NASA Johnson Space Center Oral History Project
Oral History Transcript

Milton A. Silveira
Interviewed by Sandra Johnson
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Johnson: Today is April 18th, 2006. This oral history with Milt Silveira is being conducted in McLean, Virginia, for the NASA Johnson Space Center Oral History Project. This session is a continuation of an earlier session conducted for the NASA Headquarters History Office, NACA [National Advisory Committee for Aeronautics] Oral History Project, on October 2nd, 2005. The interviewer is Sandra Johnson.

I want to thank you again, Dr. Silveira, for joining us today. The last time we talked, we were discussing your involvement in the Little Joe II Project, and we were going to move on from there into your next duties, so if you want to start there, we can talk about those.

Silveira: Okay. When we completed testing at White Sands [Missile Range, New Mexico] on Little Joe II, we had completed our [initial] part of the Apollo Program. In other words, the aerodynamics was developed, and we had done most of the aero-heating tests, so we were winding down as far as Apollo was concerned. Matter of fact, we had taken a good portion of our manpower—I had about fifty-two people at that time—we started to look at advanced missions.

One of them that became interesting to look at was a mission that we would fly to Mars. We would use a mission model where we would have a manned vehicle go to Mars. You go by Venus to get the acceleration to go to Mars. It would launch a smaller vehicle that was a sample return vehicle, and it would go ahead, go down, land at Mars, pick up a sample. Then it would come back up and recontact with the manned flyby vehicle, and then we'd bring the sample back to Earth.

Well, that was most of the activity in the branch, other than maybe a couple of people that still looked after Apollo. [That] carried on until we had the [Apollo 1, AS-204] fire at the Cape [Canaveral, Florida]. After that happened, Dr. [Maxime A.] Faget came to me and said, "You're coming back and work on Apollo again." So we started looking at some things with a system engineering [view] at various portions of the Apollo Program. We were rechecking a lot of things. Matter of fact, because of the fire, there were a number of changes in the spacecraft. One was that the Command Module went from about 9,250 pounds, being recovered, now to [a design of] 13,500. So we had to go back and look at things like increasing the parachute capability. We also looked at now what performance we still had in the abort vehicle.

Somewhere after that, George [M.] Low—he now became Program Manager for the Apollo Program—came to Dr. Faget and said he wanted someone to look at the manned recovery [of] Apollo; in other words, look at all stages of the program to see what we were doing as far as recovering the manned capsule. So it became a study [of] the abort off the pad, normal ascent, any aborts during the launch; actually, the return from the lunar surface. Then looking at normal recovery, the parachute performance; also the landing of the vehicle in the water. Also, [in] the pad abort case, we had to look if we had a landing on land, what was the survival capability [of] the crew. So we had to run additional testing [of] the capsule; what happens to the structure if it did return and hit on the land. Would the crew still survive something like that?

Also, we wanted to do some testing even on the normal mission to find out if the capsule [landed] water; whether it would land straight up or upside down. Also, if we took some of the worse-on-worse cases, where the wind was high and the waves were high and the vehicle hit at the worst attitude, would [it] exceed the structural capability of the vehicle.

I remember I was doing the presentation of the summary of the study, about the capability when the Apollo vehicle would land in the water. We had done a Monte Carlo analysis of the various conditions [when] it impacted the water. We had drawn a [structural capability] boundary around all these points. There were some points outside of this boundary. So George [E.] Mueller, who is the Director of Manned Space Flight in Washington [D.C.], asked a question [during a briefing]. He said, "Well, what happens if I land at one of those conditions out there outside of the boundary?"

I looked at the chart, and I looked back at him, and I said, "You sink." [Laughter]

George sort of sat back in his chair; didn't say a word for a period of time. The room had astronauts and engineers and operations people [there]. Finally George [asked], "Does that bother anybody here?" Nobody said a word. It was just sort of funny. He said, "Okay, go ahead." [Laughs] But there were cases where indeed if you did the worse-on-worse case, then that was a possibility. Of course, maybe 95 percent of the cases would be all right.

But we did go back—been like, oh, a year and a half between the fire and the time that we were able to get Apollo 8 successful, to redo [some of] the testing. We dropped a [number of boilerplate vehicle] tests in the Cape area to see what sort of soil that the vehicle would [encounter]. Then finally we did [some] tests back in Houston [Texas] where we used actual Apollo vehicles that had already flown in test flights, and then saw whether the structure would be all right. We got fairly decent results from [those tests]. We still considered the land landing capability of the vehicle to be similar like you'd been in an airplane crash. You might get hurt a little bit, but you wouldn't get killed.

When we started the testing with the Apollo and the Saturn vehicle, we flew the first vehicle, and it was all up. I remember Dr. [Wernher] von Braun was making a presentation again to George Mueller, and he was describing their test program, where they would fly three vehicles, initially with the first stage, and the upper stages would be dummy stages with water. Then you do three more with two stages, and the upper stages would be water. Then finally after doing three for the third stage, we came to the tenth vehicle, and it was all up at that point. Dr. Mueller leaned back again in his chair and said, "Wernher, why don't we go all up the first time?"

And I thought Wernher was going to faint right then and there. But the [plan] was pretty good as far as George Mueller was concerned. He said that's the way we ought to do it. He had confidence that it would work; and that's what we did. We did first launch all up [the first time], and it worked. It saved an awful lot of time and resources and money to be able to do it that way. We did the first flight and had a second unmanned test vehicle on [AS] 502 [Apollo 6]. That flight went fairly well, [but] we ran into a problem with a pogo, the vertical oscillation in the vehicle. Also, we had a problem with one of the engines on the Saturn S-2. Unfortunately they shut down [an] engine, but they shut down the wrong engine, so that made it a little more exciting.

Then after the flight, maybe, oh, several weeks after the flight, we had an individual, Tom [Thomas J.] Grace, look at all the photos that we got from the flight, and Tom noticed that there was a little white dot next to the vehicle in one of the frames. He looked further, and lo and behold, it was still there in a number of the pictures. When we finally examined that dot, we found out that a large portion of the shroud over where the lunar module would be failed, and it separated from the vehicle. We didn't realize it until several weeks after the flight. It was a honeycomb panel that at that time we didn't vent, and as a result, when the pressure built up between the two surfaces of the honeycomb, it blew off the side of the vehicle.

So we're in examining what would cause the pogo and why the panel failed and all that, and we're arguing about whether the third vehicle would be manned or unmanned. We were still in the midst of that study when I guess there was some information that was found that maybe the Russians were going to do something around Christmas of [19]'68. Now instead of arguing whether we ought to fly the vehicle manned or unmanned, we were going to fly around the Moon in Christmas at '68.

