisecond or half second or second or whatever it is.

In order to allow this computer to absorb and store and digest and then feed back to you the information instantly, you had to figure out, well, do I want this sensor, its input, to be looked at every millisecond or every half second or every second or every two seconds or every ten seconds. In the thermal world there are a lot of things that you could wait ten seconds on or two seconds, whereas if you're doing spacecraft avionics and you're trying to figure out where the surfaces on the vehicle are, you need that in milliseconds or something really quick.

So we spent a lot of time just trying to get the input into that computer system such that it could handle it, because I would say that half our test time that we were down was not due to the test article being down; it was due to the computer down. It was called Flex [phonetic], and we would say, "Flex is down," and we'd sit there and wait. We'd wait until they'd figure out what it was, and after a little bit we figured out that, "Hey, this probably means we've got too much data coming in." So we figured out, "Well, okay. Change the sample rate on these six instruments to two minutes," or two seconds or whatever it would be, trying to offload it so it could take this data.

After we got through the shakedown of that, since I'm creating so much ice in this thing here, I've got to find a way to unplug it, even on orbit. So each time that we did it and we got the ice ball, we had to figure out how to get rid of it. You could wait for it to sublimate, and that would take days, or you could try to help it by breaking up the ice with the water that you can squirt in there.

Fortunately, in the design the panels had, they had two nozzles; a primary one that would squirt water, and it has a little piddle valve in there that toggles, and each time it toggles a little bit of water comes in. So you get sort of a "psst, psst, psst, psst" type spurt as it goes in there. Then you've got a second one that does the same thing, and they had put a backup mode in this thing where you could actually go from "psst, psst, psst, psst, psst, psst," from one to the other. If the Primary B had gone out, you'd go to the secondary, and you'd get this milking motion.

I've got a frozen ice ball in here, so I'm sitting here trying to figure out how am I going to do it. Well, I know that if I just continue spraying this same spot, I'm probably just building on this ice ball. But if I can spray on both of them from two different directions and just mix it up in there and make it sort of like a washing machine or something like that, maybe I've got a good chance of breaking this up.

So I tried it, different sequences, and sometimes it took a long time, like 10 minutes or so—before we finally broke it up. Then I finally found a sequence where you do this for *x* number of seconds, where it's running off of a primary, and then you go to the secondary, and then you go back to the primary, and then you back to secondary. And it worked. It cleared up fairly quickly, fairly quickly as in less than 30 seconds or 20 seconds. I've got a clear thing and everything looks good.

The way we could tell that is that we had ducting at the outer, which is what the Shuttle's got in it, and if it's on the high load, it's got this big, eight-inch duct in here, and we have temperature sensors on here. If an ice ball came out that ice thing would instantly cool off that heater that's there, because it's trying to heat this thing here, and we'd see suddenly this temperature drop on us, which means that the ice cleared out of things. So that was sort of a simple way to see if this thing was working, is whether or not we've got an ice ball that moved through this thing.

Lo and behold it worked, and we'd see this ice ball go through there. I had tried probably about five or six combinations of things that would work, and this one kept working. So I tried it again. Next time we got an ice ball. So I tried it again. Didn't try to increase this piece of it another 10 seconds. I left it right there. If you look at engineering curves you usually have a sweet spot, something where everything looks like it's best. If you go too far this way, then you cause a problem. If you go too far that way, you get a problem.

I don't know if I'm at the sweet spot, but they've used it on orbit several times. It's worked, and I didn't have time to figure out what's a better combination to do this thing. The biggest problem when you get into a development test like that and the thing's not working, you've got to understand where it doesn't work so that you can then build off of that and say, "I don't need to work on that piece; I can work on the rest of this," instead of just saying it's all failed.

At that point in time—we were in '77—the tiles were getting all of the criticism about they're not ready; they're not getting them on the vehicle; they're not doing all these things. We were number two on the list of what's not going to work on this thing. When we got through the test, where I've been handed this test plan that this guy had, which I had worked with on that thing, I'm told that we've got to explain to the world how this thing worked. And, of course, it did not work very well, plus we had had the program people and we had had the technical people from Downey [California] all watching as we go through there. There were a lot of test points that did work on it, and there were a lot that we couldn't get it to go.

So Walt, the division chief, says, "You've got to explain to the world how this thing functioned during this time."

I told him, "Well, it was going to take me at least three months to go through this data."

He said, "Well, you've got three weeks to do this." I negotiated, and I think it was like five weeks was what I got, or four weeks.

I started looking through the data, and what we had at that point in time is at the critical test point time, you could get, let us say, a scan of the page; like you have on your computer, you can get a record of what that page was. So I would punch a button, and I would get a printout of what all the parameters were at that precise time when this thing was working. Fortunately, the Ham Standard engineer, Mike Harris [phonetic], who had done all of the shim correction, had done the same thing, and fortunately, we overlapped say 70 percent of the time, but he was looking for some other stuff, and I was looking for this.

We had that data, which is just a single page, and then I had notes in my book then, so it took me about a week to go through that stuff to figure out here's the gaps I got. And I also knew what the test times were for so I could say, "I want from the reel tapes." We had a bank of machines back here that was taking, on magnetic tape, the huge 12-inch reels, all this data through this thing. So I want from this minute, second, to this minute, second, plot of all the data, so I can see how things went there.

I asked the technicians there to provide that to me, just a request. The next day the guy comes in and says, "We can't find them."

"What do you mean you can't find the data?"

"We can't find the tapes."

"What do you mean you can't find the tapes?"

"They're not around." They went out and looked further, and it took them another day to look and confirm this, and they came back to me and said, "We don't have the tapes anymore."

"Why don't you have the tapes anymore?"

Apparently all of those mag reels had been used about a year earlier, and it had a little tag on it that said, "Demagnetize this tape after this date, on this date." Well, that date happened to be about three days before I requested the data. So every one of the data tapes where I'd had all of the records from all of the instrumentation were gone. Only the data that I had in my notes, Mike had in his notes, and I was in charge of this data analysis team, and a few people had theirs, was all I had.

So meeting Walt's requirement to give this briefing got a whole lot easier, because I didn't have a whole lot of data to do this, plus we'd done a pretty good job. We knew where it failed. We knew where it was successful. And it was sort of a pass/fail type thing. Can you put this much feed-water pressure in there? Can you use this feed-water temperature, and will it work all right with this? If we put a spike in it like you get when you do ascent, what effect would it have on it?

During entry, we had done entry profiles, because with a chamber we were able to depress it—it must have been in Chamber A—we were able to feed the gas or air back into the chamber, like you would get coming from entry, from 400,000 feet coming down to about 100,000 feet. You just build up the back pressure on the thing, and then at around 88,000 feet where it stops.

We were able to see all of that and do that, so I took the data, and I stood up in front of the world, and on July 20th, which is the day we landed on the Moon years earlier, I was standing in front of the world with a lot of people very curious as to what we were going to say.

Walt had suggested that I try to present what worked and then talk about how we're going to fix it, not about how bad or how terrible, and I think that's a better approach, much better, to say, "Okay, we've got a device here that we are understanding, and we went through a development test. It had some significant difficulties, but here are the areas that worked. Here's what we can do with it and what we can't. Here are the recommendations that Hamilton is already working," because as soon as they saw a problem they were already trying to fix it as such, "and that they're going to go work at."

We made a number of suggestions that I took over to the [Space Shuttle] Program Office and said, "Here, if you can fix this, fix this and this." The reason to do that is to get funding for Hamilton to make the changes there, because it's going to cost money to change that. And they went ahead and did it, plus let us test it a year later. A year later would be the verification test or certification test for this thing, and we're now getting into '78, '79, and, of course, at that time we were supposed to fly in '78 and '79 or thereabouts. But we knew the vehicle was still having problems with a number of things, especially the tiles.

We also, though, learned out of this that having just this device without the rest of the thermal—the radiators—we could be surprised, because there's a lot of sensitivities here that we're not quite sure, so I begged, pleaded, for the total system if we could. We told them we have a way to do that, because all the test hardware that the prime and his subcontractors had been using to characterize how this heat exchanger works was available, and we could just put it together in Chamber A and test it. Plus, when they had checked it, the contractor had built a a cart that interfaced with it that would be able to simulate the Orbiter's hydraulic system or simulate the payload or something like that. Then we would make up some carts that would do the same thing so that we could simulate the actual spacecraft being used in the manner in which we expected to fly STS-1 or 10 or, hopefully, the full life of the program, and be able to simulate that.

We also had at the same time already in the pipeline some radiator panels that would give us what the actual performance of them would be, but we didn't have all eight. We could get four, and I could build a simulator for the rest of them. The program bought into that, so we put together a test. This time I was put in charge of the whole thing to start with. We brought it back in '78, put it in Chamber A. It was a major activity for us, and we got to testing right around Christmastime. This time was going to be the real show and tell on the flash evaporator and the radiators, and after that I would get to operate the system the way I had hoped to, because all the while I'm going all of this, I'm also still doing the analysis of the integrated system for the vehicle.

I had excellent contractor support, a man by the name of Bob [Robert L.] Blakeley, who had created a program called G-189, in which it was able to input into a fluid flow simulation that had—from these different devices you could put heat into and you had a transport fluid that had this much lag time to get to this device, and then you would have the characteristics of whatever, like the fuel cells, how they were operating, whether there was one or there was two or three. It had this heat exchanger model so that it would have the interface between the coolant loops that we had for the active thermal system, influenced in a proper manner to reflect that particular heat exchanger's design. We did it all the way around the circuit; there were probably about eight or nine different devices that we had to put together; simulated the cold plates.

I had worked with Bob intimately on understanding how the system worked, because we would, at the same time we were working on building up a test article, we were also being asked by the flight control folks what can the system do. I was a lot of times in front of the flight techniques meeting, which is where Mission Operations [Directorate] and the crew get a chance to talk to the technical folks about how does this system perform; what if we do this.

I always equate it to the orals I had when I got my master's degree. You're standing in front of a bunch of professors here who really know their stuff, and you're trying to explain to them what you know and what your training area tests. And usually, when you do your orals, you've tested something they haven't done, but they're familiar with this stuff, so if you don't get the technical stuff right or the engineering basics right, then you're vulnerable in that.

So you've got to know that part, but they'll allow you to—because usually they—at least for me what they did was they tried to search your mind as to, "Given that that didn't work, what would have been your next step. What was your next opportunity?" Not, "We know you came and you conquered this and you solved that, whatever it is. But we want to know where is your mind headed as another solution for it," which to me is a lot of what system engineering's about, how you do that. Flight [control] would do the same thing. They'd say, "Well, what if we failed this? How would your system respond if we wanted to use these other things in this manner?"

One of the better things I learned out of that was that don't give them a quick answer that says, "Yeah, it'll work. Don't worry about it." Tell them that, "This is how I think it behaves, but I'm going to go back and look at it. Let me talk to someone," if I needed to do that, or "Let me run an analysis here and just see what kind of effect it got, and I'll be back next week, and I'll explain it to you."

They accepted that every time. I never had a problem with that approach that if you didn't know the answer, admit it immediately that, "I don't know the answer specifically, but I know enough about it that I can go off and simulate. I understand what you've got, plus if you've got something in addition, I'd like to know that ahead of time so that I don't have to repeat this again. Just tell me a few more things about what you're concerned about and how long you want to go to this thing," so I could characterize it. Then we'd come back and I'd present a bunch of plots on a viewgraph, because we always used viewgraphs back in those days, and say what it would be.

But it was a good experience, because the flight directors, flight controllers, the guys that you were going to interface with and actually run the machine are telling you what they really need.

Which, now going back to testing, is something that I could then understand how they might be using this vehicle, and I could, when I run a test point and it's not going the way I think it should, it gave me alternatives when I'm looking at the whole system. That's what the last week of this testing was after I'd done the flash evaporator and done the radiators then I had the whole system. The purpose of that was to characterize how the system works on a bunch of failures, and those guys had already cued me as to what kind of failures they're worried about; loss of one of the loops, one of the Freon loops; or loss of both of them, how fast does the thing go down. Or if I lose a fuel cell loop, do I have to power down this system?

So by having that interface, I was then able to create the test program that then characterized all the failures I could come up with on that subject, and look at what the possibilities were. But when you're testing real hardware, and it's one of a kind, there's a word of caution in there, in that if you fail this device—in other words, if you have an event occur in this failure that you have where you go too far and it actually shuts down—you may break the device. If you break the device, you cannot test it any further. It's done. It's over with.

