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GRANVILLE E. PAULES
INTERVIEWED BY REBECCA WRIGHT
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WRIGHT: Today is November 15th, 2007. This oral history is being conducted with Granville Paules in Alexandria, Virginia for the NASA Johnson Space Center Oral History Project and for the NASA Headquarters [Washington, D.C.] History Project. Interviewer is Rebecca Wright assisted by Sandra Johnson. This interview is a continuation of Mr. Paules' oral history session begun on November 7th, 2006, which reflected his involvement with the first years of his NASA career through the Apollo era. Thank you for finding time in your schedule to meet with us and allowing us to visit with you in your office. We'd like to begin this session by asking you to describe how you went to work at NASA Headquarters.

PAULES: Well, it's fun to be back again. It's interesting to have gone back and looked over the transcript from the earlier discussions. They triggered some more thoughts about things that were interesting and memorable about the whole program. I'll talk a little bit then about my transition to the [John A. Volpe National] Transportation Systems Center in Cambridge [Massachusetts], which was the Department of Transportation [DOT] assignment I had, then how I transitioned back to Headquarters from that. Is that okay?

WRIGHT: That's great.

PAULES: A lot of people ask you, well, why did you leave the space program? I thought about that a lot. The real reason—two or three of us had done this—was to me, I had met the goal that I mentioned to you at the beginning. My goal as a youngster was to go to the Moon. We went to the Moon. We had done that. I was talking, like I said, to Steve [Stephen G.] Bales, and he said, well, what do you do for an encore if you've been in the middle of something like Apollo 11? Well, of course we had the rest of the flights to go through. My old boss John [D.] Hodge had left the NASA Center down in Houston [Texas] and taken over a major responsibility up at Cambridge, which was the former NASA Center, Electronics Research Center, that had been transferred over to the Department of Transportation as a research center.

Well, the thing I liked about the work I was doing was dealing a lot with advanced command and control systems and advanced computing capabilities. I just saw that I could transition a lot of that experience—I really wanted to do this—into more advanced rapid transit capabilities. Some of the travel I'd done, I'd seen what was possible with really high-performance mass transit systems. Automated people-movers, what we call dual-mode, where a small vehicle could operate on the regular roadways in a neighborhood, and then go to something like a guideway and just drive on it and become part of a mass transit system. Everything was high-tech at that point, so I thought that'd be a really challenging fun thing to work on.

So that was what I went to do. I worked on projects that were directed out of the Department of Transportation Headquarters in the Urban Mass Transportation Administration. I worked with a lot of ex-NASA people that had transitioned over to this DOT center in advanced research. That's where I got into a much more analytical role of systems engineering, design, cost analysis, lifecycle costing, environmental impact issues, which as it turns out would be important later in another career down the road.

But the whole idea was a very research-oriented focus for the rest of my career. So that was an exciting thing to do, and I worked with John Hodge and several colleagues. Some of them old flight controllers like Harold [G.] Miller. David Reed [Jr.] was a FIDO [Flight Dynamics Officer]. Cal [Calvin H.] Perrine [Jr.] was over in the System Engineering Directorate at JSC, and he went with Hodge to this place. So the whole array of new experiences, new people.

It was very enjoyable three years there. I only spent three years in Cambridge. It was almost on the MIT [Massachusetts Institute of Technology] campus. Just living in New England was an exciting change, a big difference from Houston. I went up there on January 4th, and I drove up, and the worst nor'easter that had happened on the East Coast had just gone through. Once I got to Atlanta [Georgia] and started heading north, there was snow piled up on both sides of the freeway so high. You couldn't see over the snow on either side of the freeway. It was just like a tunnel. Nice clear days; 20 degrees. My little old Falcon really suffered trying to drive it up there. But anyway, that was a big change for me. My family came up about a month later. I got my wife and son up, and she was pregnant with our daughter. Our daughter was born in Boston [Massachusetts].

So it was a really busy three years, but the people I worked with were primarily back here in Washington. My projects were in Washington. We did the research and staffed it out with contracts and with universities up there. Well they kept saying, "Why don't you come and join us as a part of our organization here in Washington?" So I did that. That was a big decision, again because we really were enjoying the Boston area and said, "Okay, this is a good career move." So it turned into a promotion to come to Washington. I went to work for a really different group of people by that time.

This is now the short-sleeved white shirt time, flat-top-type orientation you had back down in the Houston flight control world. A little bit of that stayed with you in the NASA crowd up in Boston. When I came to Washington, the guys I worked with were all these New World folks out of the computer business, long hair, lived different lifestyles. It was really an interesting group of guys. The guy I worked for was a guy named Bob [Robert B.] Dial. He had his doctorate in computer science, and so our whole focus was on advanced transportation systems design capabilities. We were building the tools to do the analysis for this. That was a transition, my three years in Cambridge, to a fairly good stretch up until 1985. This is from '74 to '85, I was in headquarters with the Urban Mass Transportation Administration. I ultimately worked my way up to lead that division, at the time I resigned from DOT and went back to NASA with John Hodge again.

So that period with this group of folks was a real challenge, because the concept of new mass transit systems was just getting approved. Congress was really wrestling with how do we decide how to spend these billions of dollars on metros here versus LA [Los Angeles, California] versus Miami [Florida]. Our job was to build the engineering analysis tools and then the cost forecasting tools, land use planning tools that say what if this system were in place 50 years from now, what's that going to do to the way the land develops throughout this urban area, and what does that mean in terms of overall cost-benefit, the very large macroeconomic issues. So we spent a lot of money and did a lot of research in forecasting models for land use, lifecycle costing, that sort of thing. Very interesting, very different from what I had done back in Houston, of course.

I had made a real career change by that time. I moved into modeling, very much a system engineering function. I worked with guys that were all primarily engineers and computer

scientists. A really neat bunch of guys. In fact my best friend is still one of the fellows that I met in that stretch of time, and he worked for me when I was at Urban Mass Transportation Administration, UMTA. So we're still real good friends and we still stay in touch with this guy Bob Dial who retired some time back. He was the long-haired guy. His son, we've seen his son up in Alaska. His son is a professor of environmental science up in University of Alaska [Anchorage, Alaska] or something. And our daughter grew up with him and they both are very much environmental folks. Everybody in the family's "save the world" kind of thing.

WRIGHT: That's good to hear.

PAULES: Oh it is, it is. They're really great. Their kids are the same way. But anyway that group was a very important group to us. It was like something we really missed, the team-oriented group, collegial environment, the workgroup, you did a lot of social things with the people you worked with. That happened when I came to Washington. We did a little of that down in Cambridge, but not so much, and we missed that, because the Navy had a long thread through it, very much a team-oriented thing, families were very close.

We went to NASA in Houston, it's very much the same way. You did a lot of social things with the same people you worked with. So this reinstituted that idea. We really enjoyed that when we came to Washington and worked with that group. That literally was the last time that we worked with—the people you worked with were so close to you personally and your families knew one another. It's a fairly small office, I guess we had about 14 people in that office, and we'd take everybody down to Nags Head [North Carolina] for a three-day weekend a couple times a year and just get this one big old house. So everybody and all the families had

sleeping bags all over the place. Cooked seafood, just whatever they would catch when they'd go fishing in the morning. So it was a really close group. Enjoyed working with that.

Now we produced a lot there. Really you ask what you really enjoy, what you remember most about what you did and the challenges you had along the way, some of those questions. Well, one of the things that was happening during that stretch of time at Washington with the UMTA group, this research group, was that microcomputers were just becoming really feasible. The Apple IIe, the desktop computers. Since we're in the computer business, we run a lot of software systems, we built a lot for big mainframes, Big Blue, room full of computers. So we were pushing hard to get them down onto these, what they call minicomputers, which would still be a floor model computer, but something on the order of a three-by-three-by-four, still a pretty big piece of equipment, took special people to operate and that sort of thing.

But these microcomputers, these small desktop computers, allowed people that do these planning functions out in the states and in the cities and in the counties, had their planning staff that were using these tools to do the estimating for, well, if we run a transit line down here, run bus lines over here, how's ridership going to affect growth and all that sort of thing. These are all model-based ideas, like I said. The thing that we did is we got the models transitioned onto these small computers so that many many more of the people out in the field could take advantage of the tools and the planning capabilities, and the costing tools. We managed to get that done while I was still there.

We did training courses. That was a lot of fun. Teach people how to use the tools. These were real low-cost computers by that time. Not as low-cost as they are now, but they were still low-cost. So the whole idea that we'd pull that off in the time I was there was really—I really felt good about that. Dial, he was our boss. He was in software, he would write the

software. He'd translate a lot of this really complex software that used to be unreadable into this newer more usable format that people out in the field could tune up with their own software staff. It was a big change from the way people did business. We got awards for that. So part of the deal was just doing something you felt good about. That was a real satisfying effort.

Well, that was in '84. We're getting to the point where Hodge is now back, President [Ronald] Reagan had made the decision in January to do Space Station and had made that announcement. I had heard it. I wasn't paying a whole lot of attention to it. I was enjoying what I was doing over at DOT. I had no ambitions to go back to NASA at that point. But John came back to Headquarters. He left the Transportation Systems Center in Cambridge and came and took over a job as, I guess, the deputy program manager, or whatever you'd call it at that point, for formulation of the Space Station by NASA. So he came back to NASA as a NASA employee. He'd been there a couple years doing this at NASA at Headquarters here in DC.

A fellow named Harold Miller came with him. Well Harold Miller finds out that I'm over in DOT and I had all this experience in cost modeling and estimating, economic analysis and so on. They were really getting pressed at NASA to justify the Space Station in terms of its long-term benefits. So he came over and says, "Why don't you come back to NASA, now bring all that analytical experience and modeling experience and techniques and so on, bring all that back over here to NASA, and we'll use it on helping us frame the way that we're going to make the Station work." So that's what got me interested.

I went back, talked with Hodge in September of '84. He says "Hey, we're ready, come back." Again, that was a possibility for actually, I would go into a good position there. I'd be the Operations Division Director at Headquarters, which is during this formulation phase.

So all the things dealing with operations concepts, lifecycle costing, logistic support, supportability, maintainability, if this Station is going to be up there forever, you have to build it and design it so that you can repair it. Got into a lot of specifics about EVAs [Extravehicular Activities], how you use the crew, trying to automate as much as you could so the crew wasn't spending all their time maintaining stuff, and they were really doing research on orbit. So all these things were part of the Ops [Operations] Division responsibility in this early formulation of the [Space] Station Program. So that seemed real exciting and it was exciting.

I came back in the first week of February in '85. I went to work for the Space Station Program for John Hodge at NASA Headquarters. That's where I spent most of 10 years. Then that was a challenging program, still a challenging program. We reorganized the Space Station Program two or three times while I was there. Those reorganizations typically are not particularly fun for most people involved, because they really restructure things, which is what you need to do when you're in a formulation phase. You have a small group of people getting the big picture laid out and getting the program focused the way you want, getting the basic blocks of functionality defined and early estimates of cost, all that—that's what we spent our time doing those first couple years. Now it's time to go really build this thing and get really realistic about the cost.

Well, the cost, as this book [*Space Exploration*, J. K. Davies] points out, the whole issue was constantly selling the program every year to the [United States] Congress, because as you got more granularity into the design you had a better picture of how it's going to work, we started these partnerships, these Memorandum of Understanding [MOU] with the international partnerships, with Europe and with the Canadians and with Japan.

Once we got those deals more clearly defined over a period of three to four years, the effects on the NASA responsibility of course adjusted every time we made a deal with ESA [European Space Agency]. They're going to build this, they're going to put that on, but we've got to fix the interface here. So our interface design may change. The way that our command interfaces and communication interfaces had to be adjusted. The role of the astronauts had to be better defined, what they're going to do when they're in orbit, they're going to fix this, they're going to fix that. Who trains them? I was involved in the Memoranda of Understanding development, I was responsible for all the operations and logistic support functions, and I ran the operations cost analysis group that was made up of the international partners throughout that stretch.