So it turned out that to many of us Apollo 8 was the most exciting flight in the program for us. It was the first time that we were going to fly the vehicle manned, and then we were going to fly the vehicle manned and around the Moon. You would sit in Mission Control, listening to the communications, and you realized that these guys were on their way to the Moon. It was just hard to realize that this was happening. Matter of fact, the mission was like, I believe, six days, and I think out of six days, I got to spend about four hours in bed. I would just catnap, but you're just so keyed up about the mission and the vehicle working and things like that that you couldn't relax about it.

Of course, the mission was successful. We knew that maybe the spacecraft was in pretty good shape, because when the briefing was done by the crew, they complained more about the food than they did about the vehicle, so I said, "That's pretty good." Maybe everything worked the way it should.

After Apollo 8, then we had a couple of flights where we flew to the Moon and got close to it, and then, of course, the biggest flight was [Apollo] 11, and flying it to the Moon and the successful landing. I remember just before the flight we had run a test where we were concerned about what happens to the descent engine on the LM [Lunar Module] if you're firing it against a solid surface. The shock gets swallowed by the engine, and then the engine would blow up. So we ran this test. We got close to the plate that we've simulated the LM [engine approach], and sure enough, the engine blew up. So I went to George Low and I said, "We've got some bad news."

George listened to the results of the test, and he said, "Well, you ought to go talk to Neil [A. Armstrong] about this."

I said, "Okay," so I went and had a one-on-one with Neil. Neil was always a funny individual. You weren't sure whether he was listening to what you were saying or not. I said, "You've got to be careful. This thing might blow up."

"Oh, okay."

So when the actual landing was occurring on the Moon [on Apollo 11], they had to move the landing point because the exact spot had some boulders that they wanted to avoid. Everybody was very, very concerned about they're going to run out of fuel. And I was thinking, "Neil's not going to shut down that engine. I hope he runs out of fuel." So everybody was worried about if he was going to run out of fuel; I was worried that he would not run out of fuel, and then the engine would shut down before he landed.

It turned out that the simulation of landing that we did was not exactly right, I think maybe as a result of blowing up some dust or [the surface was not like a solid plate]; that actually he didn't have the problem with the engine. So at least that was good news. [Laughs]

But it was also interesting, I always noticed that when we became NASA, President [John F.] Kennedy said to go to the Moon by the end of the decade, so all our badges that were issued to us [at] NASA would expire on December 1969. So I said, "Well, that's a message for you." [Laughs] "Either you do it or you're not employed anymore."

We always had a support room in Building 45 outside of the Mission Control Center, where we had the engineers that were responsible for the design of the hardware. We would man that operation twenty-four hours of the day. I [managed] one of the three shifts. I had my choice. So, on Apollo 8, I got the shift from eight in the evening till four in the morning, mainly because that's when all the high activity on the mission occurred. I can remember I got home about four-thirty in the morning Christmas morning. At that time we had three [small] children. Three children met me outside of the house in the driveway. "Is it time to open our presents now?" [Laughter] I remember that very well with them.

But we would support the missions with maybe as many as a hundred engineers during the missions. I did that until Apollo 12. In the time period around March of 1969, and we'd landed on the Moon in July, we had already started looking at Shuttle at that point. So after Apollo 12, I had to spend all my time looking at Shuttle, other than when Apollo 13 occurred. Then I went into Building 45 and then stayed with that at least for a day or two until we felt that we were, barring another failure, then we probably had a good chance of bringing back the crew. So after that it was nothing but the Shuttle.

We started in March of '69, thinking about the Shuttle [with a piece of paper]. Dr. [Robert R.] Gilruth had gone to a presentation at [NASA] Marshall [Space Flight] Center in Huntsville [Alabama], and the Air Force talked about this reusable launch vehicle. Dr. Gilruth had come back to Houston, and he approached Max Faget, and he said, "Max, these guys are talking about a crazy thing. Why don't you look at it and see what it's about."

So Max, in his usual way, started playing with it and went back to Dr. Gilruth and said, "Bob, you know, it may be feasible." And a matter of fact, he had built a balsa wood model of a straight-wing Orbiter that he would [use as a] demonstrator. He would launch it as a normal glider, and then he would also show that it had a second trim point that it would be at a very high angle of attack. This would be the entry [high] angle [of attack] that you'd use [to defuse the] heating [during entry]. So it was sort of [an] interesting [approach].

After he had talked to Dr. Gilruth, I was the second person that he demonstrated [the model flight]. It was in his office, and Max got this balsa wood model, and he stands up on the conference table, and he launches this glider. I'm just trying to figure, "Well, the boss finally had it. He lost it." [Laughter] Then he showed the second point, and I said, "Oh, I understand." So we started talking about it, and we started the paper studies. After a period of time it looked like it would be an interesting program.

At that time the Center, and I think NASA, was headed towards building a Space Station. We had, in Houston, had thought maybe it's a better thing to get a reusable launch vehicle that would be more economic [in] launching payloads. We would be able to actually do things in Earth orbit cheaper, and we would do maybe some things that you wouldn't do otherwise unless the cost was brought down. So we started on that theme. By this time, George Low was now Deputy Administrator [at NASA Headquarters] in Washington, so we went to talk to George and said, "George, rather than a Space Station, we think we have a better idea."

So he listened and actually got the Agency to turn around and say, "What we really need to do is to build the Shuttle initially." We were concerned that the general public was concerned about "What benefits am I getting as a result of the space program." They weren't interested in rocks and things like that. So we were looking at what could we do in space to improve mankind's situation here on Earth. Doing the satellites as far as weather is concerned, communications, and all of the things that we do in space nowadays. So the Space Shuttle became the major program as far as NASA was concerned after that.

Well, Shuttle was very different, of course, than any spacecraft before, Mercury, Gemini, or Apollo, so we decided that what we needed to do was to get a [design] group together. We used Building 36 to get a group of engineers together to actually design a vehicle. For instance, Apollo and the other vehicles didn't have hydraulic systems, so we found out that we needed to get some expertise in that [area]. To either get some people trained or get some new hires in to [design hydraulic systems]. As we got into some of the [design], we realized that it was very difficult to get a center of gravity on the vehicle that wasn't at the back end of the vehicle. The engines were so heavy [it was difficult] to get the airplane to be [aerodynamically] stable.

