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JAMES A. ABRAHAMSON
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is July 23, 2012. This interview with General James Abrahamson is being conducted for the NASA Headquarters History Office in Herndon, Virginia. The interviewer is Jennifer Ross-Nazzal, assisted by Rebecca Wright.

Thanks again for taking so much time to meet with us today. We certainly appreciate it.

ABRAHAMSON: It's my pleasure. It isn't often that one gets an audience that is a little captive for hours at a time to talk about yourself, is it? [laughs] Actually, it's not about me. It's about NASA and the incredible people there and what they've done. I think that that truly is the real story.

ROSS-NAZZAL: I know that we're looking forward to it. Tell us about your understanding or your knowledge of the Space Shuttle before you became an AA [Associate Administrator] at NASA Headquarters [Washington, DC].

ABRAHAMSON: Probably the more detailed one—first of all, I've always been a technical program manager. Even though I was a fighter pilot and a test pilot, my background was program management. My first program in the [U.S.] Air Force was Spacecraft Project Officer on something called Vela [Nuclear Detection Satellite Program], which was a satellite built by

TRW [Inc.], and it was intended to help look at and detect any nation that was cheating in space on the Space [Nuclear] Test Ban Treaty. So I had a lot of background in all of that.

Then as I came out of the test pilot school, I was selected to be one of the Manned Orbiting Laboratory [MOL] astronauts, which is where I met Bob [Robert L.] Crippen and Dick [Richard H.] Truly, and all of those who turned out eventually to be just terrific bulwarks of the NASA program. We tried to learn from NASA, but we didn't learn enough. I'll tell you one story—even though it was the Manned Orbiting Laboratory, it's a story for every project manager. We were having technical problems and we were underfunded, like every program. The first year when I was there as part of the third group of astronauts—and we were all working at jobs on the Manned Orbiting Laboratory program—when we underfunded, there was a major program review, and the astronauts were asked, along with the other program managers, "What do we do? Do we slip the program? Do we try to cut it down so we could go ahead and try to maintain the schedule?"

There was a universal feeling amongst the program management team and the flight crew that we were going to be fully operational first crack out of the box, so that meant we had no choice but to slip. For underfunding of about 25 percent of what should have been the full budget, we lost a year.

The next year the same thing happened, and we had the same resolve, the same decisions, and the launch date moved out another year. The third year, it looked like it was going to happen, and everybody went and lobbied everywhere we could on the program, but that same idea was still there. Instead of slipping a year, the program was cancelled, and it was cancelled by [President Richard M.] Nixon. It was cancelled not because we had slipped, but because the political situation and the technical situation. All kinds of things had changed during that

timeframe. It didn't appear that we were going to be the big change in the technology that we had thought we would be and could be.

So the lesson is do not slip, no matter what, even if you're just going to put an empty tin can up there, and always take whatever progress you can and build on that instead of slipping.

ROSS-NAZZAL: Probably knowledge you applied to the Shuttle Program on a regular basis.

ABRAHAMSON: Yes.

ROSS-NAZZAL: Were you following the Shuttle Program then as it was being designed and built?

ABRAHAMSON: Oh, of course, of course. In fact, we would go down to Houston [Johnson Space Center] every so often and talk to some of our friends down there. When the [MOL] program was cancelled, the feeling at Headquarters was that NASA needed help. Here we were, a group of astronauts and some other technical people, program managers and others, who NASA could draw on. So Headquarters said, "We need you all. Why don't you come down to Houston?" Of course, all of us were thrilled with that idea.

The Astronaut Office, quite realistically, said, "No, a lot of our astronauts that we already have are never going to fly because the Shuttle Program is slipping and slipping and slipping, and therefore we are going to have a problem."

After the Headquarters and the Astronaut Office talked about this and argued back and forth, [it was decided], okay, anybody who was 36 [years old] or had turned 36 and over couldn't

come. If you were 35 or under, you could. I had turned 36 about three months before the program. I went down there. I talked to everybody I could. I went to the Headquarters, talked to everybody I could. "Look, I can really help you. What's a few months to your rule? Can't you just move that?"

The answer I got was, "Well, wait a minute. Right behind you there's another one who's two more months and then another two or three months behind that." They finally said, "No, we are going to have to hold to the rule."

So I then said, "Okay. What do I do?"

Well, Bill [William A.] Anders had just finished backup for Apollo 11. Of course, the world stopped for Apollo 11. Bill had been invited to become the executive secretary of a small commission in the executive office of the President, and that office was head of the National Aeronautics and Space Commission, not NASA obviously. What that commission was supposed to do was to coordinate with all of the space needs or requirements or programs between the Department of Defense [DoD] and NOAA [National Oceanic and Atmospheric Administration]. NASA had started Landsat [satellite program]. There were many areas where space was beginning to be fully recognized and as something that really can change the way our nation operates economically on Earth, not just something in space.

So I went up there and was there for a year and a half, and then the Air Force reached out their long arm and pulled me back. I was given my own first really big program, a missile development program up at Wright-Patterson [Air Force Base, Ohio], and so I did that.

Later on, one of the great programs I had was the F-16 [Fighting Falcon aircraft], and I loved that program. It was a very complex effort where we were manufacturing in five nations around the world. We had this greater fighter and we were trying to keep it as low cost as

possible but still completely effective. The F-16 had a lot of challenges, but trying to apply what I'd learned in the Manned Orbiting Laboratory, I said, "We're going to find a way and we're going to keep going forward." I did get one budget increase when I first took over the program, and after that I never let it vary. And we kept the schedule. It was really a tight schedule and we had to get operational.

During that program, General Dynamics was the developer of the F-16, and they had a huge unprecedented problem, and that was they were going to have to manufacture this airplane, not just in the United States but in all five countries and, therefore, the manufacturing plan was a really big deal. I took over at the beginning of the development program, but they had flown the first very unsophisticated and completed but flyable prototype on the airplane. We had so much redundancy here and such an engineering problem to work in all these countries with different languages, different measurement systems.

We began to tackle that, and as I said to General Dynamics, "You have got to come up with a multinational manufacturing plan," and I gave them, I think, three months, something like that, to do it.

When they sent it in, it was trash. It was just unsophisticated, a real amateurish effort. I said, "This isn't going to work. We must get this going at the same speed as your development program." I said, "You have two more months, and if I don't get something really proper that shows that we can and will work with these international partners, I'm going to take really drastic action." And I didn't tell them what it was.

They sent it in again after two months. It wasn't hardly any better. They had a few names from companies they'd talked to overseas, but very little. One thing that a program manager can do is called a withholding, and what that is, is legally if the contractor had spent the

money, we had to make the payments to support that. However, all of the profit could be gone after and with the right activity you could—there was some legal precedent—you could take a little chunk of the expenses, not much, and that was not clear in the legal history. So I put at that point the biggest withholding in aerospace history on General Dynamics, and since I was the program manager, I said, "Okay, that's what I'm going to do." I didn't tell my boss. I didn't tell the four-star general in Washington who is in charge of all this. I just did it.

Immediately the chairman of General Dynamics—he didn't try to deal with me or even my boss at Wright-Pat—he just flew immediately to Washington, went to the four-star, and he said, "This man is out of control. He has no concept of how to work with contractors. It's un-American. It's immoral." [laughs] He just went up and down.

Well, fortunately, I had enough rapport and people had enough confidence in me, that they said, "We're sorry. That's the program manager and he's done this. Now go fix it and maybe General Abrahamson will restore your funding."

So I won. But the next time—and I was called up there quite soon—I went in. I was called before my four-star, and he just said, "You know, you see this on my desk? That's a telephone. You could have called me. You could have told me, you know." [laughs] So I got a real drubbing-down here for it. But I thought I was in charge of the program, I was going to do it in a way I saw fit.

The number-two man at General Dynamics was a man named Jim [James M.] Beggs, a terrific guy. I had always worked at the CEO level there, so I got to know Jim and liked him, but I didn't really work that much with him. Then I was running the F-16, did that, we made a great success out of the whole development program, and [President Ronald] Reagan ran for his

winning presidency. Remember that was the second time. He lost the first time. He appointed Jim Beggs the head of NASA, and I thought that was great.

I was busy in my Air Force assignments, and at that point I was in a staff job in Washington out at Andrews Air Force Base [Maryland]. The next thing I heard is that my boss there said, "NASA wants you to come over and run the Space Shuttle. Do you want to do that?"

I didn't have my own program anymore. I had a staff job, which is not fun. I said, "The Space Shuttle? Wow. I'm interested. I'd like to."

So I went over and saw Jim and Hans [Mark] and talked to them about it. I knew Hans because of some things out at the [NASA] Ames [Research Center, Moffett Field, California] where with the F-16 we did some special tests there, and I liked Hans. The Air Force said, "You are on active duty. You will be an Air Force officer subject to all those things. You can go to NASA. You don't have to wear your uniform at NASA because they don't necessarily want that, because you'll be essentially a NASA employee."

I said, "Thanks," and went and it was great.

ROSS-NAZZAL: What an exciting time. NASA had only flown one mission, and you were taking over right before the launch of STS-2, which also featured one of your former colleagues, Dick Truly.

ABRAHAMSON: Right.

ROSS-NAZZAL: Tell us about that historic flight. What sort of things were you grappling with when you came into the agency?