If you can imagine this facility in space, Space Station had several kinds of capabilities. It produced power. If you wanted to put instruments or capability up there, it required power. If you needed special environments like clean environments so you could run pharmaceutical stuff with really nasty poisonous toxic materials you had to build a facility that would allow you to do that without leaking and causing a possible catastrophe in the Station. So there were a lot of design issues to build capabilities. Now the capabilities were to be shared among the partnership. That became the whole issue on the trade space and the Memoranda of Understanding.

Well okay, you get so much access to these special facilities or this big optics window. It was a huge glass window that was optical-quality, like a telescopic mirror that you could look through and not have any flaws—perfect image structure coming through. You could put all kinds of special cameras and observing instruments on the Space Station side and look through that window. Well, access to that window became a resource; getting rid of heat. If you brought

heavy equipment that required a lot of power and then generated heat, you have to get the heat off the Station, it's just a problem, so you had to have capability on the Station to do that.

Well anyway, the whole arrangement was agreeing on what the resources are, who provides them, and if they provide them, then what does that do to create their justified share of the use of all the resources, the power, the astronaut time and so on. So if they put something out—an attached payload out on an arm of the Station—and it required astronaut to go out and repair it or change something, or required the use of this big fancy Canadian arm that moves things around, you've seen that—well that Canadian arm got to be—they got tactile attachments so you can pick up stuff, you can turn knobs, you can replace screws with that arm. So Canada was having to change their design so it could do all these things, so their costs went up, but it increased the ability for the Station partners to do a lot of different things. So our job was to figure out how to allocate resources, how to share the costs when you're operating the Station.

Now we all agreed there was no transfer of funds to build it. Everybody built their piece. Then the whole issue in the Memoranda of Understanding is agreeing on now we've got it, it does all these things, how do we share it and share in the cost, because operating cost, keeping the lights on, flying the Shuttle up to deliver astronauts, repairing astronauts' EVA suits, all the cost of running the Station had to be shared. That was a real arm-wrestling match with everybody. ESA didn't want to pay for this, Japan didn't—"well, how did you estimate that cost, why is it so high, well why don't we do it a simpler way?"

Although you spent a lot of time down with your elbows and working out the deals, it was still a fun time. It was a very interesting time to figure out how to make these things work for a very long-term program that would probably not even be fully operational till we were well out of the picture, all of us individually. We wouldn't have anything—we'd be gone. Retired

and everything else. We'd be lucky to still be alive and watch it work. Well it's sort of happening now. The big modules that allow us now to connect the German, the ESA big laboratory and the Japanese laboratory, almost everything's in place on the Station that's up there now.

They'll be able to do it in the next couple years. That's the goal NASA has, to get that thing finished to the functionality that we promised in all these Memoranda of Understanding. Along the way between the beginning design until where we are today was a lot of upheaval in Congress, changes of administrations, you changed all the leadership in each of the space programs internationally; changed the structure of the ESA international organization significantly all through this stretch. So each year there was some major—either an organizational hiccup that you had to work your way through, or an "Oops, this design is not working the way we want." Like getting the pressurized interface between these modules to not leak and still be interchangeable, where you could take them apart like Tinkertoys and move it over here and attach it over there and it'd work in space. They ran into some problems with that interface at [NASA] Marshall [Space Flight Center, Huntsville, Alabama] and the contractors, and it took us a year to sort that out.

So the hiccups would cost you a year, year and a half. Every little blink where there's a marching army of guys spending money building stuff. If they're going to spend an extra day doing something, that's a whole day's worth of work. It wasn't on the books. So you're going back to the [Capitol] Hill all the time with changes in your budget estimate. That's what this is all about [referring to book]. It's very good story from the beginning of the program right up till about January this year, telling what it took, the selling of the Space Station, and what each one of the Administrators at NASA and the Space Station Program directorates had to go through

each year to bring that story to the Hill and sell it, because there were always the naysayers on the Hill, "Well what's this thing really worth, are we really going to get all this science out of this thing, can't we spend this money better on homeless people." The usual arguments against space stuff.

WRIGHT: Did you take those trips to the Hill as well? Or did you just prepare the information?

PAULES: I did. We worked a lot with staff. We worked both with the OMB [Office of Management and Budget] staff to keep them really informed about things, we wanted to give them all heads up, I thought the program in the stages when we were responsible for it at Headquarters here in Washington before [Daniel S.] Goldin came in. Goldin blew the whole program up and reformatted it, and you probably picked that up in some of your other interviews.

WRIGHT: That's one of the questions I did want to ask you about. As you're making these plans and making these predictions, the administration and/or Congress comes through and tweaks it enough where you have to basically—

PAULES: You have to reset, yeah. Every year, that's part of the point. I helped them work the chronology so people could understand what happened between this phase and this phase. Why was that changed? It turns out if Congress won't fund it, they'll give you—you go in with a request that's reasonable, even though it's not one they're happy with, but it is going to keep you on a schedule and it asks for more money. Well, if OMB would approve it and it made it over to the Hill for their cycle of review, it might bounce either in the House or the Senate side, and so

you'd end up with one of them approving it fully and another one will cut it back, and then they go into committee and resolve it.

You usually ended up with less money than you'd asked for. When you did that you immediately had to replan what your sequence was, because you weren't going to get that money to do what your schedule had, do this before that. We just started having to cut things out of the program at different times that were planned. We had to delay. The partners just really got upset because we kept delaying when we'd be ready to have them come to the Station.

Our first profile, one of the things you might find interesting is to look at the original schedule of when the Station would be fully built out and all the partners would have their elements up there. It was like in the mid '90s, '96, '97. Well, if we get there by 2015, we're going to be lucky. So all that was a result of certainly technical issues you ran into, but most of those were all solvable, but it took money. You had to buy your way out of a problem a lot of times. Some of it involved slipping a schedule a year or two. That always costs you money. Every time you slip it. Even if all those other pieces are perfectly on schedule to get delivered here, you kick them out a year or two, you mothball everything, you keep them on some kind of a low-profile schedule, it still costs you more money than you originally planned.

So that's what the story was all about, is the willingness at the Hill to keep the program going, but at this level of funding for this budget year. Then you'd have staff changeover. There were key people in the Hill that were very, very much in favor of this thing and they'd support it a lot, they were staff level generally. They would convince their congressman or senator that this is worth doing, you got to do it. Well we spent our time interviewing and talking to the staff guys, making sure they understood what the changes were about, where we'd made real progress and they could take credit for it.

WRIGHT: Was there a point in your life in that mode where you thought that the Station wasn't going to make it? That someone would eventually just stop it and cut it?

PAULES: I never got the feeling while I was active in it that it would go away. I felt like there were times when it was going to be a real hard sell because we ran into some real hiccups. The EVA problem. There was a group of crewpersons that were helping our design effort estimate how many hours of EVA it was going to take to maintain the Station once you built it this way and it operated that way and the logistic support concept was this and you could repair this or replace that. They started looking at the sequence, the timing of when things wear out and when replacements occur, if you had a failure how long it took and what kind of effort it took to get ready to fix that. This crew team started putting together an EVA profile. They said just to maintain the Station, keep it going, they had this huge number of hours every year of EVA. Well that was so far beyond any kind of EVA projections that anybody had ever imagined that that almost killed the program, because the EVA requirement just—people began to think that's undoable, we'll never be able to do that. The crew will never have any time to do anything but maintain the Station.

Well that really wasn't true. They went beyond what they should have on their estimates. So it took a lot of time to get that back in the box though. That report leaked to the Hill, and the Hill had the astronaut design crew up there. Hammered on them. Finally we got most of that resolved, but that was probably the biggest hiccup. That was one that I felt like was a real showstopper if they couldn't get past it. That could kill the whole program. People thought it was so risky, it's not worth doing, stop.

The other was the use of the Shuttle. I probably got in trouble with Andy [Andrew J.] Stofan on this one. I set up this operations taskforce, which was to design the operations concept of the Station. That's one of the things I feel really good about. You ask what things did you feel good about doing? That was one of them, was getting this Ops [Operations] Taskforce report done. It took about six months. We involved interviews from all sorts of people from folks that operated remotely in the Antarctic, how do you live in an Antarctic environment, remote environment, what do you do, survivability issues, all that sort of thing. Submarines, nuclear submarines for six-month tours undersea. Locking people up and making sure you've got a totally maintainable system that you don't have to come back home. So we had a lot of interviews helping us frame this concept.

Well, the concept was to be a design document that fed into the design. So we felt real good about getting that done. But one of the things that came up was the fact that the Shuttle is to be the delivery horse. It's to build all the pieces to assemble the Station and to support the Station. Well, the Shuttle was already not able to meet the launch schedules that it had. We had the Shuttle guys in. We looked at that, we were looking at the reality of the Shuttle schedule being able to fly 13 times a year.

This is what was being promised by the Shuttle program at that point. A dozen times a year at least. Once a month. So we said all right, and we mapped our requirements on top of that Shuttle schedule. Nobody seemed concerned, because the Shuttle schedule was supposed to be maintainable at that level. I said, "Well think about it a different way. Think about if some hiccup occurs with one of those elements we haul up to the Station, or they have to dump it and run, they have a problem on the Shuttle, and come home, and you've got a critical element of your Station, just a chunk out of it."

We all finally agreed, okay, we have to live with that kind of risk. But in that process I hand-drew a picture of how many Shuttle launches a year it took both to build it, to support it with a crew actually operating it, and then to logistically support it to fly food, fuel, all that kind of stuff up. It was interesting. When I drew that hand sketch I just drew little profiles of the Shuttle on a schedule, laid it out for five years. I made a viewgraph out of that when I came back. I showed it as my ops status report at the monthly review with Stofan, and he and his deputy were not happy that I made such a big point of the challenge of just making sure, "Hey, we're okay, but we're counting on this Shuttle to do all this for us." If you have any hiccups with the Shuttle you're in trouble. If you have anyone grounded because of a problem, whatever. Well, that was—not foreboding of what happened, but I'd been there a year, and then we had the [Space Shuttle] *Challenger* [STS 51-L] accident. That really did turn the program upside down when that happened.

There were big slips in the schedule because the Shuttle demands and commitments already were at a certain level. So we had to push our schedule out. The DoD [Department of Defense]—well when they did all the safety reviews out of the *Challenger* at that point, they said, "All right, you can't fly these kinds of payloads, you can't fly this, this and this and this." So all the Air Force went away as a customer because we had some of their payloads, which were big classified satellites, and they had fuel systems on them that carried hypergolic fuels and very very toxic fuels. Well the safety review said, "None of that, you can't fly any of that stuff on the Shuttle anymore. That's got to go on some other method." So the Air Force dropped out as a customer. When that happened, all the demand for these frequent flights was really thinned out quite a bit. The cost to NASA now was all borne by NASA. Air Force was paying for a

good chunk of that Shuttle support. That all went away. So now NASA had to pay the bill for the Shuttle, all of it.

The cost of Shuttle flights became much more significant to the Space Station Program, because they had to be allocated, well your share of the Shuttle business for your flights and support is this. So when you go to the Hill they'd add it on, well what's the lifecycle cost of this program, including the Shuttle. You're looking at $1 billion a flight for each of the Shuttles. If you just take the budget for the Shuttle for a year and divide by number of flights, really simple, it was over $1 billion a year. Well, they had all kinds of ways to allocate the cost and get the cost number that would be charged to the Station to a smaller number. But that was a huge hiccup when *Challenger* happened. The management, because of a desire to minimize risk and to get the fights for the Centers—the biggest battle we had was getting the Centers to quit fighting on who's in charge of the stuff. You've probably heard that story before. But if you haven't, that was the crux of almost all the organizational issues in the Station, was the battle among the Centers on who's in charge, and don't cut my budget.