We called [the exercise] the DC-3 study. We thought it would be the DC-3 of commercial space. Like the [Douglas] DC-3 was the birth of commercial aviation, we thought this would be the beginning of commercial space. [The study] turned out that that was a good starting point to get engineers trained, to understand the requirements of the program, to really be able to be intelligent as far as when we issued a request for a proposal from the industry. We would be able to evaluate these proposals much more intelligently than we would otherwise. It turned out to be a good exercise from that point of view. I think we learned a great, great deal.

Sort of jumping ahead, we're now using that same approach forty years later when we're looking at the Exploration Program at NASA at the present time.

Then, of course, we went through the normal preparation of a proposal. Before we issued the proposal, though, there was a group of maybe eight or ten of us that went around to all the major aerospace companies at that time. We would get in an airplane, go to Grumman

[Aerospace Corporation] or Boeing [Airplane Company] or Martin [Marietta Corporation] or Lockheed [Aircraft Corporation] or North American [Rockwell Corporation] or Convair [Consolidated Vultee Aircraft Corporation, a Division of General Dynamics Corporation], to see what their capabilities were, because when their proposals came in, we at least would know somewhat about their capabilities.

I can't recall the time period when the proposals came back, but we got involved in going through the evaluation, and then actually finally selecting the contractors. We initially issued two major contracts to study the vehicle. There was a team that was McDonnell [Douglas Corporation] and Martin Marietta, and there was another one that was Convair and North American. They got what we call Phase B studies. In addition to that, they thought that rather than eliminating some of the contractors, we decided smaller studies would be given to a team that was Boeing and Grumman, and then a little different approach was used by Lockheed, so we had a smaller contract, also, to Lockheed. These studies went on for—I can't recall exactly, but went on for maybe a year, year and a half, or something like that, to look at the details of the design.

The contract that was let to Boeing and Grumman was run sort of outside of the mainline Shuttle Program that Max was responsible for. Both that and the Lockheed study was done by JSC [Johnson Space Center, Houston, Texas]. [In addition to the major studies] I got very involved in the Boeing-Grumman study. You had to go to the contractor about every month or so to check on their progress. I found out that when you're going to Seattle [Washington] and New York, you go to New York first and then Seattle. Don't do it backwards; that's too hard as far as traveling was concerned. It almost killed me to do it that way. But a lot of good things were done in the study phase by the contractors.

Then at the evaluation of the end of the Phase B studies, we changed [the design] because of fiscal constraints to rather than having a reusable Orbiter and booster, we would only have a reusable Orbiter. We would use solid rockets for the first stage. We'd be able to recover the solids, but they wouldn't be like an airplane type of booster in [the ordinary] case. So that kind of dropped out the booster contractors, like that would drop out Convair on the North American study, and then Martin Marietta in the McDonnell study. Then the studies went into Phase C, then we down-selected to North American to be the prime contractor to build the Shuttle.

Any of these very large programs you outsource maybe as much as 50 percent of the effort. North American was responsible for the entire vehicle, but you'd have people like Grumman would build the wings. The main portion of the fuselage was built by General Dynamics. Lockheed built the thermal protection system. I'm trying to think what McDonnell did, but they were involved in the—oh, they built the OMS [orbital maneuvering system] pod on the back end of the vehicle. I'm trying to think now what—my memory—what Martin Marietta was to do. Can't think of it right now; I will later.

But I think we had contractors in almost every state in the United States, and of course, all these pieces come together. We decided the place that we would assemble the Orbiter was at the Palmdale [California] Air Force plant and took that over. But before we would go into the plant, we modified the plant. One concern was Palmdale, at that time, had what they considered the Palmdale bubble. It was an area where the ground was about a foot higher than it normally; they were concerned there was going to be an earthquake.

So we went back into the facility and reinforced the building that the Orbiter was going to be built in. We caught the building on fire one time when doing some of the work on it. [Laughter] Of course, it was a small fire, so we were able to handle it. But, a lot of times these are the problems that you have when you're building hardware, the little everyday problems that you never expect are occurring, but they're there. They'll be there all the time.

We, of course, had a lot of individual tests. We used a very different approach on the thermal protection section; did a lot of testing at [NASA] Ames Research Center [Moffett Field, California]. [NASA] Langley [Research Center, Hampton, Virginia], also; did some testing there. The development of the main engine was assigned to Huntsville. They chose Rocketdyne, a division of North American, to build the engine.

The idea of building the Shuttle, we determined that there would be three major technologies that we would pursue, maybe not any more than three, because we figured if we ran into problems with any of the three, then you had enough money to solve them, whereas if you tried to do everything new and you got into trouble, then it would be too expensive to be able to complete the program.

So we chose the thermal protection system to be different. It really was a different concept, and it would increase the performance of the Shuttle a great deal. The other was the main engine, which was a high-performance hydrogen-oxygen engine that, as I said, Marshall would do. Then the third technology we took on that we thought was a big payoff was the matter of the integrated avionics on the vehicle. In other words, using computers and fly-by-wire [systems, and] flying the vehicle unstable. We figured that was a big payoff. Those were the three technologies we thought would be the biggest payoff as far as investment into technology.

The main engine was, again, really an advanced technology. We had a number of firings that failed. Unfortunately, when the engine was so high-performance, the pumps on the oxygen side of the engine pumped like a ton of liquid oxygen a second, so anytime the engine had a failure, it was total. It would just tear itself right out of the stand.

The TPS, the thermal protection system, was also a development that had a lot of failures. You'd put [a tile] in the test arc jet. It would come back and look like a burnt marshmallow. It would be all crumbled up. We initially thought that we would make the tiles twelve-by-twelve. After much testing, they would crack in half, so we decided, "Well, we'll make them six-by-six rather than twelve-by-twelve." That seemed to be what it wanted to do, so we'll go along with it. So that's how the tiles got to be [that] size.

The avionics, the idea of having a digital flight system with a fly-by-wire was, in my opinion, one of the big advancements in airplanes. Nowadays all your major airplanes use that system as their flight control. So that was particularly a big payoff [in commercial programs] as far as the investment that we made into the Shuttle Program. It took like, I think, maybe twenty, twenty-five years before airplanes were to adapt the system. Unfortunately, the French were the first to use it rather than an American company. But nowadays, every modern [commercial] airplane uses that system.

One of the goals of the Shuttle Program [was] whatever we would build would not take any more than about seven or eight years. We figured if the development time is too long, then people won't support it. You want to go through [no more than] two presidents, two administrations, not any more. If you try to go through the third one, by that time they'd find better things to do, and you'd probably get the program cancelled. So we said, "Whatever we've got to do, we've got to do it within that seven-, eight-year time period."