ABRAHAMSON: Well, the first one was I was an Air Force officer, and the attitude in general was welcoming, very friendly, but they figured I had a lot to learn about the NASA way of making a successful space program, and I did. I mean, I really did. One of the major teachers that I had was Chris [Christopher C.] Kraft, of course, and he would always make sure that I understood that while I may control his budget as Associate Administrator, he was in charge there. I didn't mind that, of course. We developed some really close activities with all of the Centers.

In those days, it wasn't just the Space Shuttle Program, but that was by far the biggest element of the responsibility of the Associate Administrator for Space Flight. We controlled the budget, which now is split in functional ways in such a way that the Center Director has less direct control than he did in the old days. Even in Headquarters the responsibilities are split up in all kinds of ways. That meant that we had a broad responsibility, and I did, for Johnson, for the Cape [Canaveral, NASA Kennedy Space Center, Florida], for [NASA] Marshall [Space Flight Center, Huntsville, Alabama], and for the test center out at Michoud [Assembly Facility, New Orleans, Louisiana]. I had those three Centers, and that took a lot of time, but the love and the key was the Shuttle, to make that work.

I was introduced—because it was only a matter of a few months—into the safety process and how that was this massive distributed operation that went down layers into corporate America, not just the head of the company or this or that, but having hundreds of people on the calls, listening to the safety reviews. That was probably the big impressive thing, and the list and the development of the things that were redundant and therefore had a completely different safety basis than the things that they couldn't be made redundant. If I remember right, that list of non-redundant and therefore had to work and work totally, absolutely correctly, was something

like 70 or 80 lists of things. For example, main Shuttle starting mechanism had to work, the SSME [Space Shuttle Main Engine], and many, many others as you went down through the whole effort. We would go through this thing, and it went through for days in these safety reviews well before the launch, and I'd come down and I'd listen and learn and ask questions. I had some experienced people on my staff to help me as well, of course, and we did it.

I think that on the first Shuttle launch there may have been one or two tiles that came off, but on the second one we had a bunch. I couldn't imagine that what we were then left with, instead of this high technology, wonderful machine and all these things, was we sent a guy down to the beach and he'd walk down on the beach and here would be a tile floating up. We'd go grab it and look at the number so we knew exactly what tile had come off. That was an interesting challenge and one of the huge first big issues.

Other things were working as well as can be expected, but the tile problem, it was the ones on the OMS [Orbital Maneuvering System] pod. Remember in the OMS pod how it comes out in the back end, and you have all those high-curvature areas. Obviously, as they go up through the heat effort, they expand and then when they come back, and if it's been out in the rain. We didn't know all of the mechanisms too much at that point. But suddenly one of those would pop off and fall in, and it occurred mostly when they make the roll in order to go out on the course.

Later on, we had wonderful letters from people all over. I remember a lady in Connecticut who would write on every launch, and not just on Shuttle, but on others as well. She said, "You are doing something. You are putting down rays, and I have terrible headaches from whatever you're doing, and you must stop it." [laughs] We had that kind of craziness, obviously. But in comparison, one of my favorites of all was a letter from this farmer out in

Iowa, and I wish I had kept that, but I didn't. He said, "I hear you have this problem with these tiles falling off. I really like to do puzzles, and these kinds of puzzles have all these interlocking parts." What is the name of that kind of puzzle?

ROSS-NAZZAL: A jigsaw puzzle?

ABRAHAMSON: Is it a jigsaw? Yes. Okay.

Anyhow, "I like to do those, and I do understand that you've got to go through all these changing temperatures and therefore it has to be a little loose in there. But if you had made these things like the jigsaw parts in a puzzle, they wouldn't fall off."

I wrote him back and said, "You know, that's a great idea, and had we done it that way, you're probably right. But, unfortunately, we've spent a bloody fortune, all the tiles are there, at least most of the time, and we couldn't go back, skin the Shuttle, stop the whole program, and redo it. But, thank you, because it's a great idea, and I wish we had been clever enough to think about it."

Later—and I've forgotten the exact timing of each of these things—later one day in Washington, my secretary came in and said, "I've got this guy, he says he's from Iowa, and he says that you've written to him, and he wanted to come and meet you." So he came in and we had our picture taken. He was really terrific. He was still wearing overalls and the whole thing. He was really great.

ROSS-NAZZAL: Had to look the part, I guess.

ABRAHAMSON: The real issue, of course, was it's not just these wonderful people stories, but the real issue was that the team kept working on that, and after a period had really come up with that it is a rain problem and we would get moisture either from rain or from just high humid days at the Cape. That [moisture] would get down and it would come down between the tiles and then work itself in under some areas of it, so that as you go up on the next mission, as it gets colder as you approach space, then the [water] would freeze, expand a little bit, and cause a little pressure in there. Then you'd get down and that would be fine, but after a couple two or three missions, a tile would pop off.

So we did a lot of things. We began to put the fillers in between the tiles, and we had developed a syringe injection mold where they'd listen to the tile, and they had ways, but a lot of human judgment, and they'd inject down through the tile, down into the spaces. What they had were ways to combat it.

Finally it stopped because we got enough of an understanding. But it wasn't one of these things that like a good engineer you can say, "Here's this number which is the bottom of the threshold, and here's this number which is the top, and anything that goes below the bottom fails or anything that goes into the top, and you replace it and you have to pull it." It was a lot of judgment of really terrific people.

High technology, my conclusion, is not just seeing these computers in action. It is not if you go into an automobile factory and you see all of these laser welding machines that are welding the bodies together and they go flashing around and do it all. It's not all that. But in every element of high technology there is human judgment and, more than judgment, the spirit of tackling the problem and finding a way to make it work and be resolved. Then, eventually, you can get beyond judgment into standards and reliability standards and all these things. I see high

technology more as people with the right background, with the caring intelligence to solve the problems than just computers and machines.

Since you raised the issue of STS-2, on those days, STS-2, -3, and -4—and, by the way, having four flights designated as R&D [Research and Development] flights, it was as arbitrary as calling what we see the Man in the Moon and the Japanese see the Rabbit in the Moon, but it is as arbitrary as seeing that. It had nothing to do with how we progressed and improved our capability and our effort. But it had been stated in the development program, it was a milestone that had meaning to the Congress and the funders and the administration, obviously, so therefore we had to pay attention to it, and we did, after the fourth flight, declare it operational. It wasn't like a great white light came on or a voice from heaven that came down and said, "Okay, we're past the R&D stage." Not at all.

ROSS-NAZZAL: What did you think when Reagan was out at Edwards [Air Force Base, California] and made that proclamation?

ABRAHAMSON: I made that call. I'll come back to STS-3. But there was a lot of White House involvement at staff levels in the program, and I'd gotten this call from one of his political operatives saying, "Reagan wants to announce his space policy. He sees just how popular a launch is and all that, so I want to come down. Set it up for a launch, and we'll let him make his speech there."

I said, "Well, that's great. It is a better event, but you have to know that all kinds of things, a little bad weather, that you can't even see. It may be a little higher jet stream in the sky up there that we can't go through, and we'll have to call it for weather, and he may be left

standing at the altar here, unable to have the launch occur. In contrast, when we come down, we have to come down, and we're coming down out at Edwards, where the weather is nearly always okay. So that's the planned time."

They listened to me. I was pleased. The political people listened, and they understood that we were trying to make sure that he had a reliable operation. I think the argument that really made it was I said, "What happens if it looks like it's kind of on the edge, and he comes down and we have the wonderful speech and we launch and we have a tragedy? And somebody will say it's because Reagan was there and the team launched under questionable [circumstances]." Now, I don't think the NASA team would do that, but it's possible to have something like that happen.

So they said, "You're right. We'll go out to Edwards."

ROSS-NAZZAL: Did you help them shift or write that space policy?

ABRAHAMSON: No. That was Beggs and Hans and a lot of other people helping there. I didn't get to help that, although I could have, I think, because I thought I understood enough about politics. And, of course, I didn't. [laughs]

At that time he pinned my third star on out there, so I have a wonderful picture of that, and that really was arranged that the President would do that by some of your really great staff people. It kind of caught me, at least, by surprise. My wife had enough warning that she went out and bought a wonderful red, white, and blue outfit and was pleased, obviously.

ROSS-NAZZAL: How nice.

ABRAHAMSON: But STS-3 was a little different, and it was quite different in a lot of ways. We had a schedule and it was a logical schedule. It had time in between, but we did not want to get behind the launch schedule. You could hear from my earlier story, I believed in maintaining schedules. Unfortunately, Edwards had had one of its rainy periods, and the dry lake was absolutely a lake, I mean a real lake. We talked about how long would it take for that to dry up and be good. I went back to the Astronaut Office and Chris, and said, "Are we ready to land on the runway?"

They said, "No, we're not ready yet. We want to take this little risk, chop it off at a time, so we're not ready to land on the runway."

I said, "Well, are we ready to land in the water, then?"

"No, we can't do that, obviously."

We didn't know even what the water had really done to the surface of the lake, although we had people out there examining it and doing all that.

Well, as our backup plans had developed on STS-1, and I looked at that and it wasn't a very good backup plan. So I said, "We need to practice and be ready for a backup operation, landing from orbit anywhere, someplace." I put together some teams to go out to Africa for our landing at launch, and I've forgotten, it's the French colony in Africa, mostly communist at that point. I sent some guys over there and looked at our radar operation for landing, and we had not done—I think people just inherently thought we're never going to have to do that, and so they didn't want to waste money or time on it.