So they would go to their local congressmen and senators and make a big fuss either through their industry people and so on. So when the bills would come up to the Hill, the individual people for the Huntsville or the JSC, congressmen, they would fight for their piece, and if somebody finally resolved the total amount of Station money that you're going to get this year, and that starts getting allocated down to the Centers, they wanted to know exactly how many dollars were going to their Center, how many FTEs [full-time employees] were going to be affected, every budget cycle. So we had as many people working budget issues in the financial office, accountants, that was bigger than the rest of the whole staff, technical staff, just trying to get the details together for the Hill reviews.

I'm overstating the size of the staff a little bit, but nonetheless the relevance of their work was critical to convincing the Hill that Marshall's going to take a little hit here but we'll make it up next year, no loss of FTEs, no civil service reductions, no reduction in contracts, it was all the big issue. Every year we went through that. So when the *Challenger* happened and risk became a big issue again they got much more serious about things like crew safety and some of these things that we want to do. We had something called transaction management, which was a concept that allowed the Station systems if they started to fail, they could be self-diagnostic and say I'm failing, I'm going to shut this down in a safe way. But then that shutting down may cause other ripple effects into power systems or into heat reduction systems or whatever.

The whole idea was that you'd automate as much of that recovery process, like nuclear power plants do. Those are almost all hands-off, if something fails there the whole thing figures it out, the system decides what to do, and it takes action. It gets to a certain point where the real issue is a policy decision, then some guy in an operations room in the power plant says, "Okay this is going to cause this kind of problem, we got to do it this way," *click,* and that's about the role that they have in those big centers, a few people run those huge nuclear power plants. Well, the Station idea was to build as much of that automation into it as you can. Well, the flight control teams down in Houston, [Eugene F.] Kranz pushed back on that a lot. He said, "No, you better have lots of guys looking over their shoulder, paying attention to what those systems are doing, because there's too many unknown unknowns. You're going to have to have people that focus on those things." So the ops concept had to be readjusted away from so much automation to more risk aversion after the *Challenger* accident.

That was a big effect on the way we organized the office at Headquarters and the flow down to the next level of management. We were doing it through individual Centers. We had

the Center management at JSC, a guy named Neil [B.] Hutchinson. He was in charge of the program for the implementation, the build part of the program. That was run out of a Space Station office at JSC. Marshall, [NASA] Goddard [Space Flight Center, Greenbelt, Maryland] had the robotics arm. What happened is they kept fighting that JSC wasn't being fair about this or doing—they kept bringing issues back to Headquarters. So we, in frustration, said all right. Stofan came in. He says, "I'm putting an office out at Reston [Virginia], and we're going to do all the management out of an office that's offsite. It has nothing to do with any one Center. We'll staff it with people from the Centers as permanent civil service people so they aren't attached to a Center. We'll detail some Center people in to help liaison with your Center part of the world."

Well that was a big change. That cost a lot of money, and Stofan came in, he made up his list. "Here's an org [organizational] chart. I need 70 SES [Senior Executive Service] slots at Headquarters," and SES slots just don't come from anywhere. Usually you have OPM [Office of Personnel Management] limits that are set on them, how many you have at the agency level and so on. So you can allocate within the agency, and people like as many slots as they can out at the Centers. Centers want as many SES slots as they can get. Headquarters usually has a lot more than the Centers do. Well there weren't 70 SES slots floating around for anybody to grab. So Stofan starts reorganizing things, and he works with Administrator [Richard H.] Truly to transfer slots out of the Centers to his new office. He was still short some and this is just as a personal aside. I was supposed to be in one of the SES slots, they had the Directors of Engineering, Operations, I was Ops, Utilization, and then the financial were all going to be SES heads. Well, at the time I came there, they weren't yet. They were organized that way in an org chart, but they

had to be advertised. So I got caught in that process. I'm not going to say I'm bitter about it at all, but I'd just say it's just part of the process.

When Stofan came in and he saw there were four SES slots, three of them had advertised and been selected through a competitive process, including me. Well, two things happened. One was *Challenger* happened, and that stopped all the personnel actions. When they stopped the personnel actions, everything was frozen throughout the agency, and they started going through and moving managers around. Remember they gutted every senior agency manager after *Challenger* and brought new people in to run the Centers. That ripple effect slowed everything down, put the personnel process into a nightmare of a year's worth of recovery to get these actions all taken care of, transfer of people and what have you. Well, the time ran out on the three slots we had that were all selected to be awarded. So what happened is Stofan saw those three slots, and he grabs those and puts them in his lists for his people out of Reston.

So those of us at Headquarters had to go back through another—they redefined Headquarters functions, readvertised the jobs again, and we got to a point where they were selecting the jobs, and Stofan leaves and another guy [James B.] Odom comes in, and they reorganize Headquarters org charts again. He brings in people that he wants from the Centers to run the Headquarters functions. So the second round of SES announcements went down the drain again. So that's the kind of thing that happens to you when you're high up in an organization. We kept the functions, kept doing the job and everything, but organizationally there was always some noise in the system for everybody. That was my part of the story. Everybody had their own story about how they might have been affected.

Challenger triggered it. The response to *Challenger* caused a lot of organizational changes, some of them are captured in Davies' book here, but not all of them. But everybody

recovered. You ended up with an organization that started working pretty well together. The Reston thing was coming along pretty well. The Headquarters role was to get all those MOUs negotiated and settled. That's what I spent most all my time doing after we got the ops concept done. Our relationship between Headquarters and Reston was pretty significant. So when [Richard H.] Kohrs came in, he was there the last maybe five years that I was there. I was his Ops director.

Guys like Earle [K.] Huckins. I don't know whether that name has ever come up. He was a really brilliant guy. He was head of engineering. He was from [NASA] Langley [Research Center, Hampton, Virginia]. He was a brilliant guy. Also, a guy named Bryant Cramer. He was an engineer that had been down in Houston, and he went to Reston, and he was a key interface for how the ops concept would be implemented in an engineering sense in the Station. How much logistic support could be implemented with this or that, risk analysis—well if you don't do that, what is the probability of having to do EVAs at some rate to fix this or maintain that. So his group did all the analysis on the engineering side. So we got to know one another very well. He's still at Headquarters now. I worked closely with him right up till I retired. But there are a few people like that that really made things happen.

Kohrs worked with a fellow named Bob [Robert W.] Moorehead, who took over the Reston operation. He and Kohrs were like bosom buddies. They really worked well together. They did reviews. We had a Headquarters level review, and we had to agree on certain what we call Level 1 requirements. Those had to be approved at Headquarters. When we changed something that was going to affect performance or cost or relationships in the MOUs, those all came to Headquarters. We would present as our division responsibility what the effect would be, what our recommendations were and so on. So there was some tension between us and the

Reston guys, because Reston had to deal with it. They had to provide a solution if we said, you got to do it this way or deal with this policy issue. So Moorehead and Kohrs would sit on these boards and it was a good organization, the way it worked.

But those five years were like turmoil in terms of getting through the Hill. There was a lot of changes after *Challenger* that had to be reconciled, and we finally got to the point where we were on a good track where our estimates every year were starting to be really consistent on cost and performance and when things would be done. That showed up in the book as well. But we were just about there with the Hill. They were beginning to believe—it's a big number, it's a lot bigger than anybody ever expected when you first projected what the Station would cost. It's a big cost. Nonetheless everybody was beginning to support it okay.

Well, then Goldin comes in, and he does a really hard look at the cost again. He brings in his own independent guys and fellows like George [W. S.] Abbey. You know George Abbey? George Abbey is one of the unique characters in NASA. He came in with Goldin, and they were very close friends. Goldin liked Abbey, and so they start looking closely at the cost, the EVA issues. Went back through all the big challenge issues. Goldin says, "No way, this thing costs too much. We've got to get this down. We've got to do it a whole different way." He didn't like the Reston setup. He thought it was too much. Too expensive, inefficient.

So he just blew up the whole system that we had organized. Closed down Reston. In a matter of weeks closed it down. Moved all the management back to JSC. Put a whole management structure into JSC to run the program. Changed all the contracts, moved all the contracts under Boeing [Company], to integrate all these individual contracts that were working on pieces and managed by different Centers into one integration contract under Boeing. You can imagine all this design is going on all over the country and in Europe and in Japan and Canada.

Okay, what do we do now? Because you had all these ICDs [Interface Control Documents], all these control documents had been defined. Threw all that out; start over.

It was that significant a change. It moved a lot of responsibility that was held by this Level 2 office that was out at Reston. All that responsibility for control and configuration management was handed off to the contractor. So these boxes of documents and software that were used as part of the controls data and everything out at Reston were boxed up and sent down to Houston. I will bet you that very few of those boxes were ever opened. Boeing had to come in, they ran over the design as they understood it, made changes the way they saw it, set up their own ICD control process, and it was a really big hiccup. But, Goldin just felt like the program was still in a huge uncertainty on how much it was going to cost. He wanted to get that fixed. I'm not sure that he got it fixed, but he fixed it so everybody could see the costs were more reasonable. It was easier to see where the costs were going to come from and who was responsible for them.

He wanted responsibility to be really clear. It was costing more than the Hill was willing to pay. So he says all right, and the administration—a lot of these things, I don't know how sensitive they are—but administration was getting very nervous about the outbreak of peace with the Russians, and so they said, "All right, now look, you got all these engineers, you got all these people that are in the space biz over in Russia and now Russia has completely collapsed and they're being rebuilt. We got to keep those guys busy and keep them off the streets. We don't want them selling their talents to the wrong people," building weapons systems and what have you, "go make a deal with the Russians to be a partner."

So Goldin put a team together and they built a team with Russia, which has turned out to be a good thing. It's worked out very well. They got involved in the launch vehicle business.

They got involved in the rescue vehicle, the backup capability, all that. The Mir [Space Station] Program. Goldin felt like he could show some progress toward a Station-like policy and an operations concept. Started getting Control Centers talking to each other. All that got worked out.

Now that's when he reorganized everything and moved all the Reston functions and the key Headquarters functions to Houston. That's when I left the program. All the Russian activity was just beginning to ramp up, and we were setting up the MOUs to bring in a new partner, and the Europeans, nobody wanted this to happen. They just could see their little niche of resources getting carved up and handed to the Russians. They'd get a much smaller piece of the pie when it was all said and done. Yet they still had this big commitment. They had to build this lab and put it on. So it was interesting to watch that transition over a period of four, five months when Goldin sent everything to Houston, closed down Reston. That was right at the end of the year, '93 I guess it was.

The guy that was in charge at that point was the head of quality control Bryan [D.] O'Connor. He was the head of the Space Station Program at that point. Kohrs had left. He'd been sent on his way, and O'Connor was put in that position. Well O'Connor was trying to figure out what a staffing level or what the function of Headquarters would be, because he'd sent all, everything, all the Level 1, 2 and 3 functions out to Johnson. So he called us all in, the ones of us that were at Headquarters, and said, "Would you like to go work in Houston, would you like to do this and that." I decided it was clear that they were making so many changes that the "not invented here" syndrome was going to be so great that it would be hard to have a constructive role, a positive role with the new management structure. They felt like they had to bring in new

people. They were going to bring in new people and do the functions. So everybody else was part of the old core. I just felt like it wouldn't be a very constructive thing to go back to Houston.