Also, to keep the interest of the general public and the Congress, we thought the earliest demonstration you can do is good for the program. You said, "You know, there goes the Shuttle. I saw one recently." And that's one of the reasons why we wanted to do the Approach and Landing Program at Edwards [Air Force Base, NASA Dryden Flight Research Center, Edwards, California]. We decided to use the [Boeing] 747 with an Orbiter on it and do some initial unpowered flights off of the airplane. That was good, because we were able to do those tests, like about two, two and a half years before we were able to get the Orbiter to go to orbit.

It was sort of interesting that we had a lot of skeptics about [the separation of] the airplanes and that was a very dangerous thing to do. In reality, we didn't drop the Orbiter off the 747. What we really did is we put the configuration in a situation that the lift on the Orbiter was greater than the 747, and it actually had more drag by having flaps down and gears down. So actually the Orbiter dropped the 747. It dropped below the Orbiter, and then it flew off of that.

We thought that was a neat idea until we got a paper that was written by a gentleman, [Major R. H.] Mayo, in England, where they didn't have the range on an airplane to be able to fly across the Atlantic [Ocean], so they mounted a smaller airplane, seaplane, on top of a flying boat, and they did the same thing [Short Mayo Composite Aircraft]. The approach that they used, again, was that the little airplane would drop the big one. It also was neat from the point of view that when the little airplane developed more lift than the larger flying boat, they had a light that would come on and indicate that it was all right to release. We did the same thing on the Shuttle. So we weren't all that smart after all. [Laughter] Somebody had done it years before. But Mrs. Mayo is still alive and sent us copies of his reports that we were able to read.

So we indeed were able to do some additional testing of the avionics, the flight control system. We [made] a number of changes. Of course, writing the software for just the landing stage was a lot easier than the entire flight program, so we gained an awful lot of experience in it. So we took sort of these little steps in the program before we had to go all the way to orbit.

[On] the Approach and Landing Program, we didn't have to have the thermal protection system. That was an advantage. We could spend another two years or something like that [to] determine whether we had got the proper [analysis of] heating over the total vehicle. Basically it was a matter of studying the test results, making sure that we were designing the vehicle properly before we had to go to orbit with the vehicle.

We did, I think it was, four approach and landing tests at Edwards. Initially we used the Orbiter that had the tail cone that we had built when we were going to ferry the Orbiter on top of the 747. To start with, I know that on the first time that the 747 took off with the Orbiter on its back, a lot of people were concerned. Matter of fact, we had a great deal of trouble even with Boeing, convincing them that it was all right to put an Orbiter on top of a 747. They said, "The [747] tail [was] going to fall off."

"Well, what do you mean?"

"Well, it's going to fail."

"Well, what do you consider a failure?"

They said, "Well, if we get a crack that's more than three-quarters of an inch in a major structure, we consider that to be a failure."

I said, "Oh, well, you know, we fly a lot of things with cracks in it, so we'll try it and see what happens."

They were very concerned that if we had an accident with the 747, it would reflect on the commercial airplanes, and they would lose customers. I said, "Well, you know, this 747 is different than any other airplane that you've ever built, so it shouldn't relate to those at all." Well, [we] were standing by the runway at Edwards when the airplane was ready to take off [for the first time], and I remember Aaron Cohen, who was the Project Manager for the Orbiter—I was his Deputy—came up to me, and he was wringing his hands and pacing back and forth. He said, "Milt, you think this is going to work?"

I said, "Aaron, I don't know, but we're going to find out real soon."

Of course, it took off, and Fitz [Fitzhugh L.] Fulton [Jr.] was the pilot on the airplane. We had a ground voice loop to him, and he said, "Everything's smooth. Everything is smooth." And it just went very, very smoothly from that point on.

To more realistically characterize the Orbiter's gliding capability, we decided to take off the fairing, the tail cone, and fly it on top of the 747 without it. Then Boeing really got excited about doing that. They said, "You're going to knock the tail off," again.

I said, "Well, let's go fly it and see if it will." We did, and of course, everything went pretty well, too. We were able to do those two tests, and really had a good characterization of the landing capability.

Of course, the first flight is always, to any airplane, any vehicle, is always very exciting. You're wondering if that was a decimal point or a fly spot on the [blueprint], and you want to make sure that everything's going [well]. I was under the vehicle one day looking at the large area that was the thermal protection system. Apollo is just 12.6 feet or something like that, and here is this huge thing that we're now going to bring back through entry heating. I thought to myself, I said, "Do you really know what you're doing?" and I wasn't sure that the answer was yes.

But I remember the day we came back. It was the 12th of April that we flew. First flight, for the first time we had it manned, because we were very concerned about we had four flight computers and another that was the backup to the four, and we were very concerned about having a software problem or having the flight computers getting locked up, that you needed a man to be there to handle the situation. So we decided to man the vehicle. John [W.] Young and Bob [Robert L.] Crippen flew the first flight. We had left these ejections seats in the vehicle that we used in the Approach and Landing Program. Matter of fact, the first four flights were flown with ejection seats for just the pilots, seeing there were only two people on the vehicle.

The vehicle came back through all this heating and did well. We landed at Edwards. The day we landed in the morning of April 15th, I remember the day well, because after the landing we're going to celebrate, of course. A group of us, Dr. [Christopher C.] Kraft [Jr.], Dr. Faget, Aaron, myself, and our wives went to a late lunch at one of our favorite restaurants out in Alvin [Texas]. We used to go all the time. [We] celebrated all afternoon. [I] went home that evening and finished my income tax.

That was not a good idea. After a period of time I got a letter from the IRS [Internal Revenue Service] and said they had examined the return and I owed them $300 more. Well, I looked at it, and I couldn't understand a lot of things that I did. Well, it ended up that they paid me $3,000, and I didn't have to pay them any more. There were so many mistakes that had been made in the return that I made after celebrating all day. [Laughter] So it was pretty good.

So then we went on from that and had a relatively successful program. I think the thing is that technically we did what we were supposed to do as far as the Orbiter is concerned. I think the program maybe wasn't the success that it was supposed to be from the point of view that the payloads didn't develop to get the flight rate up to the point that we had envisioned to get the cost per launch down. Of course, if you fly fewer flights, indeed the cost is going to be higher. So I think that the objective that the Shuttle originally had in reducing the cost of launching payloads was not realized, mainly from that point of view. Also, the mode of flying the vehicle, I don't think we ever achieved that we would use Mission Control like an air traffic center rather than as a ground station for the flights.