Edwards wasn't getting better, so I went down to Chris and said, "What do you think if we do a rehearsal of a Shuttle recovery at not one of our regular sites?"

"What do you mean by that?"

"How about White Sands [New Mexico]?"

He thought about it. His first reaction for most of my suggestions was, "You're crazier than hell." [laughter] Chris is salty.

After a little while, however, he thought that was pretty good. And once I knew that Chris would buy into it, then I went in to Hans and to Jim Beggs and said, "We're thinking of doing an emergency practice and we will land at White Sands." I didn't plan it right either. The amount of money that cost to pick up all of our ground equipment from Edwards and put it on the train and get it out there, the big effort so we can get the Shuttle up and get the [Boeing] 747 [Shuttle Carrier Aircraft] under it, all of those things, that was a lot. It was a big, big planning effort.

I was very pleased to see we learned out of it, so we got what we wanted, but we also got a bonus that we didn't want. I was told all the time I was there they were still getting white sand out of the [Space Shuttle] *Columbia*. It was there. It was just permanently in the machine, and I hadn't thought of that and nobody else had, really. I was told later, long after I left, there's still white sand in that thing. So we did get a bonus out of it, not too bad of a bonus.

ROSS-NAZZAL: Yes. We've heard that even after the accident they were still finding that gypsum sand in the vehicle.

ABRAHAMSON: The other thing that happened is that on the day of recovery, there was a windstorm, and the weather people said that maybe this will go down. So we extended one rev [revolution], and we could do that at the point, if I remember exactly right. I know it wasn't

more than one. We were going to bring it in. I think we ended up delaying one day after that. I'm not too sure about exactly that part.

When we made that delay, there was still a lot of wind, and I was out at White Sands. I've forgotten who I had with me, one of the astronauts with me and weather people, and lots of teams were all ready to go. It was just a disaster down there. I would call back to Chris and I'd say, "We can't land in this. This is terrible."

And Chris would say, "Well, let's just wait. We don't have to make that decision now."

I said, "Chris, if you were here, you would know this."

He said, "I've got weathermen advising me. I know."

"This is crazy. Let's knock it off."

He finally did knock it off that day. Then the next day was a good day, and it was a great landing and everything worked.

We were out there, and there was a little teeny sort of low tower built on the area that was the landing strip there, and we were out there, and the gypsum was coming in through the cracks in the windows, and it was really bad. I was really frustrated because Chris would not listen to me on that. He was, obviously, but he knew how long he had to wait in case the weather might change, and so he thought about it. But I never let him forget that he wouldn't give up on that landing time and that he should have been there in order to see what it was really like.

ROSS-NAZZAL: Tell us how things changed once you moved from test flights to operations. Did things change a great deal? Did management shift around, things of that sort?

ABRAHAMSON: Not really. I think we just smoothly moved on. Some things really did change, and I was really proud of the team. We were going to make a lot of money for the government, not for the agency, because the law is such that if you sell a government service, the money does not come back to the agency. It goes to Congress, and it's sitting there in a pot that is undefined, so they can do all kinds of stuff with it, and it was out of reach of a lot of the normal checks and balances. So Congress loved that. They loved that we were bringing in about—as we looked at the early launches after our operational time for the communication satellites, we could see a billion dollars a year coming in, and that was just terrific.

And, Houston, boy, were they good. They put together special rooms where they could work with the sponsors of the satellites, where it would be comfortable for them. We could explain what we were doing, they could bring their staffs in, and all kinds of things. One thing Houston didn't like that I was able to drive through was we had the ability—and people would politically think about bringing in a non-astronaut to fly. Of course, [Senator Bill] Nelson was one of the first of those. But I wanted, as part of our sales campaign, that the people who were going to fly a satellite on the Shuttle could designate an astronaut. We would have to get them there and practice them and have them there, but they would have somebody intimately involved with the whole flight so they could have the assurance that we were going to take care of their payload and make it a success. I'll come back to that issue.

We set that up, and there were several people that got put into that program, and I think it remained an important part of our long-term Shuttle Program after. It was exercised in a different way because after we were no longer able to sell space on the Shuttle, then it wasn't as open as it had been, but, nonetheless, we did try to use that for sales. I was really reluctant, although I wasn't there, after the [Space Shuttle] *Challenger* [STS 51-L] went down, or even

before. Reagan had pulled me off about a year before for that. I tried to keep in touch a lot and see the good things and the bad things.

I would say that in that immediate thing after the fourth launch and after we declared ourselves operational, that we really began to go into the sales program, and the agency responded. They were good salesmen in their way before, clearly selling what they could do to go to the Moon. I think they got to be very professional at that, and I'll tell you a little story about where it didn't work, later.

ROSS-NAZZAL: Tell us about STS-7 and -8. Those were really notable flights because it was the first American woman to fly, and you had the first African American to fly in space. Was that a major issue or concern for you?

ABRAHAMSON: I'm trying to remember. The first flight of the *Challenger* was—

ROSS-NAZZAL: STS-6.

ABRAHAMSON: Six, that's right. I'd like to go to that one first. As an airplane builder, you're able to do things with airplanes in the test program that we just couldn't for the massive size and all the issues associated with the Shuttle. Therefore I was really worried about is the second Shuttle coming off the line going to be better than the first, and what are the real issues that we can test and can we expand that so we can get better acceptance criteria for the manufacturing process? So I spent a lot of time down in all those places and going through all of them with our

contractors and looking at our Manned Space Flight Safety and Awareness programs, all of those. I thought those were really important.

Of course, the SSME was the most suspect of all of the technologies that people thought that's where a failure could occur, because that had been pulled so far to get that much thrust out of this low weight associated with those engines. I became quite familiar with those and worked on them and talked to the people, in all of our operations everywhere, spent a lot of time doing that. I was never satisfied that we really had the acceptance criteria that gave us great assurance, and maybe it was impossible, but I wanted it to be better.

People in Huntsville came and said, "We don't want to do the test where you just turn on the SSME just for a few seconds and the whole stack goes 'bang' like this and then comes back after that. We think that's kind of risky, and we don't want to do that."

I thought about that and said, "I don't think we have enough good tests on the whole thing anyhow, and that's the first time we're going to see those SSMEs light up on this new vehicle. I think it's an important test, so I want to do it."

They argued with me. The Center Director [William R. Lucas] there, nice guy, later he got involved in something that he was criticized for. We'll have to come back to that. But anyhow, we spent a lot of time arguing about it, and finally he decided and I was able to prevail and we were going to do the test.

Of course, that was months before the launch, so we brought it up and put it on the launch stand early, and they were proceeding with the tests. It just happened that I had been called out to attend a leadership conference of all the Air Force generals and they asked me to tell them about the Space Shuttle and what lessons the Air Force could learn out of that. So I was down in

Florida on that when they were doing the tests, and I didn't feel good about that, but telling the Air Force the story about the Shuttle was worth it, I guess, and I thought it would go fine.

The preparations had been done right, so they did the tests, and I got this call that said, "Our procedure in the test is we will have sniffers out up in the OMS pods, and we will look to see if there's any potential of hydrogen that's leaking. We got a sniff of hydrogen. We think there could be a leak." And panic.

The Air Force base is Homestead, which was wiped out later in the hurricane, so that it was all gone later, but at that time that's where we always had these Air Force confabs that we got together. I was there, jumped in my rental car and drove back overnight, got in the next morning and quickly reviewed all the things that were going on. I went up on the stand and crawled around in that OMS pod. That's a long way down. These guys are all working. They had a rope underneath that was a net, and I think it was safe, but I wanted to see that. I wanted to talk to the guys.

The guys were saying, "Look, we have been working on this and working on it. We got this one little sniff of it, and now we can't get anything."

I said, "How are you doing the tests?" They're doing it around all the welds on the SSME and the connections to the tankage as the lines are coming in. I said, "Well, we've got to keep doing it and see if we can find this, and we've just got to put this to bed."

It was really good people working on it. While they were doing that and the Huntsville people, along with the Cape [Canaveral] people, were reviewing all of the aspects, going back and looking at the tests that were able to be done and all of the quality-control things everywhere, just absolutely looking. I wanted to review where we are, and they all came up to the Headquarters. Hans, by the way, always wanted to be in every technical thing. His mind

was such that he was a treasure. Now, he would say a few things that people wouldn't always particularly like what he was saying, but he said it for a purpose, and it was right to get people's attention. So he was there.

The conclusion that the Huntsville people had come to was that when you start and you remember when you look down and you see the sparks fly first, and then they turn on the engine and there is a short—I mean, it's really small—but a light-up period that's really a critical function, and then we turn it off just right away, because otherwise the thing won't stand up. They said, "We think what it could have been is that there was unburned hydrogen that had occurred in that whole process, and, of course, that had just worked its way up into the OMS pod."

So we argued about that, and I said, "Well, that's an interesting kind of option, but if that were the case, wouldn't it have been more persistent, not just a little thing?"

Then the argument shifted. It's like that wonderful old poem, the mills of God grind very, very slowly, but they grind, and I've forgotten the last thing, but down to tiny grindings. And we were doing that, which I thought was one of the great strengths of NASA. Engineers, bosses, here they are, talking to each other, arguing. When I use the word "argue," it was with respect amongst technical people, and it was that dialogue, which is probably the much better word to use for that, because they just were really good.