At the same time, the Earth Science Program was just beginning to get its feet under it. It was a small piece of the Space Science Program at NASA Headquarters. Most of NASA's stuff had been in building satellites, going to the Moon, the planets, out to the outer planets, deep space, a lot of work with satellites that do those sorts of things; planetary exploration. The Earth Science Program was just beginning to come together. It'd been justified and sold some two or three years earlier with the Hill. We built environmental monitoring satellites, the EOS [Earth Observing System] series satellites, *Terra* and *Aqua* and *Aura*. They had key functions for understanding the environment of the Earth. Everybody on the Hill liked that, because at least we're bringing some of this talent home and using some of that capability for us to understand really what our planet's doing.

I thought that was a really exciting program. I'd been paying attention to it for a while just because I was interested in it. Then they advertised this chief technologist job. I said that's my kind of thing. So I applied for it and Charlie [Charles F.] Kennel was an IPA [Intergovernmental Personnel Act] from California, and I interviewed with him. I interviewed with Mike [Michael R.] Luther, and they all thought, "Hey, you're the right guy, you got a lot of background, you've worked a lot of international stuff, this is good, join." So I went over to the Earth Science Program in January '94.

WRIGHT: Now before we go on to that, I was going to ask you a couple questions about the Station. The legal aspects of all the MOUs, how was that brought in, and how were you able to join that with everything else you were doing?

PAULES: We had lawyers as part of our negotiating team; people from the policy office, which were Headquarters policy people, along with our Space Station policy people. We had State Department people involved in the original MOU negotiations. There were two levels of agreements. One was like a treaty that said we're going to do this, and it was like a two-page thing. Those were signed fairly early at the State Department. So we all marched over to the State Department. They had this big international agreement signing room where they have the tables all around, everybody sits around, and that was really spectacular. All the flags lined the room. It was really quite an event to get those agreements signed. Now those were top-level agreements that said we're going to be a partner and we're going to do this and this. Very few basic words in there.

The MOUs were getting down to the implementation. You're going to do this, and here's how we do this, this is how we operate. This is how you organize to do it. A lot of details in the MOUs. State Department, because there were a lot of policy issues, ITAR [International Traffic in Arms Regulations] was becoming more of a big deal at that point. So we had to work all that into the teaming, people we had on our teams. We had State Department folks, and the lawyers were always part of it, because they had to get the words right. I'll tell you, sitting down and hashing out the way the words and the flow of the words and what this word means here versus down here, that's where you spent all your time. Editing and getting agreement on each word in those MOUs. Then we had operating documents, implementation plans which were referred to in the MOUs. There were several implementing documents which were to be handled by this organization in ESA, this one in Canada, so they were identified at the MOU level, but then you had the freedom to go off and work it like just a working group thing.

That's where we spent all our time. I ran the cost process. As part of that, we had to have a really clear picture of how the ops responsibilities would be held, when you would be ready to bring your piece of the resources together, and we had to make a special almost an MOU for the astronaut piece. Who flies when, and who gets to be first, and when do the ESA people earn the right to fly an astronaut, and how often will they fly an astronaut, and what are the responsibilities of that astronaut supposed to be, how qualified would they be, what kind of test do they have to go through like astronauts, they have to go through all these psychological tests. The doctors got involved. So we had all these doctors helping us lay out these astronaut agreements.

So there were a lot of specialists involved in these agreements and they were the ones that—they were really important to get the final signoff because they said, "Look, this is not clear, you got to settle this issue right here. Because they can wrap you around the axle later if something happens." So we added a new paragraph. They'd help us write it. So lawyers were involved. It took years to get those things done.

WRIGHT: Are those still standing?

PAULES: Yes they've tuned them up with the Russian involvement. They had another set of agreements and they had to go back into each one of those MOUs and change them. Lyn [Lynette D.] Wigbels, Peggy [Margaret] Finarelli, they were our key policy people that ran the MOU negotiations, and I still have copies of those. We made little minibooks of each MOU so you could chase down here's the part on cost, here's what your role costs. Because we'd drag it out in every meeting. If somebody said, "Well, that isn't what the MOU said." Oh yeah? So

you spend a lot of time doing that sort of thing. But I really felt like that was a good process and I felt good about all that in terms of what I did in that nine years I was there. The ops concept was a big deal. Getting the MOUs signed was a really big deal.

The Russian thing, I still think it was probably the right thing to do, although it did create a lot of turmoil to get it in place. Russians had a lot of capability, had been there. They'd been there and done that kind of thing for a long time. Their Mir and they'd brute force stuff. They had none of this sophisticated anything, they just said, "Okay, take it out of the boiler room and fly it," and they'd take a lot of risk. The guys that I work with even now here at Kelly Anderson [and Associates], they have a consultant that was on the teams that went to Moscow [Russia], he and the astronauts and the pain and anguish they went through to get past some of these high-risk procedures and approaches the Russians used for doing things.

Let's see, there was a book written [*Dragonfly: NASA and the Crisis Aboard Mir*, Bryan Burrough], but it was about the Mir, the Mir operation and the crew on it. Did you see that book? Yeah that book laid it out. The people that wrote the book got in a lot of trouble at NASA, because they were too frank about what they thought was going on. But it laid out, yeah this is a very different crowd, the way they do business. You got to get used to that, and you're going to have to nudge them a little bit more this way. But they're not going to change easily, this is the way they do things, if you want to go over and ride their Mir you're going to have to go their way. So there was a lot of that that went on. But it was an interesting 10 years.

WRIGHT: In January of '84, President Reagan announced the Space Station to be built during the State of the Union [Address]. Then while President George H. W. Bush was in office he announced that he wanted NASA to go to Mars. Then you had President [William J.] Clinton's

administration come in. What type of support did you feel was coming from that administration toward NASA and its goals?

PAULES: I didn't think the exploration, go back to Mars thing from Bush One's declaration ever got any traction very much. People weren't ready to do that again, and we still had too many challenges with getting the Station working, Shuttle was not performing at the rate, so there was a big bill going with Shuttle, and they say, you're ready to charge off and do yet another whole giant initiative, it just never picked up any momentum when I was there. Only when the current President [George W. Bush] was in place and he reannounced the initiative, we're going to do it this way, go to the Moon first and then Mars, was there any—that is moving on. That has some possibility. Going to Mars on the schedule they have, it'd be interesting to see if that schedule has any meaning. But going back to the Moon, I think the pressure from the rest of the international community is so great to go to the Moon that it's going to be hard for any administration, any Congress, not to be in the forefront of that, because we did it 30 years ago, we ought not to walk away from that kind of stuff.

I've been to a lot of meetings with the Chinese. They have plans and budget and they are moving out. They aren't missing any milestones. They're doing everything they said they're going to do, and they're going back to the Moon with astronauts. Their own Taikonauts. So I think that will be a lot of the pressure from a policy standpoint to keep that kind of initiative going in NASA. Now the administrators are very hard over to keep it simple. Do simple launch vehicle, simple this, simple that, go back to some of the basics of Apollo, those were all good ideas. Probably will make it work within the dollars we get. But I never could get a sense there

was any support for the early push on it. Clinton just didn't talk about it, didn't get any feet with him.

WRIGHT: I think it's a good time to take a break right now.

[pause]

[We'll begin] where you left off, which was with your transition over as the Chief Technologist.

PAULES: Now that was a fun change. It was very different. You were completely out of the manned program now, you're not dealing with human space flight at all. Focused on robotic spacecraft effectively, environmental satellites, Landsat, I noticed you'd mentioned in the list. That was an example of the early versions of satellites that we talked about. But when I joined the program in '94, the key big satellites, these were really school bus size satellites, they were big satellites, the designs and everything were all complete. The instruments had been selected. They were in the design phases. I wasn't really involved so much in that initial set of satellites. Now what happened is those satellites were huge, and they were doing them in series of three. There were three major satellite types, one of which looked at the land primarily, one of which looked at ocean and certain aspects of the atmosphere, and the other one looked at atmospheric chemistry, and they had all sorts of different sensors on them.

There were probably five to ten sensors, instruments, that were strapped on this big bus. Each of them were really sophisticated. They made certain kinds of measurements either observing things on the Earth, looking at how oceans behave, the chemistry of the atmosphere, looking at CO^2, the ozone hole, all that, all to be captured by these series of three satellites. They

had a lifetime of a minimum of five years and maybe a couple years extra. So you'd launch those in a series, a sequence, and they would last—they'd be up fairly close together. Then as those wore out, you'd have three more. So they had made a commitment that they needed a 15-to-20-year data profile with data coherence, so from the time you launched the first satellite with its instruments, as it wore out you'd have a replacement go up for it, it wears out and you got another one, you get your 15-year profile of all these measurements. Now you could characterize what was going on in the environment pretty well.

We were spending a lot of dollars on scientists to understand what was really happening in the environment, climate change, short-term weather forecasting. Partners in our case, with the land covered area, we had a lot of partnerships, a lot of agreements, many many agreements, more so than anything we've had in space Station. They were with US civil agencies mostly. NOAA [National Oceanic and Atmospheric Administration] was a big partner with the weather part of it. EPA [Environmental Protection Agency] was a part of a lot of environmental work. The Department of Energy was involved in certain specific things that they had special high-performance computing capabilities. Real high-powered computers for modeling. USGS [United States Geological Survey]. So we had a lot of partnerships. They put scientists on these study teams. What attracted me to the whole effort was the way they were very systematic in the way they defined requirements, got agreement on requirements, and then translated those requirements from a performance-based requirement right down to an engineering design for each instrument and the data systems to go with it. I was attracted by that concept.

But like I said that concept of three, three, and three satellites was done. It was committed and it was a big program. Well it turns out it was too big a program. Here you go. Budget again. Goldin comes in. Now Goldin is part of this story too. It's clear that these things

are costing a lot more to build them, and so we were in the process of building the first three with an option, but not actually started on, the next three. The idea is that from the time the decision to build the first three was made, the engineering and the technology associated with that was dated back in the '70s era of technology.

Well things were changing so fast in the sensor world, the information systems world. They wanted a whole technology program to infuse new technology into the future series of things. You bring in a new kind of a sensor and replace—but it had to produce identical data records, that you didn't lose the data continuity between the sensor on A, the sensor on B and C, so the scientists would get this 15-to-20-year data record, and the only thing that might have changed is the technology used to gather the photons.

My job, when I came in, why it appealed to me, was to go find all the really cool technologies that would help you get the cost down. Big cost reduction objective, and do things that just can't be done. There were still a lot of measurements the scientists would not be able to do with these systems on the first series of satellites. And I didn't have a real staff, but one of my jobs when I first got there, working with the head of the program, Mike Luther, we had a big workshop. We locked up a bunch of technologists from the various Centers, and we said, "Well, what kind of a technology program do you really need for Earth science?" So we all characterized the makeup of a program like that, its own separate budget to do early exploratory research and advanced technologies, developed a lot of relationships with DoD, which was also doing similar kinds of research, so we didn't spend money in the same ways.

That program lasted for as long as I was there, and it's still going on. It was a really popular program with the rest of the agency too. So their technologists, like in the space science world, the guys that go to Mars and the planets and so on, they need similar kinds of sensors but

for different objectives. But similar technologies. So we formed partnerships with the other parts of the agency, the aerospace crowd, the aviation crowd and so on, and information systems work. Large-scale modeling for simulations, they were spending a lot of money on that. So it was a good initiative back in '94, '95. I helped put that program, I still feel good about that, getting the Earth science technology program going.

Then there's an office out of Goddard that is staffed with 15, 20 people called ESTO, Earth Science Technology Office. That's still there, still doing its thing. Those early, what we call low technology readiness level research efforts would be—we'd spend money to take the technology through a series of development efforts to get it to the point where it could actually be manufactured repetitively and put into spacecraft. We'd get it to that level and that readiness level, then industry could use it. So that was the whole goal of the program. That's what I liked about it.