I'll give you a side note. In the middle of this test that we were running here, we had one of our instrumentation leads blow out of a Freon line. Freon 21 is the fluid we're using. It's not much in America; it's not even being made here anymore. But at that time they were still making it, and we had accumulated a lot of barrels of this stuff to do the testing we had here, plus it was to put enough at the Cape [Canaveral, Florida] so that they could service the vehicle and do all they've got there.

When that line blew, we could see fluid dropping down, and what we saw down here was a stalagmite building up, and it literally was not like a pyramid shape, it was very much a cylindrical thing going up. Because you've got a pure vacuum in here, and this fluid is not going to a vapor, it's building up this thing. We're running the tests, and probably we still had another day and a half or two days' worth of testing.

The first thing we did is we said, "How much Freon have we got left? Can we just feed the leak and keep the pressure up in the line so that we can actually continue running while we're watching this stalagmite grow in here after our thing?" And it worked, by instead of just saying, "Oops, we're all done; we can't do anything," we just found another way to get ourselves through that situation. But it was entertaining, let us say, as we would try to figure out, "When do we have to stop?" or "When are we going to run out of Freon that we can pump into the system while we're doing this?" But a good test team can make that happen.

So I had that background on what I needed to look for in the testing, so now we go into the test. Hamilton has now built a few more of these flash evaporators. We now have a qual unit in here that we can test. Fortunately, this time it worked pretty much every time. We had a couple of conditions where I was able to build the ice ball. The procedure worked again to get it out, but it basically worked all right.

The radiator system, we got its performance. The difficulty with radiator testing is what you're waiting for is that steady state point where you've literally sucked out all the energy and you're waiting for the temperatures to cool down to where you know that's the performance. That's what you're going to get with that environment. The way you get the environment is you put little IR [Infrared] lamps on top of them, which give you radiant heat like the Earth gives off; they're able to simulate that. So you're able to characterize that.

Got into the integrated testing, and I started simulating all these different failures. We're running three shifts, which means we're running 24 hours a day. I did the first shift. Nobody wanted to sit down and talk to Walt at seven o'clock in the morning, and I should, because it's my test; I know what's going on. He never gave me any trouble. The only thing he did to me was that about the second day of integrated testing, he said, "You're going to have to shorten this test. We're running out of money."

I said, "But I was authorized five days of testing."

"Well, now you've got four."

I said, "I don't know if I can get everything done if I've got four," because I'd carefully thought out this stuff. He told me that, and I guess it must have been on the first day we got to there, because we'd already been testing about two weeks for the flash evaporator and the radiator. What that caused was that you have procedures that you're going through, and you have test points. I literally would go through my sequence and as soon as we got to where I thought that test point had been achieved, I stopped it right there. We're moving on to the next one. I'm now conserving, because minutes saved here turn up into hours later on, and I'm trying to get five days' testing into four. I probably came in about six-thirty in the morning and met with Walt about seven, and then I'd go on shift at eight, something like that, so I'd get off at four.

At four I'd hand it off to Bob Blakely, and he was good. I would tell him, "This is what you want to do," and I would then mark up his test points and say, "You only go to here. Don't go further than that." I've got to have quality agreeing with all this, because I'm making real-time changes on this thing, and they, fortunately, just went along with what we did there, and it worked.

But I found that when Gordon's group—Gordon Chandler [phonetic] did the third—there I had people who weren't that familiar with the system, and they were the graveyard shift, as you call it. He would always get very conservative; he'd wait to see if he'd get another data point a little bit longer than that. Always I'd come in after them and say, "I thought you'd be here, and you're here."

He'd say, "Well, some people weren't quite comfortable with what we got here."

So I would rewrite the procedures until probably about 10 o'clock at night, saying, "This is what we're going to do." I would see Bob's stuff halfway through, and I'd go home and try to sleep and then come back in here. We were able to get all of my test points in there that I felt were mandatory. We had to drop a couple, but the system worked.

Again got this request from Walt that, "You're going to tell the world how this thing did, because this time we want to brag about how well it seems to be doing." I gave that briefing about five weeks after the test. This time I had all the data in the world available to me, but I knew that the other briefing had gone pretty well just going off of the data we had from the notes I had before, so I used some of the other stuff, and of course, a lot of people provided the stuff, but I was able to tell the world that, "This system looks like it's good. This was a verification, and the flash evaporator is not fully healed, but it operated the way we expected it to."

We made about four recommendations that we took to the program. There was one other thing we did in the test. Based on all the exposure to the flight techniques and the flight controllers, I set up a console in the test team there where I brought over the people in the flight control. These are the controllers, not the flight directors, but the controllers, who are actually going to run this system during flights.

I said, "I'm going to put on that screen there the actual data parameters that you're going to use during flight, and I'm going to put in a lot of different failures." I knew during the planning—we had invited them to our review sessions—that we were going to fail a Freon loop, fail a controller here, and we were going to do this. "But I'm not going to tell you when or how. I want you to tell me when you think this has happened, so that you can tell me whether the instrumentation you got is doing what you expect it to do, because I've got all of this instrumentation."

I could tell as soon as I put the—I knew what the failure was. Now I was just looking to see where in the system. Is the fuel cell going to tell me, or is the cold plate over here going to tell me that this has occurred before I get to a device that I know that Flight's going to be looking at? Also, when you have a failure, you don't know if it's a, b, c, or d that I've done here. So you're trying to quickly eliminate this, eliminate that, eliminate that so you can get through it. That's, again, where you go back and say, "Well, nothing changed in the fuel cell loop. Nothing changed in the hydraulic loop. Nothing changed in the payload loop. Over here it's in the cabin, so there must be a problem with the water loop in there, and so that's what's giving me the response I'm starting to see here." Or, "I've got a leak in the radiator system over here, and I'm going to see it at the next device, the GSE [Ground Support Equipment] heat exchanger."

But they don't have all that instrumentation, and they just have what they've got. Well, they looked at what they had. We recommended about four more pieces of instrumentation be added. We'd done a good scrub of this—I'm going to [digress] just a little bit.

Early in the Shuttle Program, we were warned that all of the systems were requiring too much instrumentation. If we do this, we're going to swamp the computers on this Shuttle. They just aren't going to be able to absorb it. So Don [Donald D.] Arabian from the Program Office had this big instrumentation scrub. What he would do is literally take your system and wipe out all the instrumentation, and you would try to put back what you felt was absolutely necessary to do that.

I got the privilege of going over there in Building 45 and defending the instrumentation for the active thermal control system. Early, this was early, before we tested anything. This is just based on my knowledge of the integrated system analysis that we were doing. We had looked at what Rockwell had put in there and what has the right instrumentation for it. He walks in the room, and we've got the schematic, and it goes across the three walls of this room in here, and he says, "Why have you got any instrumentation? Your best instrument is the crewman. If he's comfortable, you're in good shape. If he's hot, you'll know you've got a problem and you're not cooling. If he's too cold, you're doing too good. What else do you need? Why would you need a thermostat? Why would you need anything? You've got the crewman."

Of course, to us that's sacrilege, because I don't want to wait until the crewman says he's too hot or he's too cold. I need to give him a heads up that, "Hey, you're not cooling the fuel cell, and you're about to lose all your power," and not wait until the lights go out; the lights have gone out, and oh, we must be losing power.

So I went through it along with several of our engineers, and we scrubbed it. We probably went, my belief is, we went further than any other system on it. We knocked it down to a bare minimum here. When I got through with the integrated test, and I knew what the flight instrumentation was that was on there, and that's what the controllers said. I only had about four instrumentation points that I felt were really necessary for the flight control people to understand what's going on in an adequate time for them to do something as a result of it. I felt very comfortable with what we had done years earlier in scrubbing it down, because there was a lot of worry that we had scrubbed it way too much, that you need more than that.

It really helped the program, because we weren't asking for much information out of the computer as a result of it. But it proved that you really don't need all of that. You just need to be very clever about where you're picking it up at and what you're doing and trust that it works. And fortunately, all the flights we've had the instrumentation has been working.

The flight controllers, in doing that, got a lot more comfortable with what our system did, the flash evaporator, all the hiccups that we had had, because they were nervous about, is this device going to be a headache for them, or are we on every flight going to have to milk it or help it limp along to solve this thing. So to me another lesson was to get them involved early in what you're doing in the planning, and let them see what's going on.

You do have to be a little bit careful because sometimes they will—you know, a person in safety or flight control or something else, they want to feel like they're value added, so they will draw a conclusion and sometimes run with that conclusion to their boss or whoever it is before you've had a chance to help them understand it, because the best conclusion is one we both concur on that, hey, you know, we really do have a problem here. But you don't want them to stop with just saying, "They've got a problem there." You want them to also add that, "And they're looking at doing this, this, and this," because we are, proactively.

I see that in a lot of other things where there's a lot of people who will say, "You've got a problem." But they never acknowledge the fact that you already knew you had a problem, and you're looking, but you're looking at these solutions. As a senior manager, when I was the deputy director of Engineering [Directorate], I was much more searching for what are you doing next. Not, I know you've got a problem. You wouldn't be sitting here, or you wouldn't be on the phone with me with the problem.

Tell me what you're doing, and let me hear what that is, and then we will concur. Or I might expand a little bit and say, "Hey, get this person involved and get this person involved to do this," or, "Yeah, we saw that problem, and this guy has already worked something like that. Talk to him. See where he went with it, and then see if you can go that way," instead of just leaving it with this problem on your desk, and the next thing is, "What am I going to do with this problem to solve it then?"

That helped with Flight, because later on I got into missions, and we did run into problems on some of the systems, like there was a hiccup on a flash evaporator on [STS]-26. It's the flight that's after [Space Shuttle] *Challenger [*accident, STS-51L*]*. The situation there was I had sat in the MER, Mission Evaluation Room, for the first eight or nine flights, maybe ten, and I was responsible for this active thermal control system on the ECLSS team. So I was there during the prime times, during launch, during entry, if something was special, like the door opening on orbit and that, to make sure it was all right. I had stopped doing that, and now I'm into management and the division branch chief or—I'm not sure where I was; let's see, that was in '88.

We have launch, and this was a big deal, because we're back flying and that, and a lot of us are feeling good at least if we're up flying. But I get a call at ten o'clock at night same division chief, Walt Guy, again, who proceeds to tell me that they've got a problem with the flash evaporator. It shut down on them a couple of times, and they don't know why. "Can you come in? If you don't come in here they're going to come home tomorrow, and that's not something we want to do whatsoever. We don't want to go up only to find that we've got a problem and have to come back down."

"Yes, sir. I'll come in." And I went in to the MER. What I had done after the integrated active thermal control system test, that testing I was describing earlier, is I had taken the data that I had there, and to me it's not important just to test, but it's to also document what you found out and what you've learned from that test and give that guidance to whoever's going to use this system. I had written another book, in which I took every one of the test points that we went through, and some were very similar, so they could be consolidated. I wrote down very briefly what the procedures were that we did on that to solve that problem or to address it, and then I wrote down the recommendations on what you should do differently. If I could do it again, this is what I would do.

Most of them became part of the malfunction procedures for the system that was used by Flight; maybe all of them, I'm not sure. But they used that. And I put plots of the data that we had in there, so that's how I was able to use a lot of this data that I had not used from the flash evaporator test. I was able to now collect that stuff. So for every one of those test points I had carefully thought about is that the right thing to do? Did we do what was better for the system? Or is there a smarter way to do this, and try that in case this had happened?

Well, I'd put it in this book, and this was done back in '79, and now it's [‘88] and I'm going in at midnight. Take that book in, along with a description of the flash evaporator I had written a couple of years earlier, plus some other data that I had, and sat down at a console there and looked—and the guys were already working it, guys in the back room in mission control, plus the MER folks who were now doing what I had used to do.

I asked for data. They already had some of it, and we got some more. I stayed up all night looking through the data they had there, comparing it to what I saw; I had my book out there. So at seven o'clock in the morning I finally drew a conclusion.

In the meantime I also went over and talked to Flight, to the back room, to see what their feelings were on this thing, and was really reassured. I really was, that those guys, they don't just sit there and watch. They actually are thinking as they are going and learning their systems. I concurred with every decision they had made at the time. That's saying that if I was presented with this piece of data, this is what I would have—and if you're a teacher, that's what you really want from your student is feedback that, hey, that they're thinking in a logical manner, and if it works—if it's the same problem—that they would have solved it the same way you have found that it works. Or they may have improved it as such.

So that was reassuring. The caution they had was just that they weren't quite comfortable with it, and of course, they needed somebody else to agree that the approach they had. But they had already thought out some things that they might do. I was able to look at that and concur with it, and basically drew the conclusion that, hey, the device—what I discovered was that it had been performing and starting up just like it should be, and all of a sudden it just stopped.