But I was unconvinced, and I said, "Look, if it looks like a leak, if it acts like a leak, if it smells like a leak, it's probably a leak, and we better know." So I said, "Let's do it again."

Everybody just panicked on that, but we did it. I think that's right. They got it again, and it kept—I think we did it twice. But either way, what they finally did is the guys who were up there started looking in other areas, not just the welds, alongside of the pipe, which wasn't a

logical thing to do. Once we had gone far enough that we had gotten all ready to do the second test and all the lines were pressurized, but that's why I think we did the second test and got it. But we might have found it beforehand, because when you're looking for something like that, now you really do a lot of preliminary work beforehand in order to ensure that it's correct.

We found it again, and they found it in one of these long areas, and it was a little pinhole. Now, the reason that's such an absolutely critical thing is that there were, if I remember, something like 36 or 42 major welds on the titanium parts that are all part of the SSME. And because hydrogen will penetrate and cause corrosion in titanium, then you had to protect the titanium from the hydrogen, so we had copper lining inside all of the hydrogen pathways.

What we finally figured out was that the welding process had not been controlled quite well enough, so that somebody had overheated an area in the weld and that had caused heat to flow in a couple of places. It came together in a way that it got a flow of copper, which exposed the titanium, which then when you get hydrogen under pressure, began to dig into this thing and cause it to happen.

Well, as a result of finding that—and I was really proud of the team that did that—we went back and we redid the whole assembly process on the SSME, and we cut the number of welds by, I think, 50 percent or more and redid the welding procedures, different temperatures, lower for longer periods, all kinds of things. I believe that that was one of the key redesigns that in the long run meant that the SSME was, in fact, as safe and as effective as it was. The SSME, of course, was one of the first great challenges, and that meant that we were very early in the process, when technology was not as mature working with titanium like that, that the first design may not have been as good as the second.

So that was a really important thing. So that's STS-6. I thought that was perhaps one of the true credits for teams of people working together at NASA, because they just went out and redid it with the contractor. The contractor didn't argue about costs, so we all, I think, did it in a way that really changed the whole future and safety of the machine.

Now [STS]-7 because of the woman [Sally K. Ride]. She's a wonderful lady, a lot of spirit, quite an advocate of women's rights and equal treatment and all of those things. I had a problem, and I participated in all of the briefings before every launch and participated in all over the whole launch thing. I took it quite seriously, even though they may have by that time be different, but in every launch it goes down the line, and it goes from the technical people at each area, and they build up and say, "Go, go, go."

Finally, it gets all the way up to the Associate Administrator, so I would get to be the last one to say, and I took that very, very seriously. Hans ensured that I took it very seriously, because he was always good at all of that. That meant that I would go out to the morning breakfasts and the launch crew and everything as well, but then would go out for the last press conference before the takeoff. I always talked about our lady astronauts that I was very proud of and they were very professional, just like the men.

She came up to me at the breakfast of the launch, and said, "Abe, you know, it's clear you're from another era. You don't call the men 'gentlemen astronauts,' do you? Why are you calling us lady astronauts?"

What the hell am I doing wrong? I didn't think of that. [laughs]

"We are women astronauts, just like the men are men astronauts," and looked me in the eye, and I'm sitting here. So she had clearly heard that last press conference and didn't approve. See, I got a lot of education in lots of areas. But Sally Ride is, and she continues to be, in her

career since out in California out at the laboratory out there and now in lots of educational areas, she's a great lady astronaut. [laughs] But she was going to make sure I had that right.

ROSS-NAZZAL: I thought [STS]-8 was also important, especially given your military background, because it was a night launch, a night landing, as well as the first African American in space.

ABRAHAMSON: Right. The Manned Maneuvering Unit [MMU], I loved that thing. Bruce [McCandless] would always—I'd have him give me special briefings on where it was and how well he liked it, he and Rob [Robert L. Stewart], who was the first of the Army astronauts who were all part of that. I would go out to Lockheed out in Colorado and fly the MMU simulator that they had out there, and loved that thing.

My arguments that I had as being in charge, I can't just—we had great people we could trust all the way down, but, nonetheless, I could do a better job if I understood it. So that allowed me to do a lot of fun things. And I think that people appreciated that I was paying attention to it. For example, one of them at the Cape, I thought about our teams that would go out and recover spent solid rocket motors, and so I arranged at one of our meetings to go out after the meeting, and they were having a training exercise out there. They have a great big solid rocket empty booster to train their crews in the ships. My rationale is that here's something that nobody ever pays attention to, but could be dangerous and could be an area that ought to be paid attention to.

I like to dive, so that was my chance to go diving with the guys. I took a helicopter out and they lowered me to the deck. I wasn't thinking at all about it. I should have known more

about it, but I didn't. They really gave me a terrific breakfast. Bad mistake. [laughs] Then I went out diving.

The first exercise is to disconnect the parachutes and get them, beginning to roll them in and drying them out and then take them back so they can be washed. Well, they made it absolutely clear that the—it's a kind of a valve a little bigger than that, but this is a piece that is one that opens and they can hook up the main—the main hookups are this metal piece, and you can drop it and lose it. They made it clear, "That costs 40 bucks for each one of these things, and if you lose it, like any of us, you owe us 40 bucks, and here's the jar that it goes in." So I took that very seriously.

By the way, the solid rocket booster, when it takes a normal landing, about 20 percent of it is up above the water, and all the rest is down, and, of course, the rocket nozzle and everything is down in the bottom end that's down there because otherwise the bubble of air wouldn't hold it up. So it crashes in. It goes through everything. First you get that off. I think that was when the breakfast got to me, because you wrap yourself around some of the straps in there, and you're starting to try and get this thing off, and you're going up and down and up and down. I had never been ill in the water like that, and I became very ill.

The choice was, first of all, do I give up and let all these guys see, who were kind of hovering and watching am I going to drop this thing or not. I finally said, "I've got a problem." I just picked up the mask, and so it's not too bad. Lots of little fish came up. Everything has unintended kinds of consequences.

But then the fun part is you swim down, and it's about seven stories or so down. It's about 60 to 70 feet, depending on how high it's floating, and it's thrusting down there. Now, this is several tons of steel that's going up and down. The first part of the problem is you're trying to

get it plugged on the bottom and most of the water pumped out so it will go up and then fall over in what they call a log mode. Then they can tow it in, in the shallow water, tow it in and recover it.

The first part of that bottom operation is really neat. You're watching this big thing going up and down, and you're waiting. Then at exactly the right time when it's at the bottom of the swing, you swim in to the rocket nozzle, and you don't expect it. On the outside, you're watching the thrust, and you know that it's going up and down in the water, but in there you've got a zone of pressure equilibrium, so you're going up and down, but you don't really know it very much. You feel the accelerations and the changes, but you're in there like that.

Then the second guy comes up, and you help the first guy guide the plug into the right position and get out of the way yourself. You're guiding it in there and then getting out, and then he comes in and makes a final adjustment. Then they blow it up, and it seals it, and then there's a place the water gets pumped out and air gets pumped in. You hook up all those lines.

So it's a fairly deep dive, but it was really, really fun. I decided these guys have got a great deal. They have several ships. All they get to do is go out and play with their ships and their toys, and they were doing it well and I was proud of them. I have a flag, a three-star flag, that they gave me for my house in Florida, to fly under the American flag. So that was fun.

ROSS-NAZZAL: It's good to be Assistant Associate Administrator, right?

Abraham: Oh, isn't it?

ROSS-NAZZAL: Did you fly some of the planes too?

Abraham: Oh, it's great, and I would always fly the T-38s and going back and forth as well, so that would keep my flying up that way.

ROSS-NAZZAL: Did you get to fly the STA [Shuttle Training Aircraft]?

Abraham: I did fly in it, but they wouldn't let me fly it on one of the tight missions, and I'm the one that said, "Look. In the fighter pilots, we have modern head-up displays, and you should have that." It was years after I left that they finally got around to budgeting and putting in the head-up display.

Later, when I had retired from the Air Force and went out to Hughes Aircraft Company, I had not wanted to be involved in trying to influence the Pentagon, so I had made it a condition of going there that the reason I was going there was because Hughes was working for really their principal owner, which was General Motors. I put together the sector, which was our automotive and transportation sector at Hughes.

That was great timing, got this huge piece of this whole thing, but we put the first of the head-up displays in a car. Later on, in one of my Pontiacs I had a head-up display. It was too expensive, so it took a long time to get it ready and then get the production line and get the costs down, because, boy, they really run the car business around costs, you know, terrific. Anyhow, that was an important thing, and they didn't get it in the simulator aircraft until long after I'd gone.

ROSS-NAZZAL: Do you want to talk about the repair of Solar Max [satellite]?

ABRAHAMSON: That was my last flight. I was very happy with the job at NASA. The only thing I was unhappy about is I couldn't fly in the machine. I was thinking about ways to try to get that approved time and time again, and Beggs would say, "No. It would be bad publicity. You're supposed to be the manager of this thing and responsible for safety and effectiveness, and not flying." I hated him for that, and, I mean, I love Jim Beggs, terrific guy.