WRIGHT: Did you have any challenges on getting the different Centers to come on board working together with technology sharing?

PAULES: Yes. Technology sharing is not a common thing that they like to do. It's just like they're in a different world, okay we do this, yeah but we do this better than JPL [Jet Propulsion Laboratory, Pasadena, California], so don't ask JPL. JPL is on our team. So we did have—and there still is, there always will be—this competition among the Centers on key areas that they feel like their core competencies are in. Core competencies are in the eye of the beholder a lot, like sensor and detector technologies. Goddard is really a leader in that. But JPL has done some

really spectacular things in that. Optics systems, big large deployable mirror systems like the [James] Webb telescope.

Well, Marshall is probably the premier organization developing advanced optics systems. They had built the early version. They worked a lot when Jim Odom was there on the Hubble [Space Telescope], putting the Hubble together. But Goddard ended up with that role now. But that's just an example of the Centers feel like, "Well, this is our future for the next 20 or 30 years, we're not going to give up any of that." From photon to usable dataset, all the technology and the information systems along the way, they'd all like to own them, that whole chain of activity and capability.

Well, JPL has got their own. They can do deep space stuff mostly. Goddard does a lot more of the Earth-related Earth environmental stuff. JSC doesn't have a big role. They do a lot with autonomous robotic things actually. Goddard had more of the experience with robotics than JSC did because they ran the relationship with Canada for the big arm for Station, still do. Marshall optics. Marshall user interfaces with the manned program. But unmanned part of payloads, they want to be a big player in payloads. So like you said there's still that creative tension between the Centers to stay in the early stages of research in advanced technologies.

It was always some challenge on funding. We'd go out with a competitive announcement on technology work. It was a broad open announcement, it wasn't just for Centers. The Centers would team up with industry people, and they'd come in with proposals, and we'd go through a rigorous evaluation process with people from the Centers that were not—they were firewalled from some of the other people. So you'd get them all in a group, and I felt like that was a really fair process. I felt good about the evaluation process. It involved NASA people from the Centers that stayed fair and open in their decision, and then would recuse themselves if their

Center's proposal was being considered at this point in an evaluation. They would say, "I can't participate." That worked out well, but you'd get the complaints from the Centers, well the balance, "JPL got more of these than we did," that still goes on. I don't think that'll ever end.

WRIGHT: How was the response to provide technology and support for science? This was different from manned space flight.

PAULES: Exactly. Very different. Well, these ideas that we talked about in transaction management. When you get a really complex spacecraft up there, it has to have a lot of failsafe built into it. Self-healing things. Well, if the system detects this is happening do this. Drop to a lower mode. Change to a mode of operation that doesn't use so much power, or doesn't require movement of this antenna. It does it automatically, and it tells you it did it, and it tells you why it thinks it did it. So a lot of autonomous operation built into robotic spacecraft. I call all these environmental satellites robotic spacecraft because there's no people in it.

But I think that there'll always be a need for that. The thing that changed when Goldin came in, we had the program well underway before he got here. But when he came in he had this faster, better, cheaper concept. So his cost guys, which worked out of the budget shop, started really hammering on this series 2 and series 3, these big school bus sized satellites. He said, "We can't afford those things anymore, we don't want to spend money that way. We got all these other things that are competing, and the economy is just not in a position to add a lot of big budget stuff."

If you ran those numbers out, Earth Science Program would be huge with just buying new copies of those giant satellites. He was happy with the technology program's reducing cost.

Technology says break them up, these things are too complex, they're too risky. If one instrument fails what are you going to do, you got eight others that are up there, supposed to be working, but you need that one instrument, what are you going to do? Now this whole program, this is part of the Space Station Program. Matter of fact I'll tell you about that. It's embedded in all the old history, but I don't know how many people ever think about it.

Those platforms were to be built as polar platforms, and the Shuttle was to be launched out of Vandenberg [Air Force Base, California] to launch these things in polar orbit out of the Shuttle, these big platforms. They were part of NASA's contribution to the Space Station Program also. The Europeans were going to build one of these polar orbiting satellites. We'd launch it with the Shuttle. Well, when *Challenger* blew, all the Shuttle flights out of Vandenberg, it just cancelled the whole program. We had a launch pad built. They were getting ready to put the Shuttle out there. Stopped it all. No more launches out of Vandenberg. It's too risky. You were flying things that were high-risk and had all these fuel cells and all this fuel in them you didn't want to be flying on the Shuttle, because these big robotic spacecraft carried their own fuel supplies for adjusting orbits and all that. All of them were nasty stuff. They didn't want to have any accidents on the Shuttle. Put the crew at risk. So they just cancelled that whole part of the program. So these things all moved back into—they were launched out of Vandenberg but on ELVs [expendable launch vehicles], Delta IIs and that kind of stuff. Still launched out of Vandenberg, but the Shuttle went away, and these huge behemoth type things required large launch vehicles, which cost a lot of money.

So Goldin says stop. We got to reduce the risk on this stuff. Figure out how to get these things into smaller packages, launch instruments singly, have them operated in constellations if they need to talk to one another, don't put them all on the same launch vehicle. Be able to

replace them in orbit if you have to. Well, the Space Station Program was the idea, we should go up and you could launch some crew up to this unmanned platform and do maintenance, replace an instrument, replace batteries, just like we do on the Hubble. Well that all went down the tubes with the whole concept of EVAs and Shuttle support out of Vandenberg. So we're back to making them more reliable. That really ran the price up.

Get that instrument to last, all dozen instruments to last five years, and not replace it on the platform, was not going to work. So Goldin insisted that we go back to smaller, cheaper, faster, better. Says maybe it's too high-risk to try to build an instrument that'll last five years for sure and maybe two more, when you could get it to last for three and then just replace it. Maybe you could build it to last for three. So that'll be a lot cheaper, go design me a system that does that. So the series 2 and series 3 just went out the door.

So the whole program restructured itself. Went back to the requirements process. I was there during all that, which was all very exciting. I led a big big effort on looking at new ways to get those same measurements. I ran that effort as a baseline measurement profile study. We took all the basic measurements that were needed to get the long-term data record, and had people go out, we ran a big competition to have people come in with ideas of how you'd make these measurements in a smaller, faster, cheaper deal. You could do it with partnerships, do it with DoD, do it with international partnerships and so on. So we had a whole series of competitions to come up with these smaller, faster, cheaper missions. We got a lot of them accepted. A lot of them are flying. They're starting to launch all those to replace the kinds of missions that we had the big ones.

So almost all the satellites you see being launched by Earth science now all came out of that initiative. That was fun. Even though I was—I think by that time Ghassem [R.] Asrar had

taken over the Earth Science Program. He had me be the lead for this study, because most of it was going to depend on new technologies, and they wanted to make sure we didn't bite off more than we could chew. What these guys are proposing is really something you could do, it's not just a pipedream, or you're going to spend all the money trying to get the technology ready to go. So that was a fun part of the time I was on Earth Science. That was still going on.

But it got to where the missions, we try to do missions under $100 million apiece. But the missions kept coming in, you'd get some that were $500 million. Some of them were $400 million. But we were getting them down. They were not $1 billion missions. Like each of the satellites we had that we launched were over $1 billion apiece almost. Each one of those that were up there, you look at the total full cost, getting them back to a reasonable price. Goldin was happy with that, a new direction was fine with him. But then our technology program became more important, and Centers and industry would develop technology to a certain point, and then they would propose that technology maybe two years later in one of these mission concepts that we had advertised. We made them science-based. The science was the driver. The whole mission concept was, "Tell me how you're going to do this science, and convince me that you can do the science with whatever you're going to propose, and then tell me how you're going to do it. The how is the second part. You're going to use this kind of an instrument, you're going to launch it this way." So very different from the big school bus approach.

Everybody liked it. The scientists liked it because it felt like they had a whole new set of opportunities to build missions they liked. Earth Science got hit in the last few years, last two or three years I was there. The budget was just not going to be there to support a lot of the new missions. There was this big gap that's marching toward the program where there were only a couple missions going up. We had 25 or 30 satellites in orbit about 3 or 4 years ago and there's a

big picture of all those satellites with us. Some of them are ones we launched with NOAA, like the POES [Polar Operational Environmental Satellite] and the N-POESS [National Polar-orbiting Operational Environmental Satellite System] and the GOES [Geostationary Operational Environmental Satellites] satellites, which NASA built for NOAA and launched, but we counted them as part of the process because we influenced the technology that they used on them and so on. But a lot of satellites. That's going to drop off significantly over the next few years. I just think it's a very discouraging time for the Earth Science people right now.

WRIGHT: Why was the budget hit so badly?

PAULES: The budget was pretty much as the new administrator came in after Goldin, so Administrator [Michael D.] Griffin, he's made this promise, he came in on the basis that he's going to pull this Constellation Exploration Program off, but he was not supposed to raid the science budget to do it. Well, both the Space Science and the Earth Science budgets were projected to grow over the next decade to some significant level and add more satellites. Both of them. When he came in, he says all right, he said he would not cut the budgets, he didn't say that he would increase them, but he said he was not going to cut them. Well he didn't cut them, but the growth profile just went to zero, there's no growth. Your program is this level, it's going to stay there, and that's what he said he had to do in order to get rid of the Shuttle, get off the Shuttle, and get the new program going.

Well that just turned the science community upside down. They've come in, they continue to complain, it was a major cut in the program. Well it was a cut in the projected program, not a cut in the current program, because programs are still well-funded. Each of them

are over $1 billion a year, well over $1 billion. The Space Science Program is probably $2.5 billion. But they had projected it to be, by another year from now, $6 or 8 billion.

Anyhow, some of the major programs and projects were cancelled in the Space Science Program. The ones in the Earth Science Program, only a couple of things got cancelled, but most of the other new initiatives were all pushed out to the right, just delayed significantly. So there's a lot of frustration over there, and that was as much as anything an influence on my decision to leave, I just didn't see in my remaining professional lifetime a lot of activity that I would enjoy doing there, so I felt like it's time to make a change. It was a good time to go. I was just going to retire. The guy that I worked with back in Houston says, well, go and talk to these guys. So I came over and talked to Kelly Anderson, here I am. So I'm not retired, I'm still working NASA stuff, I do a lot with DoD, but I'm doing things that are actually going to happen.

WRIGHT: As far as you know.

PAULES: As far as I know, yeah, right. No, it's been a good change.

WRIGHT: Tell us about some of the projects when you were at the Earth Science office that actually did—no pun intended—get off the ground and happen that you're proud of and maybe still even watching?

PAULES: Oh yeah. Well, you picked a couple good ones. One of the initiatives we had in the technology program was something called the New Millennium Program. That was a program designed just to push technology, new technology missions, advanced technology missions. It

was a cooperative agreement with three organizations, the Space Science organization, ours, and Sam [Samuel L.] Venneri in his technology role, he was the Chief Technologist for the agency, and his technology program was embedded inside the aviation program. So the three of us signed an agreement called the New Millennium Program. It had a profile of several missions. They were dedicated missions, dedicated to demonstrating technology. The missions got selected because there was no way on the ground to prove that technology would deliver what it said it was going to do. You had to actually demonstrate it in space.

So we were having a lot of fun putting those kinds of concepts together, and one of them that's the one that I feel is a real success is one called EO-1. It's the Earth-Observing 1 satellite. It was one of these small low-cost satellites, no moving parts, really simple concepts, but high-tech technology for the sensors and the detectors. It had a hyperspectral imager on it. It was the first one that was a civilian hyperspectral imager. We launched that thing in 2000 and it's still working perfectly. I still stay very close to that. We still write technical papers on it. I'm still coauthoring on technical papers on EO-1. One of the things we pushed really hard that I felt real good about and was lead for was what was called the Earth Science Vision. That was looking at 2020, 2025 era. Where should Earth Science be and how should we get there?