I had always seen a little bit of hook or something that indicated that the temperature reversal would imply you've got ice buildup in there; that you've something going wrong that the sensor then that runs the controller gets feedback that the temperature has changed direction. It's been *x* number of seconds that it's done that. That's bad. Shut down and do your thing.

In this case, it looks like somebody had just turned it off. So I had gone through all my plots and said, "I've never run into this case." At seven o'clock in the morning I was in front of the MMT [Mission Management Team], I believe it was, in this big room, in which now you've got all of the managers are there. They want to know what's going on.

I put on the screen the data that we had, what we had, and first said, "It looks like what Flight did is what I would have done. I'm very comfortable with what they're doing. The device is in a passive mode right now, because the radiators are doing everything that they're supposed to do. You don't need it at the moment. You may have some orbits or some attitudes that you put the vehicle in where you may need to turn it on. We'd like to run some checkouts to do that. I've already worked through that with the back room, and what they want to do sounds very reasonable to me. Let's just see how that works. We ought to check these two controllers in this manner."

I was able to tell them that, "Hey, I think your group's doing good. The device, I'm not sure what had happened, but I'm not seeing anything. I've gone through all my data, and I've never had that case like this show up before."

What we really think happened was inadvertently the crew had turned it off for some reason and then turned it back on as soon as they did it. Of course, in those days—well, even now—you've got to be very careful how you word questions back to the crew, so we weren't able to really ask the question. Some guys would get very crude about the way they would ask the question, but you just wanted to know, "Hey, did something special or something occur on panel L-11 here? Was there a switch that was out of position that you just brought back in?" Not implying that you had done it, but that you had done this.

So we went on, and they completed the five- or six-day flight that we had there. We were a little nervous as it came back as to would it work, but the device worked exactly the way it should.

What I heard, though, was that on the morning when I'm giving this briefing the Director of Engineering, which was Henry [O.] Pohl, apparently had come through during that night while I was there, and he had seen me over there working on this thing. What I'm told he said was that, "Hey, you know, it's really refreshing to see some of our old engineers,"—now I'm "old"—"older engineers. They've got a problem over here, and they're working on it, and they've got these old yellow books that they're looking at," which means these are the old books that you had written before. And he said, "That's the way we ought to be doing our engineering here, and I'm proud to see our people do it." I got that secondhand or from some other people. So it was rewarding in two ways, in that the device all worked, and the people were following, but also that somebody recognized that having taken the time to write all that stuff down can be of value.

When I've gone back to talk to the folks back in [Washington] D.C., where I grew up, I've been running this system, and I still tell them that testing is good, but testing for a test's sake, because most people, that's what they want to do is just as soon as they've achieved that test point, they're off to the other one. They don't take the time to document what you did. You don't need a 10-volume manuscript to do it. What you want is the essence that you want to pass on to the next generation, let's say, as to what is it that I learned out of this that I want to share with you, and what would I do different, or what I recommend that you do different, in case you run into this thing here. And what else would I look at that I didn't look at, or what worked well for me in that procedure. That all proved out to be a very good thing, so that was the fun part.

We had a couple of other flight experiments that I was on. You'd get calls—calls. I'd see relatives; they'd say, "I saw you on TV."

I'd say, "You obviously didn't see me on TV." I didn't think I was on TV.

"No, I saw you in mission control. You were on TV."

I'd say, "No, you don't want to see somebody from engineering in mission control on television, because that means we've got a problem, a big problem," Well, in reality I have been in mission control several times for problems that we had. I've always found that they're a great group to work with. They will listen to you. But I think you do need to build up some credibility in the flight techniques opportunities. They get to see how you behave and what kind of answers that you give there where it's more of a study phase. You're still studying these problems that you're evaluating. But when you get into a flight it's quite different, and I described earlier in the Apollo-Soyuz about being in the room with the Russians and moving out, and then the flight controller there says, "Come over and let's look at this problem," that he had not had before.

[STS]-26, I had gone in and talked to a flight controller a little bit during that one, too, as we were confirming it. We had a couple of other opportunities to go in there. Mainly, it was to give the flight director as much direct input as he wanted and not for you to fill his time, but to [find out] what questions did he have that he sometimes would want to ask you about, "Now, we've tried this. We've tried this. What else do you think you smart guys back here are going to be thinking about that I might need to get ready for?" or whatever it is.

I appreciated their willingness or desire to want to talk to us to do that, and also I felt comfortable going to the back room and talking to the people who are talking to the flight controller.

When you see the console there and you see the guy, and he's on the headset and he's talking and you can't hear him, that's the amazing thing when you go into mission control. You'd think with all these people talking there'd be a loud noise. It is quiet, I mean, really quiet in there. You can barely hear a murmur as such in there, and I was shocked at that. But it made things a whole lot easier that you didn't have people shouting. If they were talking, they were always talking into their little microphone, and it was really good decorum, good management. You didn't get this "Hey, you!" It was very professionally done the times I was in there.

I always respected the back room, because they are the guys that are feeding the information in, and those are the ones that you really want. When you're in engineering and you're trying to bring up Flight, those are the ones that need to know what you're doing and how you're doing it, because they're the ones that are analyzing a whole lot more data than is even being seen in mission control directly. They've got access to other things, plus they've got access to us in the Mission Evaluation Room.

Probably the real reason is if I'm back in the MER, which used to be back in those days in up either on the third floor or down on the first floor, you're a ways away. You're not within 30 seconds of just going out this door, right down the hall and then into this room, into mission control. You've got to go from one building to another, and you've got to go from totally one different end of it, so it takes a lot of time, and in our business many times you don't have a lot of time.

You need to be there talking to them immediately, and when you're talking with them, they need to not ask the first question is "Who are you?" The question needs to be, "Here's the problem and this is what I've done. What do you think?" That's usually the way it went, "Here's the problem. This is what I've done. What do you think?" Then you just don't go into what they did or didn't do. It's let's look at the problem and see what data—do you have this data?

Most of the time they've got the stuff. They're very smart, very intelligent. There are a few times when you need to ask for more, and of course, they're learning as they go through that and do that. When I was on the floor usually you're escorted by the flight controller that's got that responsibility, because he wants to hear everything you're going to say.

We did one of those flight experiments, the SHARE [Space Station Heat Pipe Advanced Radiator Element] flight experiment. This is later as we were getting ready for Space Station Freedom. At least we had the development phase go before it was canceled. It is a heat pipe in which we had a 60-foot long blade out here that has a heat pipe in it and an outer surface in which you can reject heat off of, and the heat pipe has two grooves in there with a narrow section. What you're trying to do is take the fluid in there boil it, in effect; and so it goes to a vapor. Then that vapor goes to the other end, and it's cold down at the other end, so it condenses into a liquid. Because you've got this small tube there, it will wick back up to the place where it will get heated, and it's sort of like a closed loop.

Heat pipes are used in a lot of different applications here on Earth, but in space, they're very gravity sensitive, so if you get a bubble, and you can get a gas bubble in there, if it gets lodged into a location—in this case, it did get lodged into a location—it won't move unless you somehow bump it. When you've got this blade sitting where the arm sits on the side of the

Orbiter, there's not much you can do. You can hit the jets that are on the back, the primaries or the secondary RCS [Reaction Control] system, and maybe get a little vibration, and maybe the liquid would move the bubble.

But we got the thing lodged in a spot where we couldn't get it moved. So I can't test. It's literally like I was saying, I've failed the device in a chamber here. Well, I've failed the device here, and it's our first real proof that this thing works, because, again, sharp corners are bad, so maybe that's what the problem was. And it turned out it was.

But we are trying to figure out how I can shake this bubble loose, and I'm back in the Payload Support Room or—I don't remember the acronym for the room—they had there with my technical team. Now I'm more the branch chief, manager type, at the time, and I'm leading the group here. We've told them what our problem was, and we're trying to think of different ways. They had moved the vehicle like this, and did some maneuvers that would hopefully shake it loose, and they hadn't been very successful. So we said, "Well, our last resort is to do a yaw maneuver where you go nose over tail type situation." We told them we'd like to try that if they would be agreeable.

IMAX [camera] was flying on the same flight, and the IMAX folks, real early in the program—had done a sequence where they pointed the camera at the coast of Florida and took a shot going all the way across Florida, where they were always pointed down at the state of Florida, and so you got this beautiful shot. They wanted to do it again, and they were looking for an excuse to do that again. As soon as we described what it was, the payload officer talked to IMAX and said, "Hey, these guys are thinking about doing this. Are you guys interested in doing this?"

They said, "Sure. Let's see if we can combine the two together."

Okay, that's agreeable with me, but I'm really looking for this technical solution to this problem I got here. The way that heat pipe works, again, you've got to cool it back to down to get to the right temperature conditions so that if the thing starts, we've got the heaters on, and we've got this thing so it will do its thing.

So we're sitting in the back room there, and then I'm getting words from the payload officer through the net here, saying, "IMAX wants to know if we're a go."

We're watching the data we've got, and we're trying to get this thing back into a condition there, and I've got my engineers over here, who are some of them saying, "No, no, no, we've got to wait," and I've got others saying, "Let's go for it. Let's go for it. Let's go for it," with the IMAX thing here. So we waited. Gene [Eugene K.] Ungar and I waited. Or Gene's pushing for it. He's the technical expert, a really good engineer.

I'm hearing it from this side, and I'm hearing that one, so I tell Gene, "Are we close enough? Are we close enough? Are we close enough?" We were trying to get to this thing here. Fortunately, within about a minute of their drop-dead time that they can do the procedure, we give them the clearance, and instantly you hear the network going over, and they're going to put this maneuver into place, and they're going to start it right now. They had the procedure; it was just when were they going to start it, and it was just they could match up the timing.

So one of the later IMAX films, the reason you got a shot of Florida, is because our experiment didn't work. Unfortunately, when we did that thing, it did not dislodge the bubble, and it still didn't work after it was through. But it was a good try, and they were willing to work with things that we really hadn't—preflight—thought fully out, but there's enough wisdom in the group there that you know what's successful or what's not successful during that time. So those are the times, one of the most memorable times being involved with a flight, during a flight, in mission control.

I'm going to talk a little bit about the Spacecraft Design Office, to try to get some other areas in here. The directorate had this office under Caldwell [C.] Johnson [Jr.] and Al [J.] Louviere, who replaced Caldwell, in which they would put together teams to look at a option for a spacecraft or a system that could augment the capability of a spacecraft, and we'd do a conceptual study of it to characterize what it does, what it consists of equipment-wise or systems-wise, how much it might weigh.

We sometimes would do costing a little bit, but we weren't really very good at that, mainly because we didn't have any experience. I didn't have any experience with costing, other than I knew what it cost—I was getting feedback from the devices we were making through Hamilton Standard or with North American Rockwell or Rockwell and some others that were subcontractors, but I don't think we could be really valid characterizations of the pricing. But later on in my career I got very familiar with pricing and modeling.

So what they did is they had a leader—a person from the Spacecraft Design Office, and they'd know the general topic, plus they're part of the presenter, when the thing is done, and it was usually, I would say, like 30 days that you'd have to do this. This is while you're doing everything else, see; you'd be pulled in. So I would be pulled in from EC [mail code for Crew Systems Division] to do the environmental control and life support, EVA [Extravehicular Activity], or sometimes there was another person brought in for EVA.

Usually EVA was not involved in this, because we're trying to figure out if we put a power extension platform on the Orbiter, that would mean because of the cryosystem boil-off, we can't go more than about 18 days on orbit, because we can't provide more power. So if we had a solar array system up there that could provide power, we could stay longer on orbit, and we could do more science or engineering. This is in lieu of having the Space Station where you now have a permanent person; we don't need that now. So they looked at that idea.

Well, if you've got all this power, then you've got more than what you had before, and you've got to get rid of it. So you've got to reject it, and in the heat rejection system, you may need to augment your radiators and put what we call a gull wing; in other words, flip another radiator panel that looks like what you've got, but it swings out away from the vehicle. It's like a gull wing. So that's what we'd do. If you're going to do this, what does it do to my system? How do I interface? Do I have to do something different on the ground to cool this device as we've got it, or anything like that?

So I'd get called in for the active thermal. Don [Donald R.] Blevins would usually do the power and propulsion piece of it. Bob [Robert J.] Wren represented the structures, and he usually pulled in some other people for that. We would then conceive a design and draw viewgraph sketches of what this thing might be, and characterize it; what kind of performance, what kind of impact it had.

Then we as a team would go to present it to the program office or to the Center Director; usually it was the program office or somebody in senior management. I'm still pretty young then, so I'm not recognizing all these people that are there. Or we'd go to Washington and we'd present it to the program managers up there, and I really didn't know who those were at the time, but I guess, looking through my notes here and that Chuck [Charles W.] Matthews and a bunch of others were people that we presented to these ideas.