The way I got selected for Reagan's job here to run the Strategic Defense Initiative [SDI]. I, of course, was still very conscious of what was going on in the Department of Defense, following all that very carefully, and Reagan was going to make one of his really important speeches about defense on the 23rd of March, 1983. I didn't know all the background to this at that point, but he had decided that was going to be his speech which introduced the beginning of a research program to build a defense against ballistic missiles and change this whole mutual assured destruction thing and try to get that changed.

So I went home that night and got a glass of wine. My wife sat down with me, and we were going to watch the President's speech. It was a common speech, in fact, not one of Reagan's best, I thought, up at that point. But at the end, all of sudden, he says, "And now I want to talk about something that is really critical to the future of mankind," or something. That part of the phrases, I don't remember. He then announced that he was going to start this research program, and I thought it was pure poetry that he used, "The scientists who gave us ballistic missiles should now work on a defense against ballistic missiles." It was tied together policy-wise with reductions, negotiated reductions, everything, but done in an exquisite way.

Of course, the thought I had immediately, the Shuttle is the perfect vehicle to help in certain of these experiments, because part of strategic defense would certainly involve space

activities, I mean a very critical part. I was just thrilled and said, here this actor President that I wasn't so sure about in the old days, but by then I was clearly in his corner, has challenged this thing that I thought could really be the end of mankind, so that's great."

I had no idea that I would—because I was very happy in my job there, I didn't want to change anything. Unbeknownst, Jim Beggs, when he was asked to go to NASA, had been thinking about the Shuttle and needed clearly somebody to come in as Associate Administrator and had asked me to come, and I went. I was just completely involved in that and didn't know much about the pace or what was happening in SDI. I was really getting frustrated because nothing was happening. We weren't getting anywhere.

Well, the reason we weren't is because Reagan had overturned the whole strategic structure. He had done what I did with this boss, never told any of his people at the Department of Defense. He had just reached out and announced this thing, and everybody in the Pentagon was saying, "Oh, my god, now what do we do?"

Well, when you don't know what to do, you put a study together. So for nine months they had two really important studies. One was a technical study. What are the technologies that will be an option for this and that should be worked on, and where are they and how can we get it together, and what should an architecture of a defense look like? Of course, that was led by the ex-NASA Administrator who died about five years ago, wonderful guy, [James C.] Fletcher. That was called the Fletcher Study, and then they had a policy one as well.

Well, they started searching, and I didn't know anything about this. I was just frustrated that we weren't getting tasked, and I'd go over and talk to people and say, "While we're studying it—." [laughs]

They wanted a civilian director of this thing, and they couldn't get the ones they wanted. There were two people that were really good candidates, quite old, both of them, both retired, and they just didn't want to walk into what they knew was going to be a maelstrom of arguments and opposition, so they didn't want to do it. I didn't know that and it didn't worry me, except that I wanted us to get busy on it.

Then I got a call that said it was from the military attaché to "Cap" [Caspar W.] Weinberger, who was Secretary of Defense at that point, and said, "The Secretary would like to talk to you, so can you get over here right away?"

"Yes, sir," you know, running over.

They had said, "You've been recommended to be the first Director of SDI. How would you like that job?"

In about 10 seconds, I said, "I love my job at NASA. I'm doing something really important. I know the Shuttle can help SDI. But you're telling me I can have a chance to change the effectiveness of ballistic missiles and have a real impact on whether or not mankind survives, I'll do it. I'll be happy to." Then they wanted me to go right away. I said, "Wait a minute. Look. We're about ready to launch our last flight, the Solar Max flight, and if I get pulled off, that flight will go, it'll go on just as well as it could have or should have, but if there is an accident, somebody will say it's because you pulled me off on this last flight, because people are very used to me being in all aspects of each of the flights. If you can wait," and I think it was a month or something like that, "for a month, I'll start whatever I can do, but let me get this flight off and get it back safely, and then we'll do it."

And Cap Weinberger said, "That makes sense. I want you to be conscious of where the President can be criticized for this. We'll do it."

So we did that, and it was wonderful flight. The Solar Max, we thought we knew how it was made and we thought we had all the diagrams on it. We thought it was a fairly straightforward one, and they had simulated it. Bob Crippen was running the mission, and everything seemed very straightforward. Then we got up there and we were in position, and I forgot who was—it wasn't Bob who was running the Canadarm [Remote Manipulator System, RMS].

ROSS-NAZZAL: I think it was Terry [J.] Hart.

ABRAHAMSON: That's right, Terry Hart. And Ox [James D. A.] van Hoften was the other one who was part of the repair guys.

We couldn't grab it. We'd get over there. It was really a bolt that was supposed to be sticking out in a particular way, and the Canadarm, which works with a little loop of wire, and you just pull on it, and, of course, the loop closes down, was perfect for that. That adaptation was perfect for this. They just couldn't get it.

Finally Crippen said, "You know, we can't just keep trying this forever. We're going to run out of maneuvering unit fuel and other issues." It finally got down to Crippen said, "I know you're recommending that we should stop now." From the ground, that was coming from Houston. "But I want one more try with these guys," and they got it on that last try. It was incredible. Then, of course, they pulled it in. The rest of the mission was wonderful, and the first repair of a satellite in space was terrific.

That was my last flight, and I flew to Washington and had to be introduced but sit in a big hearing before the Senate in three days. I knew nothing about anything that was going on. It was fun, but I'll tell you that.

That reminds me of something I did skip that I thought was important. Remember I said we were doing sales and we had a really important operation, and Johnson really ran it, and every customer during a mission who was there, they were treated like royalty and they had escorts with them. Astronauts would come in and explain what's going on and all of those things.

We had two communication satellites that were both Hughes communication satellites and a Hughes satellite. We had a McDonnell Douglas [Corporation] commercial development that we were carrying and using in the Shuttle, and that was the launcher which had a big spring. This wasn't too sophisticated, but it did the job, and it would spring the satellite out, give it the proper spin, and send it out. If I remember right, about 25 kilometers out, then the Shuttle would turn over, and that was a mistake, by the way, because we didn't know what happened. But it would turn over. They couldn't see. It was time then for the solid rocket motor, which would boost the communication satellite up to geosynchronous orbit, would light off, and off it would go. Well, they turned over, it lit, and we couldn't find it. Afterwards, they turned and looked, "We don't see it. Where is it?"

I called our Air Defense people and said, "We've got to find this thing. What's happened?" I couldn't believe—here's our missile defense problem. The whole sets of radars that we had in our air defense and missile defense operation was set up in such a way so that we were aiming at the things that would be launched from Russia and we'd get to track it.

By the way, I do remember going out to one of those exercises, and it's just awful. It is incredibly depressing, because they run the exercise, and, of course, they're really checking all the communication loops with the White House and how fast they get the President in the loop and the reliability of the two-man concept for every launch. Two launch operators have to turn the keys at a certain [time]. That's in all the movies and in all that sort of thing, and that's critical.

So it's a great exercise and a critical one. I was there, along with several other officers who hadn't been—this was a long time earlier—watching one of these exercises. So what do they do? They're reporting. We're seeing missiles rising from so-and-so. Here are our operations, the signal goes up to the Secretary of Defense, and they're going through the whole thing. In about seven minutes, I think it was, into the whole exercise, it all stopped. It's a 30-minute flight for a ballistic missile to go from their missile fields and reach the United States. Seven minutes into the flight, we had done everything that we knew how to do. Everybody sits down, there's a little reporting going on, but nothing else, and you're watching. And I'm sitting there saying, "Here we are, waiting for the country to die." That was all part of my pre-SDI education that made me feel so important about that that was a job worth doing. Not me feel important, but that it was a job that was really important for all of us.

I think it took our Air Defense people something like nearly 10 hours to find that satellite, because they didn't have radars in the right position, and our orbit and the debris, wherever it was, would only go by there in range of the radars every so often. We had no idea what was happening. Obviously, the theory was that something had happened and solid rocket motor, which was the transfer motor, had blown up. In fact, that had happened.

What happened is that the nozzle on the motor, it had blown in such a way that the nozzle disintegrated. A few big pieces and quite a few little pieces were out floating in orbit, and because that had happened, the satellite had gone in an unpredictable area and had to be located and found. So we finally found it.

The one that blew up was for Western Union, I think, was launching the first of the two satellites. The second one was for Indonesia, and it was the Palapa satellite. Well, immediately we shifted into gear on, well, what can we do? The first thing, we need to go and find out why that motor went wrong, and there wasn't hardly any information from the satellite that was coming down. We just put teams out, going through all the reliability data at McDonnell Douglas, who made the motor and pulled it together, and were trying to find is there anything at all in their acceptance tests where there's some things that told us that wasn't right.

Then the next thing is, okay, they build these motors in lots, maybe six or eight in a lot. If there was a problem with this lot, is the next motor in a different lot? It wasn't. It was in the next motor going through the lineup in this lot. So, if there was a problem in the procedures, there is somewhat of a reasonable [chance] that that could happen again. We realigned the time plan for the mission. We moved the launch back as far as we could. We extended, I think, the mission about a day or something. We couldn't go forever on it, of course.

We started talking to the Indonesians who were there, and I personally went and said, "You know, this is what the Shuttle is good for. We can bring your satellite down. We can find out what the problem is, and we promise you we will get it rescheduled just as early as possible and get it up again."

He had some consultants, one from TRW [Inc.] and one from McDonnell Douglas. He went in to his consultants, and they talked about it. They came back and said, "We thank you

very much. We really appreciate this. I know you won't charge us to do all this. That's great. But we think that this is a fluke and it can't happen again. My advisors tell me it's a one-in-a-million kind of a problem, and therefore it's probably safe to launch it."