The whole concept was building this idea of interoperable spacecraft where you had small satellites doing maybe a specific function, one or two functions. If that data was properly coordinated with data from another satellite, then you could get a more important data product out of the combination of this information. You'd fly them as sensor webs or constellations of satellites. They would be interoperable so tasking, maybe one of the satellites could be like *Terra*, which has a big MODIS [Moderate Resolution Imaging Spectroradiometer] Earth-observing instrument on it. If some automated scheme is analyzing a big 300-by-300-meter

image and it says there's something changed in that image from the last time we went over that spot, says my resolution is not good enough to tell you what it is, but something changed, and you use that information to go and trigger another satellite that has higher resolution or different sensors on it, that satellite now points at that spot next time it goes by and tells you well here's what really is going on down there. So that's a sensor web.

EO-1 is in a sensor web with MODIS. So EO-1 is cued. They call it cued off of what you see in a MODIS scene. That whole thing is all built as an automated scheme. It's all automated. It's being used for wildfires; wildfire support systems, and the big customers of the dataset are the [United States] Forest Service and the state and local forest guys out in the west. Any time a big fire comes up you can spot it immediately on MODIS. MODIS has infrared sensors. They sense heat; see through the smoke. It has optical sensors, you can see the smoke. You can see it, it's really sensitive. So even a big patch of land with a little small fire starting shows up in a MODIS scene, but there's not enough detail to tell what's going on. And EO-1 is in the same constellation. They're flying around together in orbit with Landsat, with CloudSat, and with *Aura*. We've got all the big school buses in the same orbit, and then several smaller satellites with them. They all train along together in orbit, and now we can cross-cue from one instrument to the other.

I feel like that whole vision that I was talking about promoted that idea, and I promoted it ever since I joined the program. The whole concept is one Goldin really bet on, this constellation of sensors, interoperable sensor web. That would be a lot cheaper. You had one of them fail, you could just launch another replacement into that orbit, replace just that sensor. If you got newer technology, you could replace it with a better sensor. That's been a really successful thing, and EO-1 is still a very active demonstration. We're working the same kind of

concepts, what I do now, with the Europeans and with people at DoD. So that's one of the key things I wanted to keep doing when I left and came over here.

We're still working it from a different knothole, but I think that's where all the strength in these multiple satellites will be. Once you get the kind of data you need, these forecasters, these scientists say well in order to really project a climate even a decade—or a year, just forecast a year from now the effects of El Niño, what they're likely to be. Not the daily rainfall by noon on March 30th a year from now, but the fact that in the spring you're going to have a lot more rain here versus over there. Those kinds of models are getting better and better because of these satellite data systems. To be able to project climate change over decades, the models are so complex to show these—they're so sensitive to certain little guesses and changes that you want the guesses to be as accurate as you can.

So the modelers are very interested in getting these cooperative collegially gathered datasets. These are all international scientists working, collaborative groups, to do things. So it's still the future of environmental monitoring as far as I'm concerned, because we can do a lot of work there, make a lot of improvements. I spend a lot of time on the data systems side where you gather the data, make sure the data definition, when they get a dataset from a satellite, that all what they call the macros that go with them and the metadata are coherent enough that a scientist can agree that, "Yeah, I understand that data, and I know how good it is or what I can use it for."

But the information system, I actually go out and discover where these datasets are and if they exist for this region when you need them; a lot of historical datasets, just being able to grab them. These are usually pretty big datasets. You do everything through Web-based interfaces, we automated a lot of that so it's all transparent to these scientists. That's what we're doing now.

So I feel pretty good about that EO-1 thing, the New Millennium Program, the Technology Program, the Vision, getting the Vision implemented.

You had mentioned on my list the Commercial Technology Mission Management Team. That was really an activity within my Chief Technologist role, is to build bridges back into industry. Now industry has the same protective interests that the Centers have. If they have a key technology they're developing they don't want to share a lot of the details of that. So we had to come up with ways to exploit to the degree that it's feasible their proprietary technology, but not advertise the details of their proprietary capability to the world. We had the lawyers help us figure out how to leave the rights of the data and the capability in the industry hands, but to exploit it and to prove to the scientists that in fact that capability does deliver these kinds of measurements with this kind of quality.

We had a big commercial industry day, and had a lot of workshop activity, and talked about how we're going to do this. We talked about staying out of the high-resolution satellites, the GOES, and those guys that have one-meter-and-less high-resolution sensors. Well, they didn't want the government competing with them when they were going to go out on a limb and build these things and sell the data. Part of this commercial activity was to establish some NASA policy that we'll build sensors with resolutions down to this, 15 meters, but no finer. We won't go any lower. The big battle was in hyperspec. Well they didn't want us to get into hyperspectral, because they thought that was a commercial niche, they could sell to lots of people.

So we convinced them—and most of the industry colleagues convinced them too—that there was so little known about how to use hyperspectral that you really wanted to demonstrate it and let people learn how to use it so that when you finally got to the point where you had a

community of users, that when you put a commercial version up on orbit there'd be somebody there to use it and know how to use it. It's very complex.

Anyhow that commercial activity was to help build bridges to the commercial sector and to agree on where NASA and the government would stay out of areas that they wanted to claim as a commercial opportunity, or to build a relationship so we buy data from them under a competitive process. We tried to make a change in Landsat, go build the next Landsat as a commercial venture, and we'll buy data from you, but we'll only as the government be willing to pay this much for data. Well the commercial guys, everything came back, says we can't do it for that, it's got to be more, got to be more, you're not being realistic. So we just killed that project and Landsat—you mentioned Landsat in here—I'm still working on Landsat from this knothole.

The Landsat 8 or Landsat 7 is in trouble now. It's starting to wear out. It's on orbit. It needs another national sensor of the Landsat capability. We used EO-1 as a pathfinder for a new Landsat technology. We said just build another copy of this thing with a swath width that's equal to Landsat. Be a real cheap deal to do. That was what we proposed, and that didn't fly within the agency. The agency wanted to go out commercially. We said, all right, we'll just turn the technology over, let anybody have it, and they can build it. Well the industry guys all come back and said, "Well, we like this, but we don't like that about it. We still want to do it our way. But we still can't do it for the price you want to pay." They're nervous about building it without having a real community of users out there ready to pay for it.

So that 30-meter data, this is not something you will be very familiar with, but 30-meter is a little snapshot of a pixel that comes back into a dataset as a measure of what light is reflected back from that on Landsat from the Earth in a 30-meter, which is 90 feet or so by 90 feet, one

little spot on the Earth, 90 feet by 90 feet, reflects back a whole lot of stuff, but it's all averaged over that 90-foot square. That's captured by this instrument.

Well, 30 meters is not enough detail for guys in the agriculture business. They want to be down at the five-meter-or-less. We're doing crop assessments if our corn is stressed or our wine vineyards got a problem of different kinds. They've got to have higher resolution. So Landsat wasn't going to do it for them. Landsat is cover the globe every 16 days at 30 meters, everywhere on the globe. The Arctic, the Equator, everything; 30 meters every 16 days. Nobody was interested in the data except the scientists. The commercial guys said, "We don't need it. We need more detail. We need it here. We need it more often than 16 days sometimes."

That's where the commercial guys are going. They're going to help try to deliver that capability. The Earth science folks and the scientists that deal with large-scale changes in the environment still want that 30-meter every season. You see the seasonal changes and how the Brazilian rainforests are being cut out, and what that's doing to the environment in the Amazon. All that, collect all that data for these different sensors in 30-meter resolution.

That's still going to happen, but it turned out that OMB got involved and OSTP [Office of Science and Technology Policy] got involved and they finally agreed on how to do this. So NASA is building the next Landsat satellite, USGS is going to take over operations, and USGS is going to provide all the data processing as their role in this deal. But NASA is building it at Goddard as an in-house build for the next generation Landsat. Beyond that Landsat, [John H.] Marburger [III], who's the head of OSTP, says all right, we won't make any commitments for anything beyond this one, this gap-filler. After that we're going to see what the commercial guys can do, another five years down the road, see if they're ready yet to take this on.

But by now we got Indian satellites, we got Chinese satellites, we got several in Europe coming, all doing this global data collection. So the idea is, well, how do you use this vision, this interoperability thing, to gather data from all these sources and build up the equivalent of a Landsat dataset for the scientists? That's that next generation Landsat following. We're in the middle of that too. So I'm keeping in touch with Landsat because I feel we need it.

That was the commercial piece. I think it was basically engage industry in a way that would be constructive, and get them to be honest with us about what they could do and what they couldn't do. There was a lot of change going on then because they had gotten permission from State Department and DoD to go to high-res [resolution] commercial satellites. That was a really big deal when they were able to do that, because that means if they can fly them all around the world anywhere and take these pictures of anything and sell them to anybody, then that opens up a whole bag of worms as far as DoD is concerned. You're letting anybody see any part of the world at high resolution, and that means they're going to have information that's as good as we have.

So the dam broke, they allowed it to happen. Now they'll never get it back in the bag as far as DoD is concerned. That's okay because there are still other capabilities they have that are not commercial, that are unique to intelligence-gathering stuff, but the commercial guys are putting a lot of information out. You see Google Earth and all these guys now use these high-res systems. You can look at your backyard and see if you're at the pool in your backyard today. It's amazing. But it's interesting times in the satellite business.

WRIGHT: You've seen a lot of changes from the day you walked into the Manned Spacecraft Center until now on how NASA works with industry and commercial partners. Do you see a

move changing even more where NASA will become maybe the partner with industry and commercial instead of the other way around where NASA is controlling the issue?

PAULES: Yes, I think the model for the future Landsat that I mentioned just now that Mr. Marburger insisted on is probably the way of the future. There's been some discussion about whether NASA's roles in the satellite business if it fades away, is there any role for NASA at all, because you've got National Science Foundation with scientists in it, you got all the end user agencies that have science issues, EPAs, what's NASA doing in science? They build satellites. If you don't need to build satellites what's NASA doing in the business at all? So that's already been a discussion that happens, what is NASA's future in this stuff.

Well to me, staying involved in the technology advancements that are going to be required and to pull that all together, that's going to be a national investment to do those things properly. So NASA's role could still be on the leading edge, the first of a kind, one of a kind of capabilities. Commercial guys aren't going to be interested in anything that doesn't make them some money, and they're very happy to let NASA buy the first copies, and if it works and has value to a broad user community, they'll pick up the ball and buy the second copy and the third copy. But they want to add the value. They make money off the value added.

I think NASA is always going to have a leading edge role in how to use space for exploring deep space and doing environmental monitoring on the Earth. It takes a unique set of capabilities to build these one-of-a-kind spacecraft. That's why NOAA got in so much trouble, N-POESS. I don't know whether you know what the term Nunn-McCurdy [Amendment] means, but it's a congressionally mandated review process that when one of your big projects is projected to exceed the approved budget approved by Congress by a certain percentage, that

automatically triggers this Nunn-McCurdy review, and there's this huge—you got 90 days to come back to the Hill and say okay, we're going to get back in this box and we'll be out of trouble. But we're going to do these specific things to do that. It usually means cutting a lot of content out of your program.

Well, that's what happened to NOAA on NPOESS. NPOESS, which is the polar orbiting satellites, they went out with a new way to do it, they made a partnership with the Air Force to go build them under industry contracts. DoD is pretty much a hands-off thing. They turn everything over to industry and they go for performance-based delivery. On these high-tech programs—that's fine for building 1,000 aircraft or 15 submarines or something, but it's not good for one-of-a-kind spacecraft, because you have so many technical vagaries that bite you that you really need some expertise that has a long history of "If we're working with that kind of detector you're going to do this, or if you run into trouble here try this first." So the expertise, the smart buyer knowledge is what NASA has always prided itself on. We always bring in these real experts from our Centers to help us resolve problems. All right, this thing is in test and it's failing here, here and here. All right, bring in a team from—we bring in NASA guys, couple of industry guys who are old graybeards, and they'll attack that problem and solve it.