One was on this power extension platform. Another was a 25 kW [kilowatt] power system. There was another one on a solar array beam. The idea was to take the sun's energy, convert it in a satellite, and beam it back to Earth, and collect the energy you've got there and convert that into power that you could run on a power grid to power the nation. There were several other studies, but this was probably in the mid-70s through the early 80s that we get pulled in to do this. When they get an idea we'd be pulled together, and we'd work on it.

Some of them were with Orbiter enhancements. There was one study that Walt Guy led for the directorate, in which they just pulled him out of his division job and said, "You've got these two people to help you over here in Caldwell's or in Building 29, and we want you to look at what would be the changes we'd make to the Orbiter to make it better than what it is right now." He did a good job on it, but he, again, wanted me to help with the active thermal. He didn't like the flash evaporator, because there was a lot of nervousness as to how well it would do, and, of course, we're still flying it 113 flights later. It's done all right. It's had a few hiccups.

Oh, I'll say one thing about that. Out of all those test points I did of the failures I'm only aware of one actual flight condition where they had a failure. Or there were two events, but one where I didn't simulate; we had not thought about as that being anything. The other one is something that we didn't directly think about, but when they told me about it, we then found that we actually had done it. We just didn't recognize it. We had it, and what we'd done allowed us to have the data to be able to say, "Here's how you would see a response."

It's one of those cases where what really caused this—you're trying to look for what the root cause was—and that's what a lot of this test data is for is to say, if this, this, and this occurred, what you'd like to come back after five or six levels of piercing down through this thing, that's the root cause. The failure is a problem with the way this device works or responds to this thing, or the time sequence overlaps such that you've got a problem here. But you want to get down to that. It's really the useful data that you can get out of a test. So in our ability to simulate things, I always felt very, I would say, proud of the level of testing and the confidence—or the product that we got out of it and helping Flight resolve their problem with this.

So back to Walt and his thing, we're busy planning on the tests or working these Shuttle-related problems at the time, and so he tells me that, "Well, you've been working on these other studies and you need to give me some time over here in this new thing to work on this particular thing, this Orbiter enhancement, because I want to replace this flash evaporator." What he wanted to do was, one of the things was take the device we had now and create two of them and put them on both sides of the vehicle so that they didn't have to worry about this ice in the duct, which was another problem, and it would just vent directly to space.

Of course, it's possible to do that, but that means I've got two—there was one device I was worried about, and now I'm going to have two of them that we'll be worried about. So I wasn't quite on board with saying that that's the right solution for all of this. But I went to my branch chief, and I said, "I'm working this mainline Shuttle Program problem here, and I'm being asked to spend a whole lot of time—he'd like to have me full-time—over here working on this other. I can't be cleaved in two directions. I need to be guided."

What we worked out was I would just provide him the same kind of support I had for these other studies and not go over there and dedicate myself to this Orbiter enhancement thing. He did come up with some number of clever ideas, and I got to see them. Unfortunately, we never had the money or the time to solve or do them. There had been a previous study before his by Al Louviere that I'd worked on with that, so fortunately, in most of those cases, I was able to utilize some stuff we had done before. That was one of the big things I learned in the directorate when I was doing a lot of things there, because as the deputy director, sometimes you've got time available to work on other things for the Center.

In my case—I'm jumping way up here—when I became the deputy director, but when I was asked to be the deputy, Leonard [S.] Nicholson was the Director of Engineering. Leonard, unfortunately, his wife [was ill and had to be hospitalized], so I'm now sort of running the directorate, as such.

You've got to trust the people that are out there that can do their job. I was very apprehensive. I've got a lot of smart people that are working for me suddenly that I used to just work for or work with, so you've got to trust them. I'm very concerned, or became, in listening to what you've got to say and then trying to make use of it, instead of telling you, "No, we need to do it this way or we need to do it that way."

I really didn't have that experience where I felt that I could do that, plus in working all the flight stuff that I had worked with I found out the people that we've got out here are all highly motivated to do the right thing. Sometimes you can get vented a little bit off to the side, but I think they're all outstanding people that do that.

Here I jumped way over to another subject from where I was.

WRIGHT: You were talking about being put on the Orbiter enhancement project.

JAAX: Oh, yes, right. The Orbiter enhancement project came up with a whole bunch of ideas that never really materialized into anything, so we stayed with the same design that we had before. I felt that the opportunity to work on these other designs, and many times those designs, what I got from it, was that I found out who could make things happen in the other divisions.

Who could you go to to get an answer? Not "I'll look at it," but actually come back with an answer in a day or hours or minutes, if you had a problem. That really was beneficial, because all of these different studies, we used the same people, but the reason the same people were there is because they got things done, and they didn't argue about it.

Now, we went through three or four people in the avionics world trying to do it, because they were trying to find a match, plus they also had problems with the computers on the vehicles at that time. So there were several computers we called data management systems—now they call them IT [Information Technology]—at that time, but people that were also on this team that we had pulled together to do that. It allowed me to make contacts all the way through the directorate and through the other divisions, and as I got into senior management that really worked very well for me.

I want to go a little bit through my management career in EC and that a little bit.

WRIGHT: Okay.

JAAX: [During] Skylab, we did get involved in a major part of the activity. I've seen *Apollo 13*, and I think the *Apollo 13* movie that was done was very good. If I was going to critique that, the one piece that I wish that he'd emphasized a little bit more is the involvement by the engineering folks and others who were supporting that provided the thing that they then focused on—here was the solution—because it was my division that had come up with the container or the way to be able to use the LiOH [lithium hydroxide] container in the Command Module, and mate those up so that you could actually get some $CO_2$ [carbon dioxide] removal. There was some good guys that worked there. I didn't work on it at the time. I was really new, and I knew they were doing that, but we didn't get into it.

But Skylab, when it occurred, if you remember, the workshop went up first, and they knew they had a problem, because they couldn't get any signal from one of the wings, which was to be a solar array wing out there. Plus they had indications they had lost some of the siding of the vehicle on that same side and didn't know if they had a penetration. It obviously didn't, because they had gas in there and they weren't losing it, but they had probably lost some thermal protection under the thing.

So there was a big effort put into, "Well, when the crew goes up," which was going to be seven days later, "we need to take something up that will shield the spacecraft, because the temperatures are getting higher; they're getting in the 90s or thereabouts, and we don't want to have the first crew staying there for *x* number of days in their over-temperatured vehicle."

There were a number of initiatives started within the Engineering Directorate, and EC where I was at, was involved in a couple of them. One of them was to put a parasol through the airlock that allowed you to put a parasol out that would then open up like an umbrella and shield some part of it.

But we came up with a design that was more a large area piece of Mylar, or this shielding material that EVA crewmen could go out there and attach to a couple of places on the spacecraft and get hung up there, and that's what they actually did was put that on there. The effort that was put into designing that thing, qualifying it, and then getting it to the T-38s to get down to the Cape to meet the schedule so that you could have it on board when the crew got on board on their launch day was just a phenomenal amount of work and effort by a lot of people that has received no recognition whatsoever of the kind. Although it wasn't saving human life, it was saving a mission, for sure, by what they went through.

So I've been surprised that—and I supported a lot of—because now I've been there about three years—and, of course, we had no direct responsibility for the Skylab but I'm a gofer. I go around and go here, there, taking materials here, taking paperwork there, taking whatevers. Literally, they went through their division saying, "You're an expert on this. You're an expert on this. You're an expert on this," and they pulled these teams together to do this thing, and the rest of us were available as bodies to go do this and get this thing here and try this here or take that there and whatever it was.

That was a concerted effort that was done on Skylab that I think some people deserved credit for that really went that extra mile, as they say, to do that. To me, it's that forefront, foreplay, you might say, of like Apollo 13, what it took to get the actual stuff to the mission control for them to make their decision. There's a lot of effort in that kind of thing. Same way with getting everything to Cape Kennedy [Florida] to have it on board and fly, and there was some stuff that really got there late, but it all proved very well. It all worked when we got up there, to a sufficient degree that we had three crews do their normal mission.

The management stuff that I was going to talk about a little bit here, and I guess we'll wait till next time for the Space Station then, I was a member of the Management Development Program, which is a class that they had here in the mid-70s, which enabled them to expose groups of like 10 or 12—I think our class was maybe 15 to 18—people to management practices at a MBA [Master of Business Administration]-type setting. It was set up through the University of Houston at Clear Lake [Texas], but it was 12 hours, and it wouldn't get you a full 30 that would get you an MBA degree. I was able to be a member of that team, and that was my first exposure leading into a management setting as such.

They have some other courses that they put you into, but that one was a two-year process, and I liked that program. I think that's something that they could continue doing out here a little bit differently from—you know, we never have really supported MBA programs, and when I was in senior management it was something that was talked about. "Well, we've got all of these opportunities to give people additional training." Technical won out every time or almost every time.

I think there were some others that would be very useful, because for me in my career one of the things I did in college that I think helped a lot for me was when I got my bachelor's degree in engineering, we could get an option of a minor in a subject, and I chose management, because of the activity to do that, which gave me exposure to the cost accounting, people management. People management, monies, and all of that, and you only needed 9 or 12 hours. So you didn't get a lot, but at least exposure to the terminology and what the processes were and everything.

Out at the Center, if you haven't had any of that and you're suddenly now in charge of a 10 million, 20 million, 200 million dollar program, because that's what I was managing in engineering at the directorate level there. We had contracts that were, when you added them all up, 250, 300 million dollars, and that's money, real money, and you've got to understand, when things are going bad, how to resolve that issue or you need to have enough insight to understand it is going bad instead of just always taking somebody else's word. At least my experience was if you don't understand it, then there's a good chance that a lot of other people may not understand it, and you're probably headed into a real problem.

So that Management Development Program in the 70s was the first opportunity that I got into it. I competed for branch positions, but because the Center was so young, the opportunity for one of my age to get into management was delayed, whereas today, because of the hiring freezes and delays that we had there, there are a lot of people who are much younger who are getting into senior management positions than they had before.

To me there was good and bad. The bad part was that then you didn't get much money if you were interested in raising a family and having some it was difficult sometimes, because there just wasn't much opportunity to do that. Of course, salaries then were a whole lot different than what they are today. Maybe in buying power it's not that much different, but it significantly was at that time.

My first position was as a deputy branch chief, and I was placed in the Environmental Control and Life Support Branch, in EC, which was—I had always worked in System Engineering, and there they put me in charge of the advanced ECLSS stuff. Frank [H.] Samonski, who had been that branch chief for a long time, was my boss and did a good job, but he gave me responsibility for the life support activity, in which I was able to work with the people who were actually working with the hardware. I had done the analysis on some of it, and I knew what a Sabatier reactor was and other things, but now I could actually get in there and see how it worked and help them set up a test program. I was now in charge of the development laboratories they had there.

We set up laboratories that really were already in place, but I added some thermal aspects to it that they didn't have. We were able to take some of these devices that we would get from the different vendors, and we put them through some testing to see what they really did.

We were trying to set ourselves up so that if a Space Station came soon, and we always hoped it was soon and not later, that we would have enough technical experience with it to confidently be able to go to the program director or manager or whoever is trying to set up the program, and say, "You have these options for what you can do for life support or thermal control within the spacecraft. You can go with an open system that just literally you provide oxygen and then bleed it overboard, or you maybe use lithium hydroxide," which is what they used on Apollo, Gemini, and still use on the Shuttle. But it's a one-way street, because you can't regenerate it. Once you use that canister, you've got to get another canister, and you've got this old canister that we don't have a way to desorb it or anything like that.

What you want instead is a process that you can take the $CO_2$ and chemically bring it back to oxygen, and there are processes to do that that we had been studying or analyzing and building for years that I had used in these different studies when we would talk about these different applications. And I worked on a number of Space Station studies back earlier, too, that always would push those processes as the way to go.

Same way with water. You can recover the sweat, shower, and other waters and reuse them again. You have to take the soaps, you've got to take the oils, you've got take out some of the other chemicals that are in there, but you can do that. We were pushing hard for those technologies to be demonstrated as mature enough that you could test those. One of the things we did was we tried to set up a test chamber where we could integrate these boxes or components that provided just $CO_2$ removal or $CO_2$ collection or oxygen generation.

Oxygen generation would be an electrolysis process; you just take water and you run it through a solid polymer cell or there are other ways to do it, too, but you get out of that the oxygen and hydrogen. The hydrogen, you could put into a device like a Sabatier reactor, and you combine the hydrogen with $CO_2$, and it will become water vapor and methane. Methane can be used as a propellant. It doesn't have much Isp [specific impulse], but it's sort of like a putt, putt, putt, putt, putt, versus a vroom that you see with the big engines.