So I'm on the phone with Jim Beggs, back and forth, and this is all taking place, of course, at Johnson during the extended mission. Jim, he's a lawyer and a good lawyer, and he said, "Abe, you can promise to help these guys any way you want, but it is *their* decision, not yours." I think he was thinking back to what I did to him on the F-16. He said, "Just remember that. Be persuasive. Tell them when we get it back, I authorize you. We'll get it up again. But it is their decision."

Okay, now I've got backing, and I walk down and talk to this guy again and trying to persuade him. "No, we think that it can't happen again, and it's the prudent thing to do is go ahead." He spoke reasonable English, but he was Indonesian.

I had had an occasion a long time ago to work with a particular part of the State Department, which has wonderful people who think about languages, but not just is it a different language, but how do people think differently and how are they raised differently? These people would support negotiations; really great people. So I found that office and called in to them. I explained the whole problem, and I said, "Is there something about the Indonesians that I ought to understand as I'm trying to talk to these people?"

He said, "Well, they think in terms of their bosses and all that, but if he's authorized to make these decisions, we can't think about it."

I kept pressuring him and kept pressuring him, and I'd bring in information. "You know, we've gone through all these tests. Here they are," and I'd talk to his consultants. And they wouldn't budge. "We are going to launch. It won't happen again." I thought, man, what a

demonstration of the Shuttle, if we bring it back and then take it back up again, it's great. We're going to be terrific for sales, and we'll have protected these people's property.

Kept saying no, and so finally we came up at the end, and I gave them one last try and just nearly threw myself on the floor in front of him, "Don't do it! Don't do it!"

They said, "We're going to do it."

This time the procedure was turn the Shuttle over so that you have the most heat resistance that way, but use the camera on the Canadarm, stick it out here so we can watch it. Watched—boom!—did it again. Same thing. This guy, I didn't go say, "I told you so," because, of course. I tried to console him. It was just terrible.

I introduced then can we go get those things, and flew the Air Force Reserve General in who was the Shuttle commander on the second flight, Joe [H.] Engle. He came with me and went out to Hughes, where they were building the satellites, and McDonnell Douglas and said, "We can go get those carcasses." They hadn't gone that far away from our orbit. It takes a terrible amount of energy to make an orbital plane change, just terrific amount of energy, so he thought we could do that.

Now, they didn't do that while I was still there, but I kept in touch with that. When they finally got around, and Joe was going to lead the mission to go do that, they did. Joe called me, and Joe was a particularly really good friend. Well, I loved every one of those guys and remained envious, of course. I still cry at night that I never got to go because of the whole thing.

So that was an example of how the team was able to work in a commercial environment, and even though it was a failure and the customer didn't make the right decision, I later found out that I did know that this guy's boss was there. He was there up until the launch. He saw the

launch, and then he had to go somewhere else and work. He had given the authority to his program manager, and it should have been reasonable.

However, he, the program manager, if you think in terms of what I heard about the culture here in all of this, he had committed that we were going to go, and he was going to make it, and he would not undo that commitment so long as he had any advice supporting him. The real problem was those consultants that wouldn't say, "There is a possibility even." I'm not saying twist your story, but you should be complete.

Of course, all of that commercial operation went out the window when the *Challenger* really did go down, which happened about a year after I had left. My wife had died in an airplane crash, my first wife, and so then when the *Challenger* happened, it was like these whole things can happen and they're terrible.

I thought that the decision that was finally made, while logical, that they would stretch out things, operate at lower budgets—and Truly did a great job leading that investigation and what to do with it, so it wasn't really Dick, but, in a sense, it had a lasting effect, in a very important sense, on the view of the robustness and the resiliency of the Shuttle.

There was one other thing that I really had done, and I really thought I did this very elegantly. There was a mood, and there are two activities that are related. Everybody wanted a fifth Shuttle, and this was while I was still there. There was no hint that we were going to have a blowup or anything like the *Challenger*. So I took that on, and we tried to persuade Congress, and we worked with our contractors and got as reasonable an estimate as possible, because you're tacking onto the end of a learning curve.

But we could not get it by the Congress, and, frankly, there were some people in OMB [Office of Management and Budget] that have never been, in my opinion, helpful supporters.

Two guys, maybe you've heard about them before and know who they are. I hadn't worked with those people, I didn't know about any of this, but, anyhow, we could not get it through.

I put together a program, and I was really proud of this, and I called it the—I want to make sure I get it right. I called it the Space Shuttle Major Replacement Part Program or something like that. I'm fuzzy in the language of logistics. To my friends, I said, "We're going to make wings and tails, and we're going to move this forward, and if you put all those parts in the right position, it will be just like a Space Shuttle ready to be put together with all the parts flying in formation beforehand." That, of course, is what became our fifth orbiter after we lost the *Challenger*. So I was really pleased that we had done that.

My argument in Congress was that the program is getting really good. It truly is a safe operation, and so long as we are operating with the same care and concern, we can't look ahead that there's going to be that kind of a failure. But, I'm a pilot, and I know that you come in a bad side wind or crosswind, or you ding a wingtip or you do this, and things can happen. This is the toughest operating environment of any vehicle in the world, so we ought to have these major spares available to us to replace a wing if we ding a wingtip, or if it gets pushed into a hangar and it takes the top of the tail off, so we ought to have that. People bought that, so that gave us a huge financial and schedule option when Dick Truly wanted to build another, because they just used the spares. I was really pleased with that.

ROSS-NAZZAL: Tell us if you would, you've talked about the problems with the PAMS [Payload Assist Modules]. There was also a problem with the TDRSS [Tracking and Data Relay Satellite System] IUS [Inertial Upper Stage] that caused some problems for DoD flights down the line. Would you talk about that?

ABRAHAMSON: I don't think I know enough about that. That had not come up on our first DoD flight that we were all working on. I knew that there was problems with TDRSS and it was an incredibly expensive program, but I can't comment on what happened later on and how they saw it and how they solved it or not.

ROSS-NAZZAL: You did share with us an example of some of your experiences in the MOCR [Mission Operations Control Room]. Would you talk some more about some of the other events that you recall being at JSC when missions were up?

ABRAHAMSON: Oh, yes. Well, unbeknownst to everybody in JSC and down at the Cape, I had a little side program. I invited, not the bosses, but the analysts who were in NSA [National Security Agency]—listen into the phone calls—and our CIA [Central Intelligence Agency] people, analyst-level people, and I would bring them down for every launch. There would be these people in, not black suits like the funny movies, but they would be there. Nobody would know who they were and why, but they were all allowed to sit in and listen and watch operations quite early in the whole process and then go through.

My reasoning was, and I told the NSA director and the CIA people, that what they needed is they needed to learn the language that we're all using, and they needed to see what happens, what happens under certain of these things, because we knew the Russians had a Space Shuttle program, and there may be other things that they were trying to do. So, it would be good to use this as a little training ground. We had these people there all the time, and nobody knew who they were. [laughs] Maybe some people guessed. Chris knew.

ROSS-NAZZAL: How funny. I'd not heard that before.

One thing I wanted to ask about, of course, when we talk with the crews and the flight directors and things, they were moving around so often in the early days of the Shuttle, would have a Shuttle assigned and that Shuttle would slip. You would have a crew assigned, and they would be moved to another mission. Then payloads would change, the specialists would change.

ABRAHAMSON: Terrible problem.

ROSS-NAZZAL: What impact did that have on the program, from your perspective?

ABRAHAMSON: Well, it was a lot of dynamics that you had to try to keep there, but there were some things. Remember I said Joe Engle was a really good friend. On Joe's flight, STS-2, he had had a partial blackout during the reentry, critical reentry phase, and the way he described it to me, after, of course, as we were talking about it, he said, "It's just like the classical over-G or something, just kind of everything went in, and I could just see this little teeny—like looking through a telescope."

Then later, it had corrected itself before his landing, but it took a long time to move that out. I really had the doctors, who I used to kid a lot down there, working on that. They finally concluded that Joe had not drank enough water and had gotten dried out, and therefore his ability to deal with some of the reentry forces was diminished. So I got then very worried about what were the habits of the crew, and I got in really bad trouble with John [W.] Young, because I'd talked to all these guys after seeing this with Joe and others. I'd just casually talk about these

things. Several of the crew complained on how hard it is to sleep up there, and some of them used the wonderful little rigs, a sleeping-bag-like rig that would tie themselves in. And I got the impression that they were better.

But John always slept in the command pilot's seat. He would not leave that and go down for the [sleep period]. So I started a personal campaign with John, and I'd say, "John, are you sure you're getting enough sleep when you're doing that? What's it like? Is it like sitting in a car and trying to take a nap while you're all hunched over on that?"

He said, "No, it's not bad in zero gravity. It's pretty easy and feels okay."

Finally I really pressured him and said, "John, it may be important for you to set the example for all the other crews, and if you, as the grand old man with all this flight time, slept where you're supposed to sleep, you would be setting an example for everybody."

"Abe, I'm going to do it my way," in his little accent. [laughs]

Let's see. Are there any more of those kinds of things? Maybe something will occur to me again later. Every one of them are just unique, and especially because I got to know them all really well back when the corps was smaller, and I knew the MOL guys who were there, of course. Yes, it was really terrific.