NOAA and the Air Force don't have that kind of people. NOAA just buys stuff. Air Force buys stuff through contracts. So this partnership between NOAA and the Air Force got in real trouble. Nunn-McCurdy. The way it affected NASA is NASA had a whole series of science instruments that were flying on this NPOESS as transitions from the big three buses. Came up with clever things that could transfer some of those instruments, the next generation, right onto the polar orbiting platforms that NOAA is building. That was our part of the partnership. When NPOESS got in a trap with Nunn-McCurdy, they tossed off all these science instruments because

they got the buses to be smaller, the science instruments were higher-risk, because they were new, and when they did that NASA said, oh my god. The Earth science crowd really is staggering right now trying to figure out how to get some of those measurements back in to fill the gaps in this decadal dataset they were looking for, this multidecadal dataset.

Nunn-McCurdy, NPOESS, these kinds of guys, that's not a good way to manage programs. You still need a NASA-like capability. NASA needs to have enough missions going that you keep these kinds of unique core competencies available at the centers, JPL, Goddard, Langley, they're the key Centers. In terms of observing what's going to happen with NASA, I think unless there's always a research technology push role for advanced satellite and science investigations, it's going to be hard for NASA to have any prominent role in this business. Once you get a certain kind of measurement made with a certain kind of technology and you can build a second copy of it or third copy of it, NASA really shouldn't even be interested in that. That should be, "Okay, NOAA you can do that now. We took care of the risk for you." That's what NASA ought to be doing. So if they stay in a risk reduction role and stay on the leading edge of advanced technology, I think there'll always be a role for NASA hopefully. I always hope there is.

WRIGHT: You've dealt with a lot of different issues during those years that you were with NASA. Could you share with us some of the lessons that you learned that you were able to apply as you went through? Maybe even some that you're applying now in your new field?

PAULES: Yeah, that's a good question. Lessons learned are I guess that a requirements process is critical. The early initial requirements process is critical, and that the ultimate user of whatever

you're doing or building ought to be a real important part of that early requirements development process, because I found that whenever you actually start building things there are always tradeoffs you have to make as you get into the design in more and more detail. Well we're just not going to be able to do that. We can't deliver that performance. We can give you less performance or measure it a completely different way. That's a decision we have to make right now. So those guys that helped you with the requirements, the scientists and so on, these early requirements ought to be right in the middle of that meeting so they know what the impact is going to be on that ultimate measurement or capability they expected to have at the end of the day and know that that's not going to be what they expected. They can decide way back here that that's okay, we can live with that. Involving the ultimate user in the early requirements process and all through design development phase of any of these capabilities is to me an important lesson for anybody to pick up.

One of the things that I still think, in the manned program, is the concept of what I call the *ilities*, supportability, maintainability, reliability, all the things you have to design into a long-lasting system that's going to be up there forever. Logistics concepts ought to be built in from the get-go on every manned program there is, because almost all of them now are long-term programs. Everything is going go back to the Moon, we got to fly to—we're going to the [International Space] Station, we're going to operate it as a research facility for another 20 years if we can pull it off. Well, any technique you use for repairing it or adding new capability ought to be looked at in the lifecycle cost sense. That was what Hodge brought me back to look at, but engineers don't like to talk about lifecycle cost. That brings in all the risk and uncertainty that they don't want to talk about.

It's risk management, dealing with long-term lifecycle cost. Both of those are really important to any program of any duration, especially manned programs. Go back to the Moon, put these facilities on the Moon. Think that's going to be fun, but maybe has to be thought about very differently than they way manned programs typically build things. We tried to get it in the Station, but didn't succeed too well. It's still a hard Station to maintain and repair.

WRIGHT: Another word you mentioned earlier and I wanted to come back to was treaties. You did the MOUs originally with Station. At the State Department they were treaties and they had basic words. Then you mentioned later about India, China. They all have satellites. They have information. They have their own programs. Do you see a new international cooperation in the future based on what you've been able to observe?

PAULES: Well, there is an effort to make agreements already. The ones that are the most pressing that NASA is involved with is this Landsat gap-filler. Now Landsat datasets, they want to keep this data continuity going forever on the datasets from Landsat. Well Landsat 7 is going to fail before long. [Landsat] 5 is already on its last legs and it's lasted a lot longer than it ever should have. [Landsat] 7 has about lasted its lifetime. The gap-filler mission that NASA is on a really fast track for is not going to be up there before Landsat 7 likely fails. There's going to be a gap, so what the community of users is out doing, with NASA and USGS and NOAA in the middle of this, is developing agreements with India and the other organizations that are building Earth-imaging satellites that look down, and you can replicate Landsat to fill the gap between Landsat 7's likely failure and the new Landsat 8 equivalent getting up there in 2011, 2012.

There are agreements that are being negotiated with the Indians, and there are always agreements. They tend to be at the case-by-case basis on individual satellites, like CloudSat was an internationally developed satellite with the French. That was done in an MOU. It was just on that satellite. It wasn't a program, it was a satellite. They came in with a proposal and said, "This will be a foreign partnership, one of these fast track programs." That one succeeded and it's up flying now. It's doing really well. The Japanese radar satellites, which are well ahead of us in putting radar in orbit for measuring ice flows and ice changes in terrain, there are already agreements with them. They're making agreements with India, but it tends to be on a case-by-case satellite-by-satellite basis.

There's not really, to me, a pattern like we're definitely going to have to have agreements on the return to the Moon, almost like Station but probably more complex. The partners there are going to have a lot better position to argue from, because they're moving out on their own programs anyway. Everybody's moving out. Nobody had to go coerce them into joining a partnership like Reagan sort of did. They said, "We don't want to miss it so we'll join you." Then, okay now, what does that mean? So you spent five years trying to figure out what that means. Well these guys are all moving out. The Chinese are really moving out. I think agreements with the Chinese are really going to be important soon, or the Chinese are going to say, "Hey, I don't need this. We don't need you guys. Good luck. See you." They're going to do it without us.

The Indians are moving out. They've got a big program. Europe has what's called GMES, [Global Monitoring for Environment and Security]. It's for national security as well as environmental monitoring. They're building all that as an ESA set of projects with the Italians, the Germans. They're moving out. They have figured it's part of this, what's called GEOSS,

Global Earth Observation System of Systems, GEOSS. That is an initiative to formalize opportunities for collaboration. But it's all a volunteer effort. Everybody's doing their thing and they're collaborating. We'll have this satellite up and we'll exchange data. But there are no agreements. There are no real agreements that says, you're going to do this or that. The data exchange policies are not done yet. That's the big issues, data exchange policies. That's got to be something that people better start working on quickly, because the satellite process is moving out. The guys that build satellites are building them, especially in Europe, and India and China and Brazil. They're all building them. It just seems like NASA is not trying to be in the forefront of establishing international agreements on these environmental type satellites.

The Administrator definitely wants to put something in place to deal with the manned programs to go back to the Moon. But, I'm not in that program, so I don't know what kind of deals he's already maybe made or what have you. I don't see the visibility in the agreement process like I did in Station, which was very public. It had a lot of newspaper articles and everything else every time we made a deal. So these guys came over. When they came to town it was an entourage of six or eight guys and it was a big political thing. You had State Department reps [representatives] there, you had White House OMB guys. All of them were part of the group. Toured them around for the two or three or four days they were here when we were signing agreements and stuff like that. They were all senior people. But you're right, international collaboration is absolutely essential for the future of any of the space programs.

The nice thing about doing it in a collaborative sense is you don't end up with this set of tension between satellite builders doing certain things people don't understand or don't know why, because when you collaborate you're going to learn a lot more about what their intentions

are and why they do things the way they do and what the real capability is versus what you might imagine it is. So I think agreements are good just to force people to actually work together.

WRIGHT: One more question on agreement. Goes back to the early '60s when there was a UN [United Nations] treaty that nations signed that space would always be kept for peaceful uses of outer space for mankind.

PAULES: Peaceful purposes.

WRIGHT: Do you see a trend to move that more satellites will go up from these different nations that could possibly impact those treaties?

PAULES: Well, that's making a lot of press lately. The Chinese shot down one of their things with a laser-based weapon just to see if it could work. That stirred everybody up, saying well, if they can do that, what else are they going to do. The peaceful purposes objective is still one that NASA absolutely adheres to. We try to work with DoD on something, you had to be very careful that any agreement we made with them doesn't restrict the use of the data in any way from a civil satellite. It could be made open and available to anybody that wanted to use it. Even if DoD wanted you to try some specific things out, if that satellite could do some certain things, we had agreements that said well we'll hold the data for so many weeks or months, but we still have to release it. We are not going to get in the business of being an extension of an intelligence effort here. We have to be for peaceful purposes. The Japanese are just hard over, you don't do anything with the Station that's not for peaceful purposes. I think it's still a good

objective, and I hope that in the robotic spacecraft world they can build that kind of an understanding into the use of them.

These satellites are very vulnerable to any kind of intervention. Somebody wants to mess with them, they can really mess them up. We don't have them built to have a lot of protection. Even the DoD satellites they put up are not as protected as you'd like them to be. So some agreement is going to have to be made on it. It seems like there ought to be a lot more visible effort at doing it, especially at Griffin's level on the new exploration initiative. I just don't see a lot going on there yet. I hear talk. He gets questioned about it, Space News or something. He'll answer the question. But it's not a visible effort like the Space Station Program was. It seems like it should be by now, if we're really going to do it.

WRIGHT: I'm glad we got a chance to talk about some of your accomplishments. Do you feel like you have some areas that were the greatest challenge that you had to work with in order to be able to accomplish your objectives?

PAULES: Well the challenge always was—it was more of a frustration, but you knew you just had to deal with it and move on—was this issue of dealing with the realities of the budget process, the realities of the project, and having to every year reset your program because you weren't going to get the funding you really needed. Sometimes it seemed like there was a lot of wheel-spinning that slowed things down and got in the way of getting something done, because you had to revisit the issue. That was probably a challenge to keep people interested in a program like that when you felt like, hey, we're all engineers, we're going to do this kind of stuff, we don't spend our time justifying budgets. So that was a challenge, but it was more of a

frustrating challenge than something you shouldn't have expected to happen. You should always expect that to happen, that's the way it's going to be.

Other challenges? Well if you get down to specifics, like people ask about Apollo 13. That was a challenge, but it's the kind of challenge you sort of feel like you trained for. It wasn't that anybody ever felt like we couldn't just keep—we're going to make this work. It's like [Eugene F.] Krantz said, "Failure is not an option." The main thing was that everybody in the Control Center and the people I worked with—I was called back in to work on it—you knew where you were today, and you knew what you had to do to get to the next decision point. Given what you knew you built a case. In our case we developed maneuvers to get the spacecraft back on its free return trajectory so it didn't skip out. It kept moving off because there was a leak somewhere in the spacecraft. It continued to leak this gas out of the fuel cell thing, and that little bit of leak was a thrusting maneuver. It kept pushing the spacecraft away from the trajectory we put it on, and you'd track it for a day and a half and it moved some more. So we had to do little maneuvers to get it back where it belonged.

The challenge was in feeling like you've guessed all the things that you can imagine happening and deal with them and account for them, but there were so many unknown things that just keep popping up. Something new you'd have to deal with. But I didn't think of that so much as a challenge as—not a negative challenge, it was a positive challenge. We were all equipped to deal with it, I thought. People ask me, "How did you like the *Apollo 13* movie, and how well was it done." It was perfectly done except that everybody sat in that theater knew what the outcome was going to be. But we didn't know from day to day, we weren't in the Control Center.