JOHNSON: Do you think those original objectives of flying it so many times a year that they originally talked about, was that realistic, from the point of view you had during that program?

SILVEIRA: We had to justify the Shuttle. They did a number of studies where it would economically be feasible to do that, and then it came out that if you flew it about fifty-five times a year, then you would be able to reduce the cost of launching. Of course, we never even got close to that, something like that. So that was one of the reasons why to do it.

But there are a whole bunch of studies, some saying that it wasn't feasible, others that said, yes, it was something to do. Like a lot of times, your vision of what is going to happen gets changed by a number of things, and indeed, the utilization of space didn't develop as we thought. A lot of the vehicles, the satellites that were developed, had a great deal more capability per vehicle than we thought. So the demand for launching [did not develop] particularly; the big success in space in satellites [was] in the communications area.

It did make communications a lot cheaper; a lot more capability; a lot of capability as far as communicating around the world. Probably one of our problems nowadays with the outsourcing [work] now is because we have better communications. The world is getting smaller all the time because of [better communications]. Of course, being able to forecast weather, that's worth a lot of money as far as being able to understand whether you need to irrigate or demand water or whatever, depending on weather. There's an awful lot that has happened to change our lifestyle, really, because of the development that we've used and the capability that we have now in space at the time.

JOHNSON: Also, in those earlier studies, those early-phase studies, one of the things, as you mentioned, was the thermal protection system. I know that there were a number of lost tiles when they were moving the first [Space Shuttle] *Columbia* from California to Florida, and they lost a number of tiles. Then again after STS-1, they lost some tiles. Do you want to talk about that for a minute and those decisions?

SILVEIRA: Yes, when we were going to move it over from Palmdale to Florida, they did, of course, a flight test, and as a result, a lot of the tiles came off the vehicle. We found out that the way we were bonding the tile was not adequate. What we had to do, what we did, was to densify the bottom of the tile. It's actually bonded to a felt pad, and we'd get a better, stronger bond between the felt pad and the tile by densifying the tile at the very bottom of the thing under the coating.

The thing that you always still have this question about when you look at a vehicle is you'll have flows that are different, depending on little vortexes that form here or there. So the pressure [and heating] on certain of the tiles are different. So the tile—actually, there is a number of different tiles. Some of them have higher density than the other ones, and what you look for is the flow field around the Orbiter, to maybe put these higher density tiles in those areas where the [heating from the] flow is stronger. So it takes a certain amount of testing, analysis, to determine where these higher [heating areas] are and to be able to handle the application of the tile. So it's always a worry.

Like I was making a presentation to the Administrator about the [thermal protection] system we were going to use, and he said, "How many of these tiles are there?"

I said, "Well, you know, there'll probably be around thirty thousand."

He said, "How are you going to put them on?"

I said, "We're going to glue it on."

He said, "You sure you know what you're doing?" [Laughs]

I said, "I hope so."

It took a lot of work, and indeed, we had a lot of problems. We had, of course, even more recently, the concern with filler in the gaps between some of the tiles, and we had a couple of those that moved up, and we were concerned about whether they would disturb the flow that would cause the heating to increase. They pulled them out [on abort on an EVA].

But I think, with all the things that could go wrong with the tiles, I think that we get away with an awful lot; that we've been successful. The thing is when the Russians decided to build a shuttle [Buran] also, they used the same approach. They're using tile. Matter of fact, I got a tile that's a Russian tile, and it looks exactly like one [of ours]. You couldn't tell the difference of them, other than what's written on the thing; it's in Russian rather than English. [Laughs]

One of the advantages we really had, as far as using a surface insulator, was that it would allow us to build an airplane out of aluminum, which we knew the industry knew to build. It also would allow you to build the airplane early, which we did for the approach and landing system, while you're still sizing the thermal protection system to determine what thickness at what time.

Of course, the tiles vary in [thickness] from the front of the vehicle to be much thinner near the end. So it allowed you to, even if you've got some data that indicated you needed to increase the thermal protection system, you didn't have to rebuild the airplane to do that. So it sort of unlocked the thermal protection system from the structure of the airplane itself. So it made it a lot easier to be able to build the vehicle that way, than having to do the whole thing at the same time. We looked at hot metals and we didn't have to build them that way, because it would have been very, very difficult to do that.

JOHNSON: You mentioned that you were in the Houston area at the landing. Were you there also for the launch? You didn't go to Florida?

SILVEIRA: No, both the launch and the landing, we were at Mission Control, because that's where all our engineers were [in Houston]. Matter of fact, I think it was like the twentieth or thirtieth flight before I saw a launch of the Shuttle. I don't think I've ever been at a landing, even now. But that has been the case, because even in the Apollo Program, I never saw a launch. You were always at the [Mission] Control Center rather than being at the launch.

JOHNSON: Did you ever have any dealings with the Aerospace Safety Advisory Panel?

SILVEIRA: Oh yes. I used to work with them quite a bit, and they were good friends. Matter of fact, there was one member of the panel that was very much into wines like I was at the time, so we used to drink a lot of bottles of wine together through that time period. [Laughs] So, it wasn't all work, and it was a little fun every once in a while. But they had a lot of people, a lot of the individuals had a great deal of experience, and were helpful as far as things.

I know that I remember one time I was walking through the plant in California at Downey [California] with Bill Hamilton. Bill was Vice President in charge of engineering at Boeing, Boeing Aircraft. He commented to me, he said, "You know, Milt," he says, "your people got a lot of confidence in what they're doing."

I said, "Yeah, Bill." In the airplane business, you only make a small change from one airplane to another, because you're worried about the liability thing being sued. Bill would say that about 30 percent of his staff were legal people, lawyers, to make sure that the design wouldn't be liable as far as Boeing is concerned. So they do changes very, very slowly to make sure that they're exactly right.

So we were making a big change from, say, Apollo now to the Shuttle Program, and I said, "Yeah, Bill, they're confident mainly because you've got to understand these guys just went to the Moon." And it was true that when we started the Apollo Program, like when Kennedy announced that we were going to go to the Moon by the end of the decade, I said, "He doesn't understand the problem. There's no way in hell that we can do something like that."

We sat down and started work, and sure enough, we were able to do it in the time. But when we started the program, we didn't have the slightest idea how to have an entry from the Moon through the thermal environment is concerned. We didn't know how to build material that would go through the environment. So we did all these things. We made a great deal of progress during that time period, and so, yes, we became confident of ourselves.