Talked about Marsha [S. Ivins]. She was always, I thought, a very interesting and very capable person. And Mike [Michael D.] Griffin used her in really important ways, I think, in the administration of NASA when he was there. At that point, I was on the NASA Advisory Council [NAC]. Every so often Mike would comment on Marsha had done this or something. I was always pleased to see that. Later, there got to be so many that there are lots of them that I didn't know, of course.

ROSS-NAZZAL: Yes, they selected quite a few there for a while.

ABRAHAMSON: Right. Yes.

ROSS-NAZZAL: Do you want to talk about following the orbiters that were out in California that were being assembled, *Discovery*, *Atlantis*, and what lessons you learned? Like you obviously said to the farmer, you couldn't put the TPS [Thermal Protection System] in a jigsaw puzzle, but did you consider that?

ABRAHAMSON: I personally thought that the most important thing was the SSME engine. It really was critical, and I never let go of this dog bone that I had about being able to have the new vehicles as they came on board adequately and properly tested, and what new ideas did people have to do that.

The space toilets became, first of all, a genuine problem. It was real. Both the men and the women complained about it, and should, and I really went after the crew at Johnson. They had assigned that—come on, what was his name? Just great guy, loved him. But he could not solve that, and I couldn't conceive that here we've got the toilet and they can't solve that problem, so it became a joke. It got to be such a joke that it got out into the press, and the press would talk about it and ask questions too. Then the best way to deal about it was just to maintain the joke, keep it in a joke status. But it wasn't. It was real and it had to be dealt with.

Oh, the tanks. When I was at Michoud and looking at that development, I thought that the welding problem, aluminum welding on these huge big spheres, were really a big issue. It turns out that if you've ever seen pictures of these huge ships that are for liquid nitrogen carriers,

they have also these great big spheres that are all part of that, and they have similar welding problems. So I just went after how do we take the human variability out of this. We've got really good people doing it, and you're testing it, trying to get at that, but what can we do to get the variability out of it?

They put together several small programs to improve welding, particularly aluminum welding. It wasn't for years afterwards that I finally heard that we now have this friction welding capability, which essentially creates enough friction that in the aluminum itself, it creates a little pool, and it is absolutely controllable. I was so pleased to see that that kind of thing had developed.

The other one I was always worried about was escape if we had to bail out. I went to Ames and said, "I want you guys to do a better simulation of all of the phases, and particularly on launch, obviously, of speed, and in the lower speed ranges when people would have a chance to get out. What happens here?" I was worried about striking the vertical tail or the wing or some part of the wing or something of that size.

So they went to work on that, and one of the last things I did before I left was to call the guys at Ames and said, "What's the result of your simulation?" And the result at that point was that a big guy like Ox van Hoften, he would be big enough that even though he had more drag than a small woman, for example, but that he'd be safe all right, but a small woman would probably hit the wing. Not the full range, but part of the range. So I said, "What are you going to do about it?"

Later on while I was at SDI, one of the Ames guys came to me and gave me the briefing that showed that they'd figured out this pole. You'd just hook around the pole and jump on out

there, and it keeps you from going. I mean, really simple, elegant solution, so I was pleased with that.

There were these kinds of problems that just required—in an automobile line, you cannot imagine the amount of ongoing engineering that goes into an automobile and how and why that can just keep improving, lowering costs, obviously. I'll give you an example. It sounds simple, but it's one that shows it. When I had the transportation sector at Hughes, of course, long after I'd retired, I spent a lot of time where GM [General Motors] engineers would buy a Toyota and take it apart and just put it under the microscope. That's good intelligence. I was astounded when I heard that inside a GM car—and it was different numbers, but it's something like for all the plastic parts and the leather parts and things inside the human chamber of the car and the dashboard, it was something like 128 different fasteners to make that work.

Then the guy said, "We just finished taking apart this Toyota over here, and in here where we use 128 different parts, that means that it costs more, you have more problems assembling them right, teaching people to do that right, all of those things," and I think they had 12 in the Toyota. So that really made me think about a lot of manufacturing issues, so I became a manufacturing guru then and remain that today.

ROSS-NAZZAL: Do you want to talk about the solid rocket motors? You had asked Marshall to improve them well before the accident.

ABRAHAMSON: Well, on that last mission, I had left, essentially, but I got a call, and people in the recovery had found a little ash on the rubber grommet which goes in and is the basis for the whole seal and it makes that—oh, no, there's one other one, too, but I'll come back to that—the

basis for that seal. Of course, now I'm gone. I think I sent a letter over, and I've forgotten exactly where that was, and I said, "I urge you to solve this problem and not to fly again until you know what that is and how you can deal with it and what kind of hazard it really represents."

You know that there were some combination of human problems that were all part of the *Challenger*. One of them was the organization. Jim Beggs was accused of some kind of an ethical violation of some kind. I've forgotten exactly what it was. To his credit, first of all, he talked to people about it, explained the whole thing, and he didn't think it was a problem. But Bill [William R.] Graham, the President's Science Advisor, who had always wanted to come over and run NASA—and I know Bill too—was putting pressure on that. So Jim stood down, on purpose, and said, "Look, while I'm under this and while I get this solved, you should—." But, anyhow, the issue was Jim was not there.

Hans, who was always the flag bearer for reliability and serious, serious engineering work, Hans had gone down to Texas. Did you ever hear the story about when he left the last party? Hans went down to the University of Texas [Austin, Texas] to become the chancellor. There were several things at his last party there. I've forgotten who said this, but it was beautiful. He made a speech and said, "Hans, we know how much you like to work with organizations, change ideas, and are a force for constructive change. Our advice to you, the collective advice of all of your friends at NASA, is that you can go down there and do that in Texas, and it'll be well received, but don't screw around with the football team." [laughs]

But, anyhow, Hans had left, and Bill Graham, from a temporary position, he really didn't have all the authority, and he wasn't well known inside NASA. People were there, and when they made some of these decisions to go outside of the environmental arena and launch in the very cold weather and things like that, and all those were factors, but the real issue was a very

fundamental engineering problem, and properly once understood, tragically, but understood, then that became fixable, obviously.

In fact, I was at that point invited by some—I'm not Jewish, but with my name, I've always been thought to be Jewish, and therefore I had some really quite good and very nice Jewish friends who would invite me here and there, and then they'd figure out that I'm not Jewish. But by that time, I'd be well enough in their circle of friends and everything, that I'd not get thrown out. So I was like that. [laughs]

But, anyhow, since my wife had died in December, and, of course, the *Challenger* problem was in, I think, February, wasn't it?

ROSS-NAZZAL: January.

ABRAHAMSON: January. The Israelis had wanted me to come over and participate in a planting of—they plant trees over there as part of their recognition of people who had died and things like that. So I went over and planted a tree for my wife and, even though I was gone, I was no longer at NASA, planted trees for the crew of the *Challenger*.

ROSS-NAZZAL: Should we talk about cannibalization of the orbiters? Should we talk about that? That was a pretty big issue.

ABRAHAMSON: And that was an issue that I saw, again, of course, in the last years, I was for five years on the NAC under Griffin and enjoyed that, but that problem came up time and time again. We didn't have that much of a problem in those early flights because we really only had the two

birds, *Columbia* and *Challenger*, while I was there. Then the others came after that, so it wasn't as much of a problem. But it clearly was a problem, and even though I'm not aware that there was a safety issue that was ever created by that, I think the team was good enough to be able to find the right way to deal with it. Now, I may be wrong, but I'd never heard of an issue that came from that.

But it cost money, it didn't save money, because in the long run, it made the crew sizes—you couldn't get the processing crews down at a more reasonable level, particularly at the Cape, and what that meant then was that the Shuttle remained this incredibly expensive vehicle to operate, which was a major problem in its replacement. Mike Griffin had bitten the bullet and said, "We are going to have to pick a date for the Shuttle and it'll be gone." But, he was trying to run through with some arbitrariness that wasn't totally appreciated by everybody, and I understand that, too, with the replacement vehicles for the Space Station.

The agency could not get more room. The idea that [President] George W. Bush would say, "We ought to pick goals now that are going to be, again, NASA-challenging goals, and the way we're going to do this is that we're not going to make any extra budget available for you. But, with goals there, you can make the right decisions, so that you can manage your budget and transfer in a reasonable way." That's a good management principle, but it got pushed too far. The excess costs associated with the Shuttle was one of the reasons that it had to be terminated early, in order for NASA and the nation's space program to grow, and what that means is that that was a negative factor in our moving ahead.

Now, that's kind of extrapolating a long ways from the trouble or the problems of cannibalism and the effort, but it's all a factor in that. Even though they put the alliance down

there and that plan got implemented long after I was there and I wasn't the author of the plan, but it was a good plan, I thought.

I think I've covered a lot of the main parts.

ROSS-NAZZAL: I think so. I think we can turn for a short time to privatization.

ABRAHAMSON: Privatization. Nobody, or very few people knew it. First of all, Jim Beggs was a really good Republican, meaning he is always going to talk about we need private business to do as much as they can everywhere they can. So Jim said, "I want you to ensure that the financial community and Wall Street in New York understands what we're doing so that people will like McDonnell Douglas and when they put together their private launcher for the transfer vehicles and others can find ways to fit into the program."