Whereas for the water, I can take it over to the electrolysis system, and I feed that into that electrolysis cell, and I come out with the oxygen that I breathe, so you've got a regenerative process. With the water recovery I can take urine or any other source, I can run it through a VCV, vapor compression cycle where I literally evaporate it, and then the solids that are there, I can collect. The liquid is water, and if you run it through an evaporation process, it's pretty pure. We can then treat it with various ways to keep bugs, microbes, from growing in it and various other things, and then you can recycle it and actually drink the water and recycle it through there.

It's something that people have always been reluctant to drink that water. We've done it, but we have tested it, and it's a process that we understand, and they're finally flying it now right on the [International] Space Station. But back in those days we had it available to us, and so I set up a chamber or set up a facility that we would be able to test those things. I never really got a chance to test it then, because they moved me on to other locations.

What happened is that the division chief would periodically run into problems, and I'd be one of the people he'd pull in to solve the problem. So I'm maybe this deputy branch chief in charge of advanced life support activity, and I also got to do one other thing that was there, and that is set up a life test lab for the Shuttle mechanical equipment that we had in the fluid systems, the water pumps, the fans, and the ECLSS—you know, the Environmental Control and Life Support System—and the Freon pump.

What we wanted was fleet leader testing so that we knew the Shuttle was going to fly—at that time each Shuttle was supposed to fly a hundred times, and that's a lot of hours of operation.

What you traditionally want to have is one device at least of that type that's going to be going, that's expected to go a hundred flights or whatever it is—where you've tested it for at least that duration or longer, and you call it a fleet leader.

We set up a laboratory where we actually turn on the fans, and then, of course, the IMU [Inertial Measurement Unit] fans and the cabin fans are always quite noisy, so we got the chance to look at the mufflers for them to try to quiet them down. In the vehicle we had to do the same thing, because it was really quite loud in the vehicle at the time. It's quieted down now quite a bit, but back then we were really working some noise problems with it.

So we ran those. The unfortunate thing with that kind of static testing, it's often a corner nobody looks at, but it takes money to run it. When the program gets short on money, one of the first things they're going to want to do is shut those things down if they can. Of course, you used to sit there and plead with them that, "I need a fleet leader out here so that when a bearing goes or I get this weird sound, I got an idea of what it might be and I can solve it or address it." Or, "I could already have the contractor, who still has an interest in this device, because he's got three more on the shelf he's got as spares." We can already be fixing it there, so that when you encounter that problem, you can just replace the part. It's already got that weak element replaced, and you've solved that then.

That was a good activity that needs to be done on these programs now. They need to think about that as they do it. It will always be in the proposal. It will always be in the first years of planning. It will always be scraped away when you get to, "I can't afford to do all these things. Which one of these test articles or things—?" What they always look for are the ones that just keep eating away year after year after year.

If you automate them, like we were able to do then, you can really have them run quite simply, because later, years later when we were doing Station, we were able to put up a minisystem of the Station thermal control, over in that new building that was back there at the TTA [Thermochemical Test Area], and run it for a period of time. They have shut that down, or at least to my knowledge, and so they don't have much more experience. But then again, they are today just now getting the thermal system up there that would be the one they're running. It's got a lot of hours, but it's not got the opportunities that they really could have had or should have had.

I'm doing this and setting this up, and then [the division chief] runs into a problem in that I had worked a lot of payload stuff for Shuttle, and in working these different problems, you get to know people. He came to me one day and said, "I'm going to move this person off of representing us for payloads. You're going to be the guy in charge."

What he told me was that, "You'll be successful, because you've first got to find out what is it that's the problem." He said, "Well, I don't want any more phone calls. I don't want any more phone calls from the program office or from the directorate about this subject."

The first thing you do is you go over there and you find out who it is that's making the phone calls and say, "Don't call him. Call me before you call him, and I will see if I can't solve that problem," and then we went through and tried to solve it.

I would be pulled up to the division staff, work on this, and the first time they did it they put me on a 90-day—"You're going to be here for 90 days. Then you're extended another 90 days. Then you're extended another 90 days. Then we need to move you back to the directorate, because you can't go too much longer, because the Human Resources folks start saying, 'Hey, he's either in this position or in that position.'"

So I went back to work a little bit in the life support, and then they decided to make me permanent. Permanent doesn't last very long, but permanent representative for the division to all the up and out stuff with the payloads and payload interfaces. With that came a lot of other responsibilities. For each flight when we do an EVA, we built back then an EVA Annex, which is a document that describes what the EVA is supposed to do, an overview of the procedures or techniques, and then the equipment that's going to be required.

Then we negotiate that with the provider of the hardware that is going to use it, whoever's got the experiment or the payload that's flying in it, for each one of those. So I get to work with them on doing it, and I had a boilerplate of here's what I want on my document. I'd send it to you electronically. You'd fill it out. Then I would review what you've got, and we'd go through several negotiations, saying I need more detail for this, because this becomes then the data that's given to Flight to tell them what it is that's expected and what resources and commitments that we have on that.

Then we have an integration hardware-software review [IHSR]—in the early STS-10 through about 17 or 20, this is when I was doing this particular thing—in which this payload is going to use services from the Orbiter. And since we are a service, we, the Environmental Control and Life Support System, and the thermal control, and thermal, I'm going to cool you, so I need to know how cool, how much level heat you're going to put into me so I can be sure I can meet your requirements, and you're aware of the contingencies I can run into so that you are safe when those occur. You may need gas, like oxygen, nitrogen, or something, which is what we deal with with the environmental control system.

So we work out how much we'll allocate for you and what the requirements are, and they will come in for review, the payload will, with his plan on how to do this. They call that an

IHSR, and it's usually about a year before flight. That's a firm commitment then on both sides as to what they're going to do before we get to flight.

From then on you give it back to the contractor who's making the modification. Sometimes we had to put in new plumbing in the vehicle to meet this interface that they wanted to meet at, because sometimes we were flying satellites or something that was not intended originally to come into the Shuttle, but the Shuttle became the only transportation device you had to interface with this location. So where we had everything in a nice area that was good for us, we then had to accommodate what they had, and we'd then work out the design to make that happen.

They replaced that with something they called a cargo integration review, which was basically the same three-day period, but at the end of it you're now talking in Building 1966 in front of the program manager, or at least the one that's managing all the payloads, explaining to them your system and how it's going to interface with them, what the problems might be, and what issues we've worked out.

I got to know a lot of payloads and payload activities, and that's where I was at the time when we were building in the early 80s and were flying the Shuttle and were trying to determine what we are going to do [for the] next type activity. Mine, I thought it was going to be advanced life support, but it turned out to be, for a couple of years there, working the payload integration piece.

At the same time they were trying to come up with a design for a Space Operations Center, which was a way to put a Space Station type operation into space, and again this is where I provided the ECLSS design, and so we're splitting time between these early Station concepts and working on the Shuttle payload activity. And I'm going to go through here.

Oh, there's one other piece here. I worked a lot on the first four flights of the Orbiter. The first four flights of the Orbiter were the OFT Program, the Orbital Flight Test activity. Mainly there it was an extension of what I had done in Chamber A with the testing of the integrated ATCS [Active Thermal Control] system, in that they weren't going to fly any payloads. They were just going to check out the Orbiter to see what all the systems could do and how the flight mechanics and all that worked. It would give us a chance to look at our system in the real environment in the real way. Of course, there you're very leery about introducing any failures. What you just want to see is how like in our radiator system, analytically we had figured out a way to model this thing to predict its performance, but it was all analytically based, and we had not seen anything in orbit with it doing it.

So you can orient the vehicle in many different positions. You can look top to the Sun, or you can have the top to the Earth—top; I'm saying "top" because that's where the radiators would be exposed to, or you could be looking at deep space. In all three of those environments it reacts differently. As you go around the Earth, you're going to get some cycling of things and so we would predict what that would be, but the orbital flight tests would be a way of checking that. So I built another document that was—it was before computers were really useful in our work; of course, I was still old-style then, not really utilizing the full resources, and I had a lot of younger people who were pushing me to work it there.

We got a chance to say, "All right. We'd like in these tests there to orient the vehicle full to the Sun," for some period of time. The forward radiator panel could be raised or lowered, radiated from both top and bottom, and we thought we knew what the performance was with it deployed open, but the orbital flight test again gave us an opportunity to do that. We would work very closely with the flight planners to say, "During this particular flight, we'd like to get data in this beta angle,"—beta angle was the angle between the Earth and the Sun and the orbit that you're in there—"and see what the performance is there." Then on another flight hopefully they'd be at a much lower beta angle so we could sort of map how this thing reacts in all environments, so that we would know.

What you're really looking for is in those cases where the radiator is not providing sufficient heat rejection, the flash evaporator's going to have to top it off and be able to support it. So we would then be able to tell Flight that, "You can go into this orientation for this many hours, but after *x* hours, I'm going to run out of water over here, so you can only plan to be in this experiment or this satellite this much exposure,"—it wouldn't be a satellite; it would be an experiment or a payload—"to this environment for *x*," because we became a constraint. What I wanted to do is give you real data, not just my best guess at what it might be, so that we can maximize the efficiency and the support that we can give the people.

That became a very strong driver for us, as to what they did in the OFT Program, is trying to correlate our analytical models. I had a team of people from Rockwell here who were trying to characterize it, and we spent hours just going through their data and then looking in and saying, "Well, that don't look right," like I did in ASTP [Apollo-Soyuz Test Project] earlier. Then we decided, oh, let's try this, and they'd come back later. It ended up being a very good model. They did a good simulation. OFT solved all of our concerns—not solved it; it addressed it in probably 90 percent of the environments we wanted to look at. We caught the others.

By about the tenth STS [Space Transportation System] flight, STS-9 or thereabouts, we had caught it, because sometimes when you have a large payload like the Spacelab sitting in there, you get feedback from it, and you were not quite sure how it interacts with the devices you've got out there, this radiator. With Spacelab we were able to get the final one, because we could then get that interaction in the environments it was going to fly in, and we know if we're going to heat your surface too much or if there's a combination that we had to stay out of.

There was also a concern about the coding on the radiator. Originally they had a coding design that was just a mirror-like surface. Of course, a mirror, if you happen to be looking out the windows in the back and the Sun came from there and bounced off the mirror into your eyes, you'd be blinded for a second or two. So we didn't want it to be that shiny as such.

We also had a problem with the glue on the radiator that was holding the silver Teflon. You put silver Teflon out on the outside surface of the radiator to give you the thermal performance you're looking for, because it will conduct heat and get rid of it or allow you to get rid of it very easily. But when you glue it down to this metal, you have to have a glue that has no air bubbles in it, because as soon as you go into a vacuum, you go into space where there's no pressure outside, that air bubble becomes a bubble. This miniscule thing here suddenly grows into a three-inch bubble that separates. If it separates from the metal, then you don't have the silver Teflon touching the metal, and it has to go through a radiation process, which is less efficient, much less efficient there to go through these tubes, so you lose performance on those radiators.

We ended up putting dimples in all of the silver Teflon so that we could get all of the bubbles to be sure that we didn't lose large areas of the surface on that thing. Some of that we learned from the testing that we did in Chamber A, because we saw bubbles grow there, and that's how we went initially to the dimpling. But as soon as you put a dimple in you're losing a little bit of area, because you now no longer have this surface out here that's smooth.

A lot of it was done analytically, but some of it was a little bit trial and error, trying to figure out how we could do that. So we mapped in OFT the rest of the radiator environment. The flash evaporator worked fine during those phases.

The only surprise I had on that was on STS-1. We were unable to simulate the pogo effect. That's the effect that when you've got the solids; they've lifted. You've got the main engine going and everything else. When you lose the solids, you get a little bit less thrust on the vehicle, so you get a little bit of vibration, you might say, or pogo. But the real one is when it cuts off the main engines, the main engine cut-off, which is about eight minutes, eight and a half minutes into the mission. You've got all this push on you, and all of a sudden it goes away. Of course, the crew, they can start floating, because the fluid that's being pushed up here suddenly comes slamming back down, because nothing's pushing on it. All of a sudden it's free.

So you get this fluid, and in our case, we're pushing water from the front back to the back from the water tanks, and you get what appears to be a loss of the feedwater supply to this thing. So the device, it's full bore pushing out all the water it can through these little valves. All of a sudden the water goes away, and so the temperature of the coolant that's going through there is now a nice 38 degrees, plus or minus 2—that was our tolerance on this thing. It's started to rise in through here, and the pogo effect, you usually will see something. We knew theoretically that it would affect us a little bit, but I didn't know how much.