Maybe overly so, but again, the thing that's interesting, later I, in my career with Dr. [Hans] Mark, wrote an encyclopedia on space, and we had a number of the papers were contributed from the Russian people. They would comment; they said, "You Americans were really something, because you said you were going to do something, and you did it."

When you look at the Apollo Program, we said we were going to go to the Moon by the end of the decade, and we did it. We did something as complicated as the Saturn V, and we flew it successfully the first time. When you look at the Saturn V Program, with the exception of [AS] 502, it appeared that every launch was successful. There was an awful lot going on to get one of those things to—you know, it's 317 feet or something like that long, and it was really a major accomplishment. And you have to understand that most of us were like in our late thirties or early forties time period, and it really was a great team to accomplish what we were able to do at that time. That's like I sort of laugh when people say, "Well, you know, so and so is too young to do this."

I say, "Hmm. That's not the case. Not anymore."

JOHNSON: As you mentioned, I think in Mission Control, the average age was twenty-six, and so many of the engineers were so young. There was another engineer we were talking to recently, and he said that he was there as a student first and then later hired on as an engineer. He said they were given projects, and they were expected to figure it out—

SILVEIRA: Yes.

JOHNSON: —to figure out that outcome, and the whole atmosphere of if they needed advice or help they got it, but they knew they had to come up with a solution.

SILVEIRA: These young people were given a lot of responsibility. They really were. I look back at my group was responsible for looking at the landing dynamics of the Lunar Module, landing on the Moon. When you just stop to think, that's in front of the world. If that thing fell over, it would be a bad day. [Laughs] But those were the kind of responsibilities you were given. Indeed it would land, and then you're able to fly back off of the surface of the Moon.

I remember one time we were in a meeting with Dr. [Kurt H.] Debus from the Cape, and he was commenting on—he said, "You know, I look at what all the equipment that we have at the Kennedy Center to launch a vehicle, and yet, you know, here you are all by yourself on the Moon and launching from there."

And I think it was Chris or somebody that said, "Yeah, Kurt, we've been wondering about why you have all that stuff." [Laughs] "Because, you know, we're launching a vehicle from the Moon just with two guys and a lot less equipment than we do with a launch vehicle."

But it was a good time. I think basically we, at the time period that we were in the Apollo Program, the attitude of a lot of people in other countries wasn't as favorable to the United States as it had been. I know that a lot of people that we have met since that time in foreign countries really look to the Americans as really being able to do something and do it well. We have the technical capability of doing whatever we decide we want to do.

JOHNSON: Well, I think we're going to stop just for a second, and I'll change the tape before we go on to your duties at [NASA] Headquarters [Washington, D.C.].

SILVEIRA: Okay.

[pause]

JOHNSON: When we stopped, it was about the 1981 time period after the first Shuttle flight, and you were appointed as the Assistant to the NASA Deputy Administrator, Hans Mark, during that time.

SILVEIRA: Yes, the thing that I figured after the Shuttle Program, it was now time to maybe go outside, particularly to go out and earn some money, because NASA's an exciting place to work, but the salaries are not the greatest in the world. So I thought that would be the proper move. Well, Hans Mark was a friend. He was Director at Ames when we first started the Shuttle Program. I had told both Dr. Gilruth and Max Faget, I said, "We need to go to Ames and make him a friend, because we're going to need to use his wind tunnels in the Shuttle Program."

So, indeed, we became good friends, so much so that when Hans—Hans had just finished being Secretary of the Air Force when he was appointed to be Deputy Administrator at NASA, and I was telling him that what I was going to do was leave NASA and go to industry. He said, "No," he says, "I want you to come to Washington and work for me in Washington."

Of course, at that time we had a lovely home in Nassau Bay [Texas]. You'd walk to work in the morning. The community was really a neat place to live, near the water. I said, "Why would you ever leave for something like that?"

Well, [we] left to go to Washington, where—of course, the cost of housing was very, very great, compared to [Houston]. But anyhow, I did. What we were trying to do, of course, is to get the Space Station Program, going, because even though the congressman who had asked us, he said, "Well, the reason you want to build a Shuttle is so you can build a station to [use] the Shuttle."

We said, "Oh, no, no. Shuttle is to make payloads cheaper to go to space. It's not related to the Space Station."

Well, when we had to go back to the Congress, we said, "Hey, you're right after all. That's why we need to have the Shuttle is to go back to the Space Station." [Laughs] So we started to get that program [started]. Initially, like, we had in the Shuttle Program, we ran a technology study program to look at what technologies needed to be developed to build a Space Station. Of course, in the meantime, we were still involved from Headquarters in the Shuttle Program and watching the development of a lot of the satellites they were using.

We had a particular satellite. It was called the Solar Max satellite that had failed. When it was designed, it was built with the idea that if it failed, you could go up and repair it. So we developed that program, and we went up and we fixed it, and still [continued to] work. What we were trying to do is to get a solar cycle, which is about, I think, over an eleven-year time period that we wanted to get data, so we needed to have that satellite working over a period of time.

We also had a case where we were launching a couple of communication satellites out of the Shuttle, and the solid rocket that was to take them from the [Shuttle] orbit to the Station to be geostationary failed. We had two of them, and both of them failed. So we had to develop a mission that would go and recover them and bring them back down and then repair them.

Later I became Chief Engineer at NASA, and then you now had a bigger view of everything that went on, because you not only had the manned program, but you also had the unmanned program, and there were some differences between the way an unmanned vehicle would be launched as compared to a manned vehicle. I think in many cases what we were trying to do is to indicate to the unmanned people that it was worthwhile to use the high quality that you used in the manned program, because you get a better success rate in doing that. So it was a matter of getting that philosophy across to the engineering world.

Of course, the Station Program developed. Then, of course, in [19]'86 we had the [Space Shuttle] *Challenger* [STS 51-L] problem. Of course, it was a very, very bad time, and you got a great deal of pressure to understand what happened, try to find the fault. When the accident happened, I happened to be in Washington. I had a terrible, terrible cold that day. I thought that because of the ice on the launch platform and everything else, we weren't going to launch, and actually, I was getting ready to go to lunch when the secretary said, "They're going to launch."

I said, "Oh?" and walked into the Deputy's office to watch the launch.

Because of feeling bad as far as the cold, I didn't realize what was going on. I just couldn't believe what was going on, anyhow, to start with, and then I was told, "You'd better get to the Cape right now." Well, it so happens that our plane was down for maintenance, so I was told, "Find an airplane."

So I called the FAA [Federal Aviation Administration] and talked to the Director, and his airplane was inbound. He said, "You can have it in about an hour."

I said, "Okay, we'll take it."