I said, "Sure, boss, I'll go do that. I love it." So I would, about every four or five months, maybe, go up to New York and, of course, NASA would always attract a lot of attention. Various people like Goldman Sachs or others would sponsor a meeting of analysts, and I'd give them a big briefing on what we're doing, and say, "We're interested in you knowing what we're doing so you can support these businesspeople who are trying to do different things."

A good example of that is when we took the Space Shuttle over to the Paris Air Show. I had one of my press conferences that I invited a group of young entrepreneurs to come, and one of that group were three young men who were in those days trying to build a transfer vehicle for the Shuttle and make that into something really impressive. Their briefing there, which I sponsored, was the start of Orbital Sciences Corporation, and Orbital Sciences Corporation was the start of this company when we broke off from them for a lot of reasons. But, anyhow, in a

sense, these programs for private industry and privatization I think are marvelous, terrific. Well, we had somebody to try. Remember I talked about the fifth orbiter problem. There was an ex-Goldman Sachs multimillionaire who had contacted me, and I went over and explained this to Jim Beggs, that he wanted to build the fifth orbiter, but it could only be done if we could put together a program that would allow him to make enough money to recover and make that work. His name was William Sword, and he had several people. One of his support people that we negotiated with became a very good friend until he died about two years ago, but he was there. And the economist who put together the original Shuttle business plan for the agency [Robert Lindley].

ROSS-NAZZAL: I know the company, but I don't know the name of the economist. Mathematica [Inc.].

ABRAHAMSON: He really pumped up how many missions we could do and the size of the market. He's still alive and he's around yet. He had joined up with Bill Sword and they were doing these studies. I'd go up there or they'd come down to Washington, and we were negotiating on the building of a private fifth orbiter.

The problem was that the only way it seemed that it made financial sense was for NASA to turn over a larger percentage of the Shuttle base on our missions than his single orbiter, and therefore there was this imposition and where you could potentially have these big arguments about where you put your agreement so that he could make money to invest in us and we would get a fifth orbiter, but he would impose on a very large percentage of the fleet for the flights.

We tried every way possible to see if we could make that work, and, finally, after, I don't know, a year and a half or something, he gave up and I gave up, and I had to go back to Jim and say, "We can't find a way to make the finances work." So that was one of the first big tries.

ROSS-NAZZAL: That's interesting. Tell us about your support of ELVs [Expendable Launch Vehicles]. I thought that was particularly interesting because the Space Transportation System was supposed to be national. Everyone was going to be launching off of the Shuttle, but there was still a market for private companies. Talk about your support and the White House's support for Expendable Launch Vehicles, because it seems contrary to me.

ABRAHAMSON: Well, Hans was probably the most dedicated supporter of the idea that the Shuttle will do everything, and, of course, Hans had come from the Air Force, where he was very much aware of the classified space programs that the Air Force was running, and he had participated from the Air Force side in—I don't know exactly how much or when, because I think the parameters of cross range for the Shuttle, all of those things were set. The bay length was built around one of the very important classified military satellites, and the cross range where they could get to was such a big change for their operation, that that was a big deal. That had determined the whole shape, aerodynamic shape, and the wing, the philosophy of the architecture of the wings to the body. All of those things were determined by requirements that had come out of the Air Force.

Now, in return for that, what Hans wanted and NASA—not everybody in NASA, but many—said, "We have to be able to say we can do everything, and you guys need to let all your other ELVs die." So when I took that job, I would try to advocate the whole flexibility and the

capability of the Space Shuttle, and I will have to say that the things that people foresaw at DoD were, "Well, if there is ever an accident, it will go down for a long, long time, and the nation will not be able to afford not being able to launch these vehicles. So we cannot take the Titans and the other ELVs out."

That argument was never properly resolved, but the Air Force and the classified programs never got rid of theirs. Now, I had to get rid of the Delta, because that was the only one that was in mine. I'd go down and talk to the Delta people, and they would say, "Abe, this is a big mistake. Delta can't compete with the Shuttle, but we can provide flexibility to the whole fleet. It's really great."

I'd go in to Hans. It wasn't a problem with Jim. He was kind of neutral on this extreme ball game, but Hans was just dedicated to that. So I'd go back to Hans and I'd explain all this, and I'd say, "We ought to keep the Deltas going for a while."

He'd argue with me a little bit, or debate with me, rather, and then he'd say, "Well, so long as you keep working reasonably, people that have payloads that are going on the Delta are probably a good reason to keep it going for a while."

So, it just kind of slipped through the mesh. Thank heaven, because when I got over to SDI, I think this incredible team pulled off one of the most amazing space programs that anybody did. It was a particular experiment, and it was called Delta 180, and it was the first intercept of a thrusting body in space, and it was all designed so that we could watch what happens with the gases as they come out. Supersonic aerodynamicists know that when the hot gases coming out of the rocket engine turn right at the edge of the shape that comes out that is the nozzle, it accelerates the gases. Even though the rocket is accelerating, the gases can accelerate faster than the rocket. Now, that was important to us because we had to see our

targets, if it was a ballistic missile, from a long way away and right up to the very end, because we were going to intercept ballistic missiles, and we demonstrated while I was still there with something with no warhead. I don't know if you're aware of that. All that happens in an intercept that now we're doing absolutely routinely, and we have implemented an operational defense program now, took longer than I thought we needed because of the politics of it, but what runs into it is there is a little vehicle about that big that maneuvers. It's the interceptor, maneuvers all the way in, and it has to see that rocket so it knows to hit at exactly the right place where the warhead is so you can destroy the warhead and not just knock off the tail of the vehicle.

It just hits it. We call it hit to kill. There is no warhead, no little pieces of metal that are out there, shrapnel or anything like that. It just knocks it. A warhead is about that—there are bigger ones, but a smaller one that the US uses is about from the floor up about that high [demonstrates], and the cone has a base of about that big. It's a pretty small target to be hitting it at 15,000 to 20,000 miles per hour. So you'd better be able to see it and see it clearly.

We put together this program. I've shifted to SDI, of course. I was spending money on this whole concept called hit to kill at such an incredible rate that I said, "We have to know what it looks like all the way in and whether or not those gases are enough of a problem that we're not going to be able to see it, because that will invalidate the whole effort."

I took a young, great engineer from the Applied Physics Labs at Johns Hopkins, whose name is Mike Griffin, and I'd gone over there and several other places, and we put together a concept for this mission. I said, "We're going to do this mission in one year." It was the most complex one because the ABM Treaty, the Anti-Ballistic Missile Treaty, dictated that we had to

do things that were just crazy, and we did it all off of Delta. So I was thankful that we had the Delta there.

That mission, we didn't do it in a year; we did it in 14 months, even though the Delta ahead of us in the production line had blown up. We just kept that throttle going and made that. That was perhaps one of the most amazing small space missions that's ever been done, and it made Mike Griffin's reputation, and I was thankful for it. There are a lot of stories about that, but that's not what we're talking about.

ROSS-NAZZAL: They're all sort of interwoven.

ABRAHAMSON: Yes, they are. The space business is an interwoven thing.

It's so tragic where we are as a country now, in my opinion. I saw, and I don't totally agree with it, but I saw an interesting [video of HBO television show "The Newsroom"]—you know how your friends send you all kinds of emails, more than you should ever get. You waste your time trying to get rid of them and decide what do I do with that? Do I just throw it away or not or what?

But it was really good because it was a panel that—and this is related to this—it was a panel, I don't even know who all the people were on the panel, and they were taking questions from students, college kids out in Colorado. A young lady had gotten up and asked what I thought was a wonderful question, and I applauded it in my mind until I saw what happened after that. She said to this group of panelists, "Would you mind explaining why America is the greatest nation in the world?"

A couple guys took a shot at it, and then this man, who was really very—he used terrible language and all kinds of things, using that which I won't repeat, he said essentially, and he just went off, and he said, "America is no longer the greatest nation on Earth." And he just went through all the statistics, some of which you related to when you talked about we're 47th in education and stem activities and we're 3rd in manufacturing and 26th in this and that, and number of the age at which people live, and all kinds of things. He just went off at this.

Now, this is a Republican, and I'm a Republican too. But the point he was making is that the country is headed in the wrong direction and it's been headed there for some time. Our first problem is we're no longer first and we're going to get worse. There's no way to make it better unless we change our policies, which is a political takeoff point that he's trying to say.

Well, I didn't think it's as bad as he said, but he said, "We no longer undertake great impossible projects like the Apollo Program." He didn't say the Space Shuttle, but like the Apollo Program and others. "And we go to war not for moral reasons, but for other reasons," and all kinds of terrible things. So it is something to think about.

This and its preceding program and NASA is an inspiration to the world, and right now we're approaching apogee and we're beginning to do this. We need the nation. The nation needs a kind of inspiration that this provided to all of us, and especially our kids. We're so distracted in silliness, in my opinion, Twittering and all this nonsense.

ROSS-NAZZAL: We're coming up close to the time that [we allowed].

ABRAHAMSON: Okay, you're running out. Have we covered the main things?

ROSS-NAZZAL: I'm not running out. If you wanted to stop and we can come back another time, or would you like to continue?

WRIGHT: It's your time, so it's up to you.

ABRAHAMSON: I really should go. I don't know if I'm dealing with—I see that there are some we haven't done right here yet.

ROSS-NAZZAL: We can stop and we can come back and pick it up at a later date.

[End of interview]