That first flight I know that—and it was probably [John W.] Young that was over here on Panel 11, had his finger on the switch to restart the flash evaporator just in case that thing didn't work. So we saw the pogo effect. It was about a three- or four-degree swing, maybe a little bit more. But it caught, and the evaporator stayed on, so that was probably the first time he moved his hand back over, at least in my mind; it may not have been that, but he did say that they were nervous about that.

We could characterize it, and it was the first time we felt comfortable that they would now characterize the whole mission phase from the ground testing plus this first phase of the flight. But there was a little bit of unknown as to how this thing was going to work, and when it comes back, is it going to flood or anything, and we didn't see any of that. Everything worked basically the way we had tested it here, so it gave me a lot more confidence.

The way we would test it inside the chamber—it's easy to push water down, but hard to push water up and get it to evaporate without flooding the bottom. But that was the worst case, so we tested the device down, sideways, and then up, to make sure that it could work under all of those conditions. And it worked in all of those, after we got it all modified. So the ground testing, you've got to think through how I'm going to apply this, and what's the worst case, compared to what's on orbit, that I can simulate down here and make sure it works in that thing. But I think that was a wise piece of the planning that they did, that test.

WRIGHT: Did you have much interaction with the Approach and Landing Test?

JAAX: Not a whole lot, because our devices weren't on there. You've got to have a cooling system on the vehicle, because you're running all these avionics, all these black boxes and everything, and you've got people in there, so you're having to cool it. So you've got some lithium hydroxide in there. You've got the cabin heat exchanger picking up the heat. It's running it to heat rejection devices, but the heat rejection, you can't operate the flash evaporator, because you're not high enough. You're not above 100,000 feet. They're flying much lower and dropping off the B-52 and coming in.

I'm trying to remember what device or how they rejected the heat. Ammonia boiler is what typically does it on the Orbiter, if you got down that low, and they've had the ammonia boiler just operating, because you didn't have the radiators and didn't have the rest of it. What we did was an analysis of how we thought the ECLSS would perform in that thing, but it really wasn't that difficult a problem, because it was a very short flight, and then, of course, it was a dead vehicle. It just flew into a landing as such. I think what we did was just some analysis to prove that it worked.

In planning for STS-1 a major effort, because of Apollo 13, was what if you have a failure of a fuel cell or something, and you've got to power down. If you remember in the movie they show you that they had to do that real-time. John [W.] Aaron's back there throwing switches and trying to figure out what would be the right thing way off in one of these simulators that they had there.

Well, we weren't going to be caught with that again, so a lot of this was flight techniques reviews, too, as they would simulate a failure, and then we'd have to tell them how much power they could leave on because of what we could reject. If we only had one loop of the Freon loop it's not half, it's something less than that, or maybe it's a little bit more; it depends on how much you want to—you have bands you work within, and then you've got a little wider band there that says I'm still confident it will work. If I go above this, I'll have electronics fail or I'll have a system freeze-up or something, depending on what end you're on.

So we worked a lot of simulations. This is where I really got to know the analytical model and what it would do, because we would fail something or simulate the heat load had dropped off by this much, and what I would give them back then was saying, "Hey, we can pick this much, this many BTUs [British Thermal Units]," and you convert that to watts, and you'd say, "You can operate this device." We would get down to, "You've got to operate this device for one minute and then leave it off for three minutes, then operate it for one minute and not leave on for three minutes." Or, "You figure out what boxes you want to turn off. All I'm going to tell you is I can't collect any more than this. That's all that my capability is here."

That's pretty much the give and take that we had with Flight or the other people working the problem, and we did a ton of those, just lose a Freon loop; lose a FC-40 loop, which is in the fuel cell loop; lose a hydraulic system; lose this. We went down to single failures, to double failures, and three failures. Well, even two gets ridiculous, because it can be any two, anywhere, and we eventually learned. We could study it forever, because you can always put combinations together. We eventually learned; you want to know what a single failure does, absolutely. You've got to know what it does. There are a few critical double failures that you really need to understand how they work. But the rest of them, you need to just know that when that fails, it typically by itself would have done this, and if I combine it with this other—because it would take you forever to analyze the results. To me, you've got information overload. I know too much. I need to be able to synthesize really quickly to here's what I want to do and here's how I want to do it. So what are the major failures, and we learned that end so we could go right through it, because I'd be standing in front of it and saying, "Well, what if you failed this at the same time you failed that?"

After a while we'd say, "Time out. If those all occur, it's really a bad day, because it's not what the thermal system's going to do; you now have no flight control. You can't do anything. So even though I can run, you're not going to be able to solve your problem as to this, so let's don't analyze all these cases, because I haven't got the money, I haven't got the people, and I haven't got the time to solve all of those. So let's refocus back on what you think is most important, and we'll do all of those, and for those we'll have the answers." So, the malfunction procedures and all that were tried out.

We did power-down profiles, which is the term that they used at the time, for lots of different things, and those are still there. Even on this last flight of the Orbiter, they didn't talk about it, but they were ready to do a power-down profile. It was like the fuel cell. They had problems with one of the fuel cells with a phase and a motor, or I think that one of the phases went out on them. We had looked at that. There was a power-down profile if you had to come in with one of those situations there. There are failures which you don't walk away from. You just—that's it. But on most all of them that we had, we had alternatives. That was the beauty of a lot of the systems that we had there is that I had another way that I could help you with this, and that's what we get into is a lot of—it'd be real-time discussion. You'd ask the question, just like you asked. I want to fail this; what would you do?

You'd give an answer, and then somebody else would say, "Well, I could do this."

You'd say, "Well, okay, that helps me here, but that may cause a problem over here."

Then you'd have somebody over there who'd say, "No, I think I'm all right with this. If you can do that, do that."

That's the dialogue we'd get into in the flight techniques. It was not that I'm smarter than you, and I know the answer. It was more of I know this piece of information. Can you help me with what you know and what you could contribute to this thing? That's the way I recall it, because I don't recall ever getting into a confrontive—you know, "You're not supporting. You don't understand. You're not trying to help us. All you're looking out for is—."

Never saw any of that, because I think the biggest thing was that if you didn't know, you said, "I just don't know what will happen. Give us a little time." Sometimes it was a day or two; other times it was a week or maybe longer. Let us go off and talk to either—well, certainly talk to some people, but also think about it a little bit, because there is a lot of options. Sometimes you can't just real-time, off the top of your head think of them all; and you'd come up with a solution.

I've felt very comfortable after we got through with all the flight techniques that we understand pretty much what we're going to do, and certainly the people that are asking the questions are the ones that need to know, and they're not holding anything back. If they didn't believe something, they wouldn't be shy about saying, "Hey, you know, I don't think that thing's going to work that way. It's going to do this." And you have to defend why you think it works this way, and sometimes you'd have to bring back additional data, which is good, because it made you think again about these guys don't ask these questions just to make your day bad.

There were some times there where you would like to get off the stage a lot quicker than you did, but I think that all that activity on the power-down profiles, thank goodness we have never had to deal with all those, but they're there. My only leeriness today is that all of us that worked it aren't there anymore, so the rationale as to why we're cutting all this off, they're going to have to trust. Fortunately, they pretty well do that.

WRIGHT: You didn't do a little book on that one?

JAAX: No, because they were writing a book. The book is the malfunction procedures that they had there, and they understood them pretty well. What we provided them was little reports or studies, maybe. Usually the way that worked was they'd give me a problem, and you'd go off, and I'd have Joe Chandless [phonetic] or Bob Blakeley or someone else do the analysis on this thing. We'd look at the results, and then I would take what I thought was the important thing off of it, and I'd bring those two, too, one of them or the other, and listen to the question, because many times having four years or six years here instead of just my two made it a whole lot better, because then you could say, "He really was looking for this."

There's a lot of nuances in the way people say things that sometimes you're so busy thinking you're not listening. You need those other people to listen, so I'd always bring backup support to at least listen to the thing. Then I would try to put down in bullet charts with one-liner—you know, "We did this, this, and this. Here's the results we got out of it here." And then have a plot. Always have a plot of data that showed you here's how the thing behaved, and guess—your best estimate—as to which parameters they'd really want to look at.

The instrumentation that's on the vehicle is always just what the instrumentation was on the vehicle. Even on my analytical model we'd have a lot of other stuff that's instruments that would say, "Hey, it's doing here." I've got to admit that there were a number of times I was nervous about how this flight controller could determine what the failure was or what the cause might be, lacking all this other stuff that I had seen in the test data.

I haven't encountered a problem yet with it, but I will say that certainly during the '79 test I knew what the problem was far sooner than they did, because that was the important thing. They were to tell me as soon as they thought there was a problem. We'd set the thing in. I wouldn't actually do it. We're in one room. The flight controller, along with the people who actually worked the hardware, are in another room, and I'm sort of like the Sim Sup [Simulation Supervisor]. I just call the shot, but I don't make the change, and the hardware person over here is told to do this. The network is such that the flight controller can't hear what it is that has been done.

Now that I do know what the failure is, I'm looking to see where is the first instrument indication that I've got of this problem I haven't seen in effect. Then I'm waiting to see how long it takes this person—there was a woman and a man who flip-flop back and forth on that—how long it would take them before they say, "Hey, I think I've got a problem over here." To me that was critical, how much time I was giving you, or how much time you had available, and then how bad were we off at that point in time. Were you at a situation where you couldn't recover, or was it a situation where you had plenty of time, and you just need to look at a number of things? Then we just wait and see what they do.

There were a number of times when I shut it off. I would stop it before they arrived at their conclusion. Part of that was that they just weren't near as familiar with the system yet. They had not gone through all the sims [simulations]. All the sims that they go through over there with all the failures and that make them much sharper. I've participated in a lot of those sims, a lot of them. The early sims for STS-1 and that they would bring us in to sit with them or to counsel with them as they do it, which I thought was a good idea, because, again, if you're going to run into a real-time flight problem, bring me in then, and I now have to get acquainted with what's your room look like, what resources are here. That wastes a lot of time.

WRIGHT: Sure.

JAAX: What you want to be able to do is shake their hand and say, "Morning. What's the problem?" And already know who they are, what they do, why they're there, what their expertise is, or what their concerns are, and I think that really helps on our early Shuttle flights when I did some of those other failure things. But that worked out real well, having them there.

But the failures and that instrumentation question was always something that nagged in the back of your mind, because I've found that, like on the flash evaporator, there was one piece of instrumentation that I had available to me that it gave me the frequency at which this valves were cycling, which was not in the flight data. It's a state; but as soon as I'd see it start changing like this, I knew that it was having trouble. I didn't know why. The first thing you look at is, well, is the heat load going in a lot greater? Did they get its pulse there? If not, then I'm probably building an ice ball in there. That would be my first clue.

Flight didn't have that; doesn't have that. We recommended it in the final briefing that we gave to the program, saying that I would add this piece of instrumentation. Didn't have time, and they didn't put it in there. But fortunately, we had a solution that if you did get an ice ball, here's a way of getting rid of it.

Plus always with the failures that you do in the simulations and that are—at least in my experience—far worse than what you really encounter on orbit and we're able to resolve it, unless it's a catastrophic event, and there's nothing you can do with that. But it's a good process that they've got that's worked well, or it's worked with us.

The one caution that I would make is that it's sort of like when I grew up going through school we had to do everything longhand. You learn the multiplication tables, you wrote the equation out, and you went through the different breakdown of the equations till you got to the answer. I think usually by college there you still had it, because we didn't have computers yet. It wasn't the answer; it was the process that you got that they were looking for, that you go through these steps to derive this solution here.

Today where you have calculators at your disposal that can do that in an instant, all you've got to do is put in the constant—excuse me; the constants are probably already there. It's just the variables and just picking the right equation. It spews it all out there; you're really dependent upon that probably being right, instead of being able to investigate what the pieces are that make it up, and say, "Hey, this is the wrong assumption. It's only as smart as the guy who programmed it, and it can't make any real-time changes that may be necessary because things are a little different than what they were before."

So that's the caution I'd have today about how they prepare for flight. Don't get so dependent upon that computer to always have the right solution that you yourself couldn't write out that equation or look at that piece of data that's being plotted and feel comfortable with it that that really should look that way. Should this curve go up and then come down, or should it flatten off? If it's not flattening off, then you probably got something incorrect in your solution or your equation that you're trying to solve this thing with. To me, that hands-on, having to work it and work my mind through it, is a real asset that I hope the next generations can keep, because if you don't have that, then you're dependent only on what somebody as smart as you earlier did, and you don't have the insight that they had to arrive at that conclusion.

I was going to go through a little bit more of the supervisory thing here. I went up to do payloads. Then they made me the payloads person officially for some period of time, and I would compete for—I was still looking to get a supervisory job as a branch chief so I competed for a couple of them. I finally was selected for the Thermal Test Branch.