In the meantime, I was told, "There's a change." We were going to go out of [Ronald Reagan Washington] National, and instead there was a change made. "Go to Andrews [Air Force Base, Maryland] now, because the Vice President's going to go to the Cape." So we went down to the Cape on the Vice President's airplane at night.

We told George [H. W.] Bush at the time that what we thought, that it was a failure in the external tank, because we could see a glow on the side of the tank, and it looked like that's what failed. Of course, it took a while to find out that, no, it was a solid [rocket booster] that caused the problem. We, of course, had a presidential appointed committee, unlike—when we had the fire in Apollo, we kept the committee in-house, within the NASA organization. [In that case] everybody understood what we were doing and how we did it and things. So that investigation went a lot smoother, and we were able to get back to flying again faster.

We got the commission from the presidential level. We got a lot of people that weren't familiar with the way the Agency worked and how we designed hardware and built hardware and flew it. So it took a little education and also a little more time to do, and as a result, it took a lot longer to correct the problems. We thought initially that we had a fix that we could use that would get us maybe back flying within six to nine months. Of course, it took, what, about two and a half years or something like that to finally get it.

One of the interesting members of the panel was Dick [Richard P.] Feynman, who was a Nobel physicist, and he and I got along very well. I think Dick didn't get along with the rest of the commission at the time, but I think we understood each other pretty well, and I think he understood what was going on a lot faster than anybody else in that.

But it was just a very, very difficult time, to think that you lost a vehicle and lost people. All of them, of course, were very, very good friends, I think, particularly Judy [Judith A.] Resnik was a very close friend, and was badly missed. But I guess that's the thing that, with some of these high-risk programs, that every once in a while you miss it, and we sure did on that.

I thought that I would get through my lifetime, but—I worked almost all my life on reentry flight, like, and I thought that we would be able to always do that successfully, and then, of course, [Space Shuttle] *Columbia* [STS-107] came along, and it was a difficult thing. Of course, I was not with NASA when that happened, but my daughter and my son were working in that program, so I was very close to what they were doing and the team was doing. I was called by the [Columbia Accident Investigation] Board to talk to them about some of the design features that we had on the Orbiter. You don't really like to have failures, but I guess if you're doing it, then you're going to have that happen. Every once in a while, it will occur.

JOHNSON: The *Challenger* accident actually affected some other projects and programs. The Centaur-G Rocket Project, I think, was terminated after the *Challenger* accident because of some problems that it was having.

SILVEIRA: Yes. Yes.

JOHNSON: Do you have any recollections of that, in particular—or any other—of that termination?

SILVEIRA: Well, after the *Challenger* accident, then we would be much more detailed as far as what we were doing to make sure that these other programs would work. I think that it made a lot of the programs much more expensive and it look a lot more time to make sure things were correct before doing it. It probably increased, maybe more than it should have, things like the traceability of hardware, the paperwork that's involved in the quality programs and the like, the amount of people that you would have looking at things at the same time, and just using a lot more care than you would otherwise.

But about a year after *Challenger* is the time period I felt that the job wasn't fun anymore. I had about thirty-six years in, and one day I mentioned to the wife that whether I went to work or didn't, the difference was about $12,000 a year, and she said, "You're nuts! You're going to quit." So I left the Agency at that point. I decided it was time to do a lot of things you never had time to do. Still did some consulting, but for a period of time just did all those things. I wanted to improve my cooking skills, so I started taking cooking lessons, and then I ended up teaching cooking. Then I wanted to learn about art, so I became a docent both at Corcoran

[Gallery of Art] and later at the National Gallery [of Art], because I never had time to do that before.

But after a period of time I got bored with all that, and when again Dr. Mark came back to Washington to be DDT&E [Deputy Director Test and Evaluation] at the Pentagon, he said, "You're coming back to work." So I went back to work and been doing it ever since. Because when you look at all your life you trained to be an engineer, that's what you wanted to do, and actually, that's the most fun you can have. So that's where I am. Now I'm again, after about six years supporting DoD [Department of Defense], I'm devoting most of my time with NASA again, because we're going on a new program.

JOHNSON: You mentioned that after *Columbia*, you were asked to come back and talk to the Board about some of the design aspects. Can you talk about any of the details or anything about what you discussed with them?

SILVEIRA: Yes. The point I wanted to make with them is that the Shuttle was designed in the 1970 time period, more than thirty years ago, and how many things around the house are thirty years old and still working? It was time that we need to develop a new system to replace the Shuttle, because the technology was getting old, particularly you're starting to run into a lot of problems with things not being available anymore as far as spare parts were concerned and the like, and it was time to go on and do things differently. It seems to me that we tried to stretch out the Shuttle Program a lot, lot longer than we should have; that it should have been retired a lot, lot earlier. Indeed, some of the airplanes that we use nowadays have lifetimes that we never expected to have, and they're still flying and still useful. But I think there's a better and safer way of doing things than using the Shuttle now.

JOHNSON: During your career you've worked with a lot of very important people with NASA. [Bob Gilruth,] Max Faget, George Low, George Mueller, Aaron Cohen, Hans Mark, are just some of the ones you've mentioned during your oral histories. And then you yourself, of course, were in management positions for a number of years. Is there anything about any of these people in particular that you admired as far as their style of management or anything that you ever patterned your style of management after?

SILVEIRA: I think that in my career that probably the one individual that I would more model myself after would be George Low. George was very smooth, very smart, handled the program, and the way he did things was very good.

I, of course, was closer to Max Faget. I found him to be a very brilliant individual. I guess I think one of the big privileges in my lifetime was to be able to work as close with Max as possible. Matter of fact, we developed a lifetime friendship that even after he left NASA and I left NASA, we would still get together whenever he came to Washington or I went to Houston. We're very, very close, and like he was just a brilliant mind to work with. I know a lot of times we might be in a meeting, and he would come up with an idea, and I could look at people and feel that they didn't really understand what he was saying. Fortunately, I had that kind of relationship with him that we understood each other pretty well.

Another one with Hans Mark, again a brilliant individual. One time I was at a Board of Regents meeting at the University of Texas [Austin, Texas], and I asked the head of the board, "Well, how are you getting along with Hans?"

He said, "It's mind-boggling to deal with a genius."

I said, "Yeah, I understand that." [Laughs]

But these people were just very, very sharp and very interesting to work with. Chris Kraft, Bob Gilruth, just having known those people is just an opportunity that you can't ask for anything better than something like that. They always had great ideas. They always instilled good ideas in yourself. I think you accomplished a great deal because of your association with them.