Other challenges, I can't think of things that I think of as negative challenges. They add a little frustration to your life along the way, but they were actually fun. The MOU thing was a big challenge to get that done, get those things signed. I worked on that right up till I left the Station Program, they reorganized and moved to Houston. The agreements on the cost and resource allocation process were still going on when I handed it off to another guy. Those were all challenges, but they're what you'd expect, the kind of challenges you expect.

Dealing with organization change, I think that's usually the most frustrating challenge for people that are comfortable with it. They get in a niche and they like what they're doing and the way. We got this all under control. Next day it's changed. You got a big shuffle going on somewhere. I've grown to accept that as an expectation. That's going to happen to you. Budget problems are going to happen to you. So are they challenges, something you put on your list of things to do? You just have to deal with it.

There were a lot of fun things that we didn't talk a lot about.

WRIGHT: Let's talk about fun things.

PAULES: Splashdown parties.

WRIGHT: Let's talk about splashdown parties. We want to hear about those.

PAULES: Well, splashdown parties, they were—the big pleasure you get out of certain things, you look back and say well, I did all these things in this mission, I worked at Houston, and when you look back at what do you remember most about all that, the biggest thing you remember is

saying "go" when the flight director goes around the loop and asks are we go. You had to do that several times every mission when you're ready for a big maneuver or anything else. So that's a real pleasure, feeling like you were in that front room doing that, that was your job.

But the splashdown parties. Missions really had different things happen to them. They all ended up with different outcomes, all those unmanned missions, we had things you never imagined, always happened. The problem you always had was not one you simulated. But the closest we came to a problem that was like what we simulated was the actual Apollo 11 landing where the alarms went off. That was as close as we had to something that we knew how to deal with directly, and it's a good thing we did, because we were sitting on that console, these alarms went off, and Jack [John R.] Garman, the guy in the back, he was sitting in the back, and he was the guy—Bales and I were out in front, Garman was in back. We probably had 10 seconds to figure that, or five, to figure all that out and make sure that we could say go without any trouble. Told them what to do, that went on.

But other times all the simulations, all they did was give you a feel that well, whatever happens you can deal with it. That's all simulations did for you. It was just they gave you the confidence, "Well okay, who do I ask first or where do I look first?" Those were really important. Simulations were really important for any kind of an activity, but when you get to the splashdown parties you rehash what really happened. A lot of the splashdown parties were a lot of fun. They'd last for hours. You ever been to a splashdown party?

WRIGHT: No.

PAULES: You need to go to a splashdown party. Do they have splashdown parties anymore?

WRIGHT: I'm not quite sure.

PAULES: Now when the Shuttle lands, see, it's not the same. I don't think it could be the same as it was in Apollo or Gemini or Mercury.

WRIGHT: Well, give us one that lasted your memory.

PAULES: Well, remember the old Flintlock Inn? Well, the Flintlock Inn was a great place to have splashdown parties, because they had this whole open second level deck that was open from one end to the other, you could get hundreds of people in there. I'm sure we violated every fire law they ever had cramming people in the place. But you'd get in like [AS-]201, there were things that happened like that commanding sequence we had on [AS-]204 trying to get the commands in before they went over the hill, because they had a maneuver coming up. The guy from the command console down in the bowels of the building just and said, "I never thought you guys would pull that off." We sat around, we must have rehashed that for half an hour and laughed about it. You'd laugh about a lot of things. You end up—crazy things. Arm-wrestling, Phil [Philip E.] Shaffer, did you know Phil Shaffer? Did you interview him?

WRIGHT: We did.

PAULES: Did you? Okay. He was one of our favorite guys.

WRIGHT: So you were an arm-wrestler.

PAULES: Arm-wrestling, Indian leg-wrestling. You remember you get on your back and you lock legs together, try to flip the guy. Crazy stuff. Drank a lot of beer. Drank a lot of beer and ate those things that—what was the place in Dickinson?

WRIGHT: Hofbrau Garden?

PAULES: Hofbrau Garden yeah, that was another really good place, because you can get a lot of people in there. They were all a lot of fun. Everybody showed up. [Christopher C.] Kraft would show up. Everybody showed up. They went to all of them that I remember. They wouldn't stay long necessarily but Kranz would come, he'd hang out, and [Glynn S.] Lunney would always be there. Everybody went. It was a good way to defuse or depressurize after the mission was over.

WRIGHT: Very much a personal level more than a professional level, I guess.

PAULES: Oh yeah absolutely, yeah, people you talked to that were down in the RTCC [Real-Time Computer Complex] you actually never saw, except at splashdown parties. Let's see. The Ops Taskforce was a really good thing. That was the one where we put the ops concept together. We spent a lot of time as a group down at [NASA] Kennedy [Space Center, Florida] locked up in one of their barns down there to do that. That was good. One of the side benefits is when I worked in the Department of Transportation in the planning area, the systems planning, it got me a call to join the Rockville City Planning Commission, because they're always dealing with a lot

of transportation issues and so on. So I spent eight years on the Rockville City Planning Commission because of my UMTA experience.

WRIGHT: That's a pretty growing town at that time, wasn't it?

PAULES: Oh yeah, it's a pretty good size, it's more than 50,000, but it was very aggressive, well-managed city management thing. Had a very active planning commission, a very active city council. That was fun. I guess one of the frustrations was—because I pushed a lot of the cost issues on Station—getting people to accept what it really was going to cost to do what you said you're going to do on Station was hard to do. Within NASA and the management, they just didn't want to—it always came out as a bummer to talk about cost, because you always came out with a cost that was more than they wanted to hear. Then the lifecycle cost, ops costs are going to be these kind of things, you can't get away from this. Built it this way, if you'd built it that way, you'd have had some reduction, but that was in terms of feeling like you were always fighting an uphill battle, was convincing people internally that the costs are going to be this kind of cost. They do everything to keep those costs down when they had to take them back to the Hill, justify them.

WRIGHT: Was part of that because of the different financial culture of doing the Apollo program compared to the Station Program?

PAULES: I'd like to think that was part of it, because I had no clue when I was down in Houston in flight control as a console guy. I wrote requirements, we'd justify them, we sat down with

IBM [Corporation] and all these contractor teams, and we'd sit there, and we'd discuss and discuss how to build this software to do this thing for us, the command system and all that. Had no clue what cost was. Had never heard anything about cost. Never. If that's the culture that came forward, where you had no idea what the cost was, or you didn't care—senior managers just said tell [James E.] Webb, he'll go get another $500,000. That was during Apollo. Now that's not happened in Station. You got to fight for every nickel and you have to tell them why. I think they're fair questions as a taxpayer to ask those questions.

WRIGHT: Were you still on board when the Congress took the vote where it passed by one vote?

PAULES: For Station?

WRIGHT: Yes.

PAULES: Yeah, oh yeah. It's in the book.

WRIGHT: Okay, good. I'll catch up on my reading.

PAULES: That was a scary time, yeah. New Millennium, that program with EO-1, I was real pleased with how that went, that was a big success. This interoperability stuff we're doing with taking the Earth Science vision and translating that into a very international kind of a concept with this GEOSS stuff I mentioned, I felt real good about that. I hope that actually keeps moving on. I didn't really talk much about my parallel career in the Navy.

WRIGHT: No, you didn't.

PAULES: When I was on active duty, I was commissioned out of University of Texas [Austin, Texas] to be a permanently commissioned officer just like out of the academy. I went to the NROTC [Naval Reserve Officers Training Corps] program. I was full-time regular commissioned guy, so they assume you're going to stay for a career. Well, I always wanted to go to the Moon. That was my goal. The Navy didn't have time to go to the Moon. This is not what we do. They had big missile programs, the Polaris program and so on. I decided, okay, I'm going to resign my commission and go to work for NASA. That caused a big uproar in the Navy. The said, "Well look, we're sending you to PG [Naval Post Graduate] school, we'll send you out to Monterey [California], post graduate school in weapons systems." I was a weapons and missile ops guy on the ship I was on. It was a brand new commissioned ship, great ship, and got to do a lot of fun things in the four years I was on active duty.

When I decided to resign I got a letter, orders—well I actually got orders—what triggered my—to resign—I got orders to go to PG school early. Go off the ship, go to PG school for three years, get a Ph.D, then move up in the chain of command in the Navy in the weapons world. My wife was in South America with her family at the time, and couldn't—in those days you couldn't call anybody, couldn't send a wire, couldn't do anything, and I had a week to make my decision, because they must have had an opening and they said well here get this guy, don't let him get away. So I had to send them a thing.

I talked to the XO [executive officer] and I said, "No, I don't want to do that, I'm just not ready to sign up for another 15 or 16 years right now. I want to go work on NASA stuff." So I

did that. I left the ship in '64, went to work for Lunney. He hired me down in Houston, but I stayed in the Navy Reserve for 30 years. So I retired as a Navy captain. It's like a parallel world out there, when you walk away from all the flight control stuff, close the door on that, you go do something completely different like a lot of summer cruises in these two-week things you had to do, training. Really a great change. I had a whole different world of people I dealt with on the Navy side for 30 years. So that made life even more interesting.

WRIGHT: No kidding, because that's a long time. You managed to work that in with everything else you did.

PAULES: Kept that, and planning commission, I was in the [Boy] Scouts [of America] with my son, scoutmaster, and what else did I do? I got an MBA [Masters in Business Administration] during that time at Maryland [University of Maryland, Baltimore, Maryland]. My wife remembers it all. It's a big black hole out there. Anyhow it was fun.

I enjoy what I'm doing here, working on space-related things. I work primarily with industry folks that want to go to work on this Constellation Exploration program but are not in the group of industry they're working with. We match make some of these high-tech guys out of the nuclear power industry that do a lot of autonomous stuff, high-risk systems, high-security-required, get them teamed up with the industry guys to work on exploration. Lockheed [Martin], we take them over, get them really embedded in the NASA process, who all the players are, that's fun. It keeps me up to date on what's going on on Constellation.

Then on this GEOSS activity and interoperable remote sensing stuff, I'm still doing the international piece with IEEE [Institute of Electrical and Electronics Engineers]. I'm on the

advisory committee for IEEE that does the collaborative activity there. I'm also on the board of directors for what's called Open Geospatial Consortium, which establishes standards for interoperability among remote sensing systems. It's all Web-based, so any user can sit down at a computer and get access to all these data sources and so on. So I stay involved in the remote sensing side that way, and in the manned space program side the other way, trying to matchmake. So as long as it's fun, I'll keep doing it.

WRIGHT: Sounds like you got lots more adventures to gather.

PAULES: More adventures. Well, it's been fun. NASA was a great place to work. All the government, I enjoyed all my government time. I never regretted being in the government. Nice thing about being in the government is you can have a big influence on lots of things, and I felt like I always was in a job that you had that chance, and it was a real opportunity. The thing I feel I'm a little frustrated with now is the lack of programs that attract young people, engineers and stuff. Everybody says this, but I see it in spades. NASA needs to work harder at incentivizing people to get in the engineering science programs. Find ways to do that. They try, and I know they're struggling to do it. It's just a real challenge.

That is the challenge for the future or we're just turning everything over to—the Chinese have thousands of engineers and scientists that are working on this stuff now, literally thousands. You go to these meetings with the Chinese there, we had one of these IEEE meetings in Seoul, Korea, and half the people that came were from China. They were all engineers and scientists. They're moving out. But on the US [United States] side almost all the students in the universities are foreign students. Isn't that interesting? Anyhow, it's still worth working on. Fun stuff.

WRIGHT: Well, we thank you for all your information.

[End of interview]