Before that we got rid of the System Engineering Branch and we created something called a Special Projects Branch, because we were doing a lot of special projects. Once we got the Shuttle flying, one of the big problems we ran into is there's nothing to fly. All the payloads that we were planning on flying aren't ready until STS-11, 13, 15, or something like that. So what can we fly early that would help us technically understand issues that may help the Shuttle or some conceived thought of what we're going to do with Shuttle or with Station.

So there is where we put a lot more people together in EC to look at EVA, how are we going to use EVA to help with the satellite retrieval and various other things. We came up with all sorts of devices to rescue an EVA crewman in case he gets loose from the Shuttle or, more likely, because we're thinking of the Space Station, because Space Station Freedom started coming along. If they float away from it, what are some devices that you could throw maybe back at the Shuttle with a rope and capture, sort of like the bolo that's being used by the South American caballeros or whatever to catch an animal.

So we came up with a number of those devices to test, and we would design them, we would build them, we would test them, and we'd fly them from our division. In the thermal area we were encouraged to come up with devices there and then ECLSS or whatever it was. But that was a make-work program that actually turned out to be really good for us, because it got us more exposure to the real environment and gave us another test bed that we could test our different devices on. I got to do some of that activity in the Special Projects, because that's what we were called is the Special Projects. Will [Wilbert E.] Ellis, who seemed to be always my supervisor, direct supervisor, was the branch chief, and I was deputy under him.

Solar Max was a nice experiment that we came up with a way of trying to capture the device there. I worked on that and really was more of just supporting my people with it, because I'm in a management position. During this time, the Galileo and Ulysses payloads were being developed. They used a Centaur rocket to launch on, and it was decided that the Centaur would be put into the payload bay of the Orbiter. The RTGs, which are radioisotope thermoelectric generators are a heat source that would be sitting right underneath the doors of the radiator.

So I'm integrating the payloads as my job here, and I see that they're trying to cram these heat sinks—that's sort of like an oven it's glowing—that's very hot, and the radiators, of course, aren't going to like this very much. I was put on a Tiger Team to help figure out what the best way would be to integrate this in, and then is there any way that the Orbiter could cool it, since I knew the active thermal control system.

It was quickly decided that the GSE heat exchanger, the one that's does the cooling of the vehicle while we were on the ground—they just put coolant from a cooling cart on the ground, and then you unplug it just before liftoff, and then it's on its own—wasn't being used. It's a device that's sitting in there. So perhaps we could go through that, and that would be a way of picking up that heat from the RTGs and then running it through the radiator and everything, because that's where it was in the loop, fortunately. We had placed it at the head of the radiator system. Then on orbit it could cool it there, and while it's on the ground, we could cool it directly through the GSE heat exchanger again, because there was passages there for us to do that.

So, [I was] put on the Tiger Team; came up with a solution, and I was put in charge of the Tiger Team to work out the technical way we'd do that. And now I'm still on the payload thing; I had volunteered, because the payload activities were only requiring about half my time productively as such. It's a lot of work but I was used to doing a lot of things so I volunteered to be the test manager of it. I wouldn't be caught like I was before with the flash evaporator and suddenly being put in charge of this thing.

I volunteered to do it, and I got my hands back down on working on a schematic, where I actually could draw this is what I want this thing to look like; this is how the test article will be put into the facility. We had to build up a piece of the facility in Building 7 out in the high bay area there, and we had to put the facility pieces together with this. We had to work with JPL [Jet Propulsion Laboratory, Pasadena, California], who owned the Ulysses, the spacecraft and the Centaur folks; had to work with the Program Office and with Kennedy [Space Center, Florida], because what we wanted to do was test the cooling cart that the RTGs were going to use for their interface in with our system. So we made sure that everybody could—they'd do end-to-end testing where everything worked together then.

So I was able to sit in my office there and actually look at the schematics, red-line here are the instrumentation points and everything. The test engineer who was building the thing would come in, and we'd work. It was just like the old days. I'm back to what I was. It ended up it took about two years to come up with the thing, and in '85 we did the test in there, and everything worked very well.

It was a new application, but what really made it work was the fact that after we had completed the testing in Building 32, the Chamber A test and the integrated test, instead of throwing all that hardware away, we convinced the program that give us a little bit of money, and we can put it in Building 7, and we can have this capability to test different devices to try to address anomalies that might occur in flight or new flight configurations we might need.

If you look in Building 7 above the 11-foot chamber there's all this plumbing in there, and there's actually a small chamber with a flash evaporator in it. There's a radiator simulator, and all of the heat exchangers are simulated and we used real plumbing lines with all the right line length. And we had a GSE heat exchanger. We could plug right into it, test it with the active thermal control system, and run it all at the same time. We had an old set of consoles and they were set up to do this thing.

That proved well worth our investment. That was done probably in ’80, and we didn’t conceive of this idea until ’82 or [’8]3 as something to do, and we tested it in ’85. It proved to be a very beneficial thing.

My recommendation has always been to don’t throw away the hardware that’s been used for the development and certification, if you can get ahold of it, capture it, and put it into a facility. Don’t let it just sit on the shelf. Go ahead and put it back together in a form that’s usable, so that when a need arises you’ve got the capability there to test it and not be just dependent upon analysis or maybe a very jury-rigged simulation there that doesn’t give you the full capability.

So that worked out very well to conceive, and I guess I put together the system that was put in 7-A of the active thermal, since I really knew that stuff, and then got to design this RTG cooling test, and that all worked out quite well during that time.

Looking more what we did here. [Turns pages.] Got a lot of letters of recognition or whatever it is here, and that’s what I put down.

Oh, in that same time frame in the early 80s, Space Station Freedom was something we knew was coming so we really were trying to set ourselves up to be able to put this regenerative life support system into the thing. One of the things that they’d put me on was putting together some test beds that would test the technologies—thermal technology, that’s thermal test bed, and the ECLSS test bed, which would test out the regenerative life support systems—because we were trying to be ready to answer that question that the program manager would ask you. “Do you have confidence that this regenerative device or this new heat exchanger, a new concept of doing this thing, would work?"

So what we did for Space Station Freedom is in the thermal test bed, we proved that a two-phase fluid system could be used, in lieu of what we do now [which] is just pump fluid around all the way through this. The two-phase fluid is you're collecting heat, like I said, in the SHARE flight experiment, you collect it; boil it so that it becomes a vapor and goes out to some cold location. At that cold location it condenses back to a fluid and just recycles. Well, there's a whole lot less pumping power energy or power that's used in doing that kind of a system than today what you require. You can save the power that the vehicle has on board for experiments or for other systems and you become much less of a consumer but more of a provider of services.

I built up a test bed that would support Space Station later, and I was put in charge of having it done. At the same time we were looking at this 20-foot chamber in Building 7 and outfitting it so it could house three people. It could have on the second deck where they put a wardroom, and we worked with the habitability folks so that they could figure out what kind of color, what kind of room shape, what kind of support systems as far as a desk or TV or a console or whatever that you'd want in there; what kind of bedding, what kind of whatever.

So people would stay in the chamber, live and work in there, while the equipment that is providing their oxygen, their $CO_2$ removal, that's collecting their urine, we would have that equipment working downstairs, and they would pull maintenance on it, much like if you were on a Space Station, like the crew is doing up there right now. They would be able to keep the thing running, and we would have a test—what did we call it?—a room where from outside we could monitor everything that was going on. But it was basically to be a self-contained test facility as such.

I got that started and developed before they then—well, I moved on up into the division staff to work more Space Station Directorate stuff. But the division itself was always proactive and trying to develop those things back in the mid-80s to late 80s; trying to put together a capability there so that we would be one step ahead of where we thought the program was going. Usually you could do that for minimal resources, but when people would look at what you'd done, they'd say, "How on Earth did you pay for that?" And we'd be accused of misusing—I don't want to say "misusing"—of not working on the things you're supposed to and working on that. We'd then point to all the things that we were doing.

But in the meantime it's sort of like when I was working the payloads, and I said I had time available to work on the RTG. We had people that were doing multiple things. It wasn't that you just did this and then went home. You did multiple things and would work on it that way. It's just a way of thinking, of being proactive on what you're producing and what you can have. It worked very well, but it sometimes made us vulnerable to these questions as to how on Earth could you produce this.

Later on I'll talk about how we got into that problem with the X-38 and the TransHab vehicles, because nobody could believe that you could produce what we did with the minimal amount of resources that we said it took. I've been accused of being too—I don't know how to describe it—I'm very detail oriented, so when I said it cost this much to do this thing here, I have gone down to the core and worked back up to get you what the cost is, and it's not just a guess or it's not to impress you because we'll just cover the cost someplace else. It is to give you what we thought it really did cost in that time.

I don't know. I think it's an attitude we have at the Center here of being very can-do, and we will work the problem, and we're working not just on that one but we're working on the next one. It's like when we were working ASTP, Skylab occurred, and we turned to to work on Skylab and did everything we could very quickly. Then we were back—I was back on ASTP; the others were back on Space Shuttle, working the early preliminary design on it. But it's just an approach or an attitude we had here, whereas I'd go to some other Centers and they had one job today, and that was it. When they were through with that, they were done. We'd sort of say, "There's nothing else that you're working on?"

"No, this is it."

We'd say, "Gee, it's nice," but to me there's a lot of talent that's available that you can really use, and at the end of the day, you're feeling good; feel really good that I did a lot of things.

There are some people that I ran into in my career out there that you give them one job, and that's it. You give them something else, and they just cannot—to me, I guess it's the decision making you have to make in both of them. It's difficult enough with one to make sure it's going all right, and now if I'm thrown in this other where you've got to make other decisions they really don't feel comfortable because they're still worried about this first one.

You can work with those people as long as you identify it quickly, because you can also get in trouble with them, because they will feel like they never can get ahead, they never can catch up. They're always overloaded, overworked. So a supervisor needs to understand that or look for signs of that. I don't know that there's any one telltale sign, but usually it's if they're slowing down on what you thought they were really good at, then it's probably because they're working some other stuff that's overwhelming them a little bit and you need to back them down to what the expectation is.

For me, I was—I don't know, I'd never turned down a job. I would tell you, though, it may take a little longer because I've got this other thing. But I'd never turn any of them down.

WRIGHT: Did you ever participate as a test subject in all the testing that was done in your division?

JAAX: No. No, I didn't. I know some others—when they were doing the early spacesuit evaluations, there were a number of people who were subjects in that, and I would hear their stories about that, and I'm very glad I didn't. [Laughter] There were some that those guys were very lucky, very lucky, that bodily harm didn't occur due to they just didn't know, or wouldn't realize it.

The closest could have been—and it was just where you are in your cycle as you're going through it—when they did the closed-chamber test, because later on after I had that facility built, it sort of sat in limbo for a while. Then when I went up on the directorate, Leonard Nicholson went ahead and pushed EC to go ahead and do a 15-day, then a 30-day, then a 60-day, and a 90-day test of closed chamber with people in there as subjects, just working on the equipment. Those proved to be very good.

At some stage in that, if I had been 20, 10, 15 years younger, I could have been one of those, possibly. But, more likely, here's what I think really would have happened, because there were a number of times early in my career when I would talk to my supervisors and tell them having worked with Flight or MOD [Mission Operations Directorate] and the others I got to know them pretty well, and I said, "A rotation over there would probably be a good deal, because

I can see better when I can get over there what they need, and when I come back I can work it, work better, be a better provider of what the resources—."

I would always get, "The answer is no, we need you to work over here, because once you get over there, you'll stay." And it was more like, "They will keep you." And I honestly never had a strong desire to be a flight controller, although I think I could have done that easily—well, to me it would be; it's probably much more difficult than I'm imagining, but it would have been fun. However, that's all you do is just look at that system, and you become a real expert on all the different pieces that you've got on that thing, and that's sort of what I was doing anyway in doing this, what I was doing.

But every time I asked—I asked three or four times probably until I got to be a supervisor. I would say, "You know, why don't—?" Because there would be periodically a request for people to help, move over to MOD or something, or to do some interchanges of technical folks.

It would always be stopped before it got out of the division. They would just say, "No, that would not be a good thing."

I think the same thing would have been on the test subject. If I'd have volunteered for that, they'd say, "Why, then, you're dedicated to this," because I just got moved around to these different other areas.

But spacesuit, I never actually got into a spacesuit, and that's the one thing I probably should have done when I was in the division but I was a little taller and a little bigger than some of them. But I could have done it, but, boy, I feel like I'd have been claustrophobic a little bit with that helmet, because when you get in there and you're talking, it all echoes [imitates echo] right back at you, and it's all really there. It would have been interesting. The other thing is with broad shoulders and that it's a tight squeeze to get through that, because I've done pieces of it, when we check it out.