I know Hans had a—matter of fact, his father was a teacher to Edward Teller, who is, you know, the father of the hydrogen bomb, and Hans would come down from Ames to visit JSC to see what was going on there, and he'd bring Edward down. In the morning he would tell me, "Milt, how about taking care of Edward for the day and show him around?"

The difference between the minds between Edward Teller and myself, I was worried that we could even talk. But it was very interesting, because he would come up with some great ideas and some things that you hadn't even thought about on something like that, and it just turned, a lot of fun to be with these people.

I think now, too, at the present time I've been working with a lot of the young engineers at NASA. We've been going through a design for the advanced spacecraft, and it's very interesting to work with these younger people that they're a lot smarter than I was when I came out of school. I think they've got the stuff that they'll be successful in what they're doing, and it's just a lot of fun to watch them solve problems. Really a great, great opportunity this late in life. [Laughs]

JOHNSON: And you're still working, you mentioned before we started, with the Constellation Program?

SILVEIRA: Yes. Yes.

JOHNSON: As a consultant?

SILVEIRA: No, what they decided to do is to do an in-house design again, very much what we did in the Shuttle Program. They put together a team from all the NASA Centers. Then they got about ten of us that were involved in the Apollo Program, and they would use us as mentors to the younger people so that there are various disciplines in various groups. We work with them to give our experience that we would go through, or like in many cases, we would tell them, "Go look for this report, because we did these tests, and you'll see what the results were from them."

People like—one of them was John Young. Ken [Thomas Kenneth "T.K"] Mattingly [II] is another. Bob Sieck from Kennedy, Bob [Robert S.] Ryan from Huntsville, Tom Modlin, Jim Jacks. I'm trying to think of all the people. Oh, Warren [L.] Brasher, who was head of the Propulsion Division.

We worked with these people and sort of guided them into—our experience before, there's a number of things that, "Don't do that, because we tried it, and it didn't work. Try something like this." It was a good experience. I think it was good for the youngsters and also for us to be able to talk to them and pass on to them the experience that we have.

JOHNSON: Were they generally accepting of your experience?

SILVEIRA: Very much so. Matter of fact, it got to the point where they would keep coming for you for information, to the point that, like right now, I'm in the process of reviewing some reports, and they send me a report on Friday afternoon. "We want your comments by Monday morning." It's like I spend all weekend working on reports. [Laughter]

JOHNSON: Your hours haven't changed a lot since those early days. [Laughs]

SILVEIRA: No. They were very receptive as far as the things that you said. They seem to listen and they seem to absorb what you're talking about. No, it's very good.

JOHNSON: And quite a benefit for them to have all those years of experience behind—you, as you know, didn't have that advantage when you were doing Apollo.

SILVEIRA: Yes. Well, the thing that I hope that this program will be successful, because we do have that background, and what we're trying to do is to have, again, a small increase in the capability that we had before, and I think it will make it successful, and the schedule will be quicker, and the cost will be less as a result of that, so I'm really hopeful that it will be successful. I really do.

JOHNSON: Well, as you look back on your career with NASA, and as you say, it's still going on, what would you consider to be the most challenging aspect of that career, either a program or an incident or a time period or a position?

SILVEIRA: Well, there's no doubt about probably the most exciting and the most challenging part was the Apollo Program. You still look at that as—you look back at what we did, and you still wonder, "Did we really do that?" Because it was a big step. There's no doubt that because of the demands by the program, you continued to try to get more education. You worked hard at that to get new knowledge to keep up on the technology of the time.

As you moved up into management, you suddenly felt like you were losing your capability, but you sort of understood that now it was time to—the capability you really needed to have was to get people to work together and solve problems, rather than your sitting down and solving the problems yourself.

It's an interesting thing to try to get a large group of people to accomplish a single goal. A lot of people don't have that capability to be able to do that. You take, in a lot of cases, like in our programs, it takes a single strong leader to make the program work, and then to get some strong people behind them to be able to do things. When you look, like Microsoft [Corporation], when you take a single individual to do what they're doing, it's just hard to understand. But that's what it takes is some leadership and the motivation to make a team to do something. It really does.

JOHNSON: Is there anything that you're most proud of, any accomplishment?

SILVEIRA: Well, I have to admit that probably having four children that are fairly successful is a big accomplishment, as far as I'm concerned. I have three out of four are engineers, so I figure that's pretty good.

JOHNSON: And working for NASA, a couple of them, right?

SILVEIRA: Yes. I think that it was gratifying that they thought that what you were doing was important and they wanted to do the same thing, too. But I still stay very close to where I went to school, the University of Vermont [Burlington, Vermont]. I'm on an advisory board for math and engineering, again with the idea to get these younger people to get the best opportunity they can to be able to go out and do things. I think that's pretty rewarding to do. I found out that this position on this advisory board is supposedly for three years, and then I figured out the other day that I've been on the board for twenty-five years now. [Laughter] So I guess it's working.

JOHNSON: You're doing a good job. [Laughs]

SILVEIRA: I guess they like what I'm doing or whatever.

JOHNSON: That's right.

SILVEIRA: Something like that. But it's rewarding to have people come along behind you and be accomplishing things.

JOHNSON: Is there anything that we haven't talked about or any specific projects? Any anecdotes that you'd like to share? Anybody, any person that you'd like to say something about before we close?

SILVEIRA: No, there are just many, many people that you'd like to talk about, and how they helped. I think the first experience that I had in program management with the Little Joe II Program that I worked with their program manager at Convair, Jack Hurt. He was very helpful to teach me [about program management]. I think during the Apollo and the Shuttle Program, again, an individual at North American, or Rockwell now, Charles Feltz, was very useful to me. With the development of the thermal protection system [for the Shuttle], Jack Milton at Lockheed was very helpful along that line.

When I came to Headquarters, in addition to Hans Mark, the Administrator, Jim [James M.] Beggs, was very useful as far as learning things from Jim. We're still very, very good friends.

I go all the way back to college days, and I had one professor that taught a single course in aerodynamics, [Howard Duchacek]. We only had one semester course. He's dead now, but I'm still close to his wife, and I used to kid him about based on that one course, I became Chief of Aeronautics at JSC, so I thought that was a pretty good course.

JOHNSON: An effective course. [Laughs]

SILVEIRA: Yes, and I've been blessed [to work] with a lot of good, interesting people in my lifetime, and it's been a lot of fun. It really is.

JOHNSON: Well, I thank you for coming today and sharing your career with us again.

SILVEIRA: Thank you. It was a lot of fun.

JOHNSON: Good.

[End of interview]