So I envy those guys who have done it, and I commend those that actually do it. [Laughter] That would have been the most likely area to have been a test subject. There are some stories that some people could tell that you probably don't want to hear as to decompression, some things that—this was in the early 60s or mid-60s and after that.

This almost brings us to my Space Station stuff, so let me look through and see if there's anything that's missing.

I became the branch chief for Thermal, and then I was brought back up onto the staff again to work Space Station stuff, and that's probably where we could start when we come to that. I'll flip back through here and see if there was anything.

I was going to say on the two test beds, the ECLSS and the thermal test bed, I did write those, or they were written in my group and I had a lot of input on that. But we were really trying to come up with a design that would be useful. I got to see both of them being used, and that was rewarding to see that.

I'm looking through some of these things. The Manned Maneuvering Unit was an interesting project. I always got to talk about it, but I never got to really work with it. Ed [Charles E.] Whitsett [Jr.], who has passed away, is the guy who, if you were doing the history, would have been good to talk to, because he went through that period.

But the whole idea of having a spacesuit that's a suited crewman who is out there independent of the Orbiter and not tethered to it or anything else, was a foreign—I would go to these cargo integration reviews or working with payloads and since we did EVA and I'm promoting EVA, because use this for this. And the feedback I'd get from the program usually is, "Why would I want to put a man out there in a suit; and he has a problem, and I've got another problem. I've got a vehicle I'm worrying about here. Why do I want to have a man out here in a suit?" They were men only at that time. They were just nervous about using the spacesuit to do anything.

But when we had STS-11 and had the Manned Maneuvering Unit in the sky and saw the astronaut do his thing there, it was proud—it was a reinforcement to us in the division who were working the hardware all the time that we really can put something out there that's an independent spacecraft of whatever the vehicle is that took them up there, and we can keep them alive. We can keep them breathing, meet their physiological needs, and we have gloves that allow them to do the dexterous things that they need to do. We can have a device on them that actually pushes them and turns them and does the things that's needed to get them from one location to another.

That was probably a real good feedback to us that—because a lot of that work was done internally in the division and it was while I was working the advanced life support that a lot of that hardware work would—but, we built that again, or a large part of that Manned Maneuvering Unit, with people in the division, plus with Martin Marietta, who did the equipment.

Two other things. I get asked questions when I'm doing mentoring now about promotions. When I came in, I was fortunate to come in as a GS [General Schedule]-11, but getting to a 12 came within a year; 13 was a number of years, and a 14, 15 took a lot of time, because we did not have a lot of changeover, because the group just ahead of me that came in the early 60s and mid-60s were all my age or just about. I was in graduate school, and they're out here. Or I was in the Army while they were out here doing their thing. So today there's a lot of question about why can't I go up to 13, 14, or 15 as such, within a year or two or so after their previous promotion. There's this perception that it goes like that; it's in a rapid sequence, and you get up the thing.

To me, there's two dilemmas with that. One is you need seasoning to sometimes do some of these jobs, and seasoning is gained by experience at working at a level or whatever it is and acquiring the skills that go with that. And second, you can get topped out fairly early in your career, and then—I saw a number of people who that happened to—you lose that drive or that push to go to the next level or whatever it is, because you sort of burn—I mean, I can't go any higher unless I get through the SES [Senior Executive Service]. So there's a lot of effect on this early promotion that I think it would be more beneficial if people would accept the idea that seasoning for a while in a level, because they have step grades within the normal GS rate system that can compensate, if concern is money. But let that system work for you, and I think it will work out all right. So promotion-wise, I do get that as I mentor. Some of these people out here are saying that, "It's been a long time since I've been promoted."

You ask them how long, and it's been two years or a year, and I say, "Well, it took me five years to get to here, and it took me seven years to get to there. And I know it was late in my career that I got SES, but did it hurt me? No, I don't think so. I think it made me—you've just got to live with what you've got," but there are some expectations that are built up out there that we didn't have.

Let's see there's another; I was going to mention something else. Oh, I volunteered once to be a grievance fact finder. Have you ever heard of that program?

WRIGHT: No.

JAAX: If you've got a problem out there, and that problem is with a supervisor or an employee, and you want to file, as an employee, a grievance, you can have a fact finder, independent person, go assess what the facts are to support the grievance one way or another on this thing. I was appointed to that after getting a little bit of training back in the early 80s. I never had anyone call me to take use of it, but I think it was a good piece of training to allow you to understand all the assets that are available to people through the Human Resources activity and various other things that are out there. I think in a person's career as they go through it, there are other little things that you can volunteer for. You may not get selected to do it, but all of that will help you get a bigger picture of just what all is done, and towards the end I think we had the best Human Resources Group anywhere that I ever saw.

I discussed it with my wife, who worked at Baylor College of Medicine [Houston, Texas]. What we did out there and what I worked with them on is totally different from what hers—hers was more the hire, fire, and bye. There it was a much more complete package and very competent people. But getting into the grievance thing, and I was on a lot of source selection for people to go to things or do things or whatever and that it just gave me a real strong appreciation for that. But the grievance thing was something I've never seen used or heard used but it was a program that was supposed to balance things and make things more equitable as to how you dealt with a problem, and give an independent view, sort of like an ombudsman or something like that. That could be what they transitioned it into is the Ombudsman Program.

I did get to go on one recruiting trip; it was back to my university at Kansas State [University, Manhattan, Kansas]. Unfortunately, it was unsuccessful, in that at the same time they sent us there we had a no-hiring. [Laughs]

WRIGHT: Oh. Kind of hard, huh? [Laughter]

JAAX: I'm sitting here, "Why are you sending me up here?" It gave me a good opportunity to go back, but that's another thing that I would—I don't know. I could not go out and hire you off the street, or never had the opportunity to do that. I don't think it's possible. Usually the recruiting is done by totally independent people, and maybe some through Engineering, but more likely you'd come in through the Co-op Program, and that's how we got most of our employees. But I always wanted that desire to be able to go out there and talk to the person face to face, to see what they've done, how they've done, and make the decision on whether or not they could be hired. I know we do recruiting trips. I did the one way back there in the 80s.

This technique we've got right now works pretty well when you're hiring just a few and you do it through the Intern Program, because it exposes that person to what the work environment is here. The dilemma is that you'd have never gotten me, because I went through school, and I was going to go through the four years and then did all that I did. I would not have had the opportunity here, so it would be a cold call for me to come in here to do that.

So I think there's good and there's missed opportunity in the present program now with the recruiting trips and I've sent a number of people on recruiting trips, but I'd always try to find out, "Is there a chance we can even hire anybody out of this?" Because you do due diligence; it's difficult to characterize in 30 minutes when you've got another one sitting there, and at that 30-minute mark, sitting in front of me. You've got to do the interview and then do a quick summary of who this person is, and after you've seen 15 of them, you just—number one was a she or a he? They were interested in what? So that's a difficult job.

I appreciated the opportunity to do that, but it's not something that we depended on. But I would have liked to have seen more, more direct input as to who we brought. The way I compensated for that was—oh yes. This was when I became the deputy division chief. The interns, when they came in—not when they came in, but before they came in—I had a great admin [administrative assistant], Donna Mays, who's still out here, and what we would try to do is cherry-pick. We would get the list of people. We'd see their interests. We'd see where they were from. We'd see the GPA [Grade Point Average], and we'd go through there and say, "That one looks like the right one, and that one looks like the right one. That one looks right."

So we'd go to a division- or a directorate-level meeting on how are we going to disperse all of these new interns—did we call them interns? No, it's these students that come in in the Student Program, because we knew eventually they'd be the hirees that we'd have three years later, or two years or four, depending on what kind of program they were in. I'd go in there and I'd have my draft picks all ready, number one, number two, number three. I was amazed that almost nobody else did that, and so we'd almost always get what we considered the cream of the crop. But you just go in a little and read the resumes just a little bit. You didn't have to read a whole lot, just to see what kind of experience they had and what kind of interests they had and we had some great people we picked up.

This was in the late 80s but I always teased Donna, "I'm going to go in there and get my draft picks, and here's number one, number two, number three." She'd just sit there and smile as we'd go through it. I was just surprised people didn't prepare for that, because that was your future. That was who you want.

Of course, then I would get on them and say, "You're always focusing on Purdue [University, West Lafayette, Indiana] and [University of] Michigan [Ann Arbor, Michigan].

There are some other schools out there that we ought to—," because you can get sort of—or [Texas] A&M [College Station, Texas] or UT [University of Texas, Austin, Texas] I'd say, "You needed some other experience brought in to help broaden this." So sometimes they'd get us to do some interviewing.

Probably the most difficult one was at the black universities because we always had to pick up, or at least try to, and that was the most difficult thing that I ever found in hiring or in bringing people in. They'd look at the demographic and say, "You guys at NASA are really low on black male engineers. I mean, you just don't have many, and you need to increase that." We would make a strong push to try to bring them in or whatever it is, but they just weren't interested. We tried role models where we would send out—we have one or two or three, and that's really—the numbers are not big whatsoever. We just still could not recruit them, could not get them to be interested. We could get the black female, but we could not get the black male for some reason, and that's still what I see out there, the same problem. We tried really hard to, when they got here, give them meaningful work. But they'd sometimes leave.

I think the real problems was that the really good academic ones and that were getting so much more pay going to the—any company that did business with the government was under the law that you've got to have a racial mix that's met, and so they paid them top dollar, and we just couldn't—you know, we were picking them and made no difference to me whether you're what race or what you were as to what dollar you got here, so I think that was the one dilemma. But we were able to recruit most other minorities pretty well, pretty good Hispanic and the black female. But the black male is something that I don't know how they can overcome that. It's not for lack of trying, because we really did try to focus on that when we were doing it.

I will say, early in my career, to keep myself busy, I would write these books, so when I got to the tests, the two that I described. But before that I had written one on the environmental control system requirements for Space Station—this is back in '69 or '70—it's really because I'm interfacing with the prime, and I'm trying to interface with our NASA development folks. I'm trying to get requirements that everybody will sort of agree upon, so that when we're making this piece of hardware, it is supporting either a four-man or a six-man or a three-man, and we're working with products that would work. So I did one for an airlock, wrote some requirements for it, and I did it for various other things there.

But mostly it was I came out of the academic environment in graduate school, where it was sort of like a publish or perish—you publish a lot of stuff or you don't go anywhere as such. I was used to writing a lot. Don't know if it was written very well, but it allowed me to pull together the thoughts on how these systems or how these things worked and sort of could digest them and wrote them down. I wrote about eight or nine documents during that time; probably only one or two were read by anybody else, but for me it was a way of pulling things together and learning, which helped me later on when I did the test reports or tested things, which were much more focused on something that was actually going on at the time.

But that's how I filled that early time when—again, I'm used to multiple things going on, and you may have this one assignment or two, and I'm trying to expand it into this other thing. I did get chided by my branch chief once that, "Hey, if you'd knock off on the writing and do more of this, that will help." Well, that's all I need is a cue to let me know. But that was my way of bringing myself to a comfort level with the subject to understand it, was to sort of write down what it is and try to make it into something that you could read and you could understand.

So that was my suggestion for those early in their career if they're feeling like they're a little, "What am I doing? The day is eight hours, and I'm only filling it with about six." Although today, with the access to the Internet they can do a lot of searching on there and all that stuff, and hopefully—we didn't have access to all that.

I wanted to say one other thing. I'm a registered professional engineer. Now, that doesn't mean anything out here at JSC, and I don't use it, because the government doesn't have professional engineers. So what I became was one of the token professional engineers that if the Center needed one to attend some activity that was going on, because that would be the right thing to have to do that, and we got several other people. But what you do end up doing is giving the recommendation for somebody else who wants to apply for that.

That's something that's never been emphasized at JSC, and it may not need to be as such, but I always felt that if I'm going to be an engineer I ought to be registered as such. There's a little work that's required, and today it's harder work than it was when I did it, but you had to—first you had to take the EIT [Engineer-in-Training] exam when you were in college, because that's the book exam, and that's the only time you were really smart on the technical stuff. Then the later exam is more on your work experience that you have here, and you do that early in your career while you still can remember a lot of the equations and a lot of the stuff that goes with it.

But being a professional engineer did not turn out to be a requirement out here. I don't know that I'd recommend it to the next one. It's more of a comfort factor for yourself as to whether you feel like if I'm doing this job, should I do it. Still registered, but I'm retired, and they have a special category for that, so at least it costs a lot less than it did before. But I never found that to be a big thing.

WRIGHT: Thanks for coming today.

[End of interview]