# ORAL HISTORY 2 TRANSCRIPT

CHESTER A. VAUGHAN
INTERVIEWED BY SUMMER CHICK BERGEN
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BERGEN: Today is January 12, 1999. This oral history interview with Chester Vaughan is being conducted for the Johnson Space Center Oral History Project at the offices of the Signal Corporation in Houston, Texas. The interviewer is Summer Chick Bergen, assisted by Kevin Rusnak.

Thank you for coming to talk with us again.

VAUGHAN: It's my pleasure.

BERGEN: Let's start back up—we'll back up a little bit from last time we talked about Apollo. We were talking about anniversaries before we started. This year will mark the thirtieth anniversary of Apollo 11. Can you share with us your memories of that event?

VAUGHAN: Well, it was a great event. It's also the thirtieth anniversary of all the things coming up to Apollo 11. Apollo 8, which is the anniversary we just passed, was probably one of the most demanding and challenging decisions that was made by NASA management to go do the Apollo 8 mission at the time that we did that.

But the Apollo 11 was just tremendous, along with Apollo 10. See, if you've been working on an objective for eight or ten years, and a lot of us had been working on it since 1962 or so, it's really a good feeling when you make it happen, see it happen, and then get the crew back safely. So, a great feeling.

BERGEN: Wonderful. Did your group or any part of your group play a part in the recovery of the Apollo 13 mission, with all the problems they had?

VAUGHAN: Well, we supported the mission, obviously, very much. The Propulsion Power Division, which I was not heading at the time, I was still section head in the reaction control area, but we had people who worked with the failure investigation after the flight. We also had people who helped understand and provide information about the various propulsion systems during the mission. We had not used the lunar ascent engine or the descent engine in the fashion that we used it, and I guess it was a descent engine then, now that I think back on it, that was used for the mid-course corrections and for bringing it back to doing the trimming to come back to Earth, since the service module engine was not available.

So when we had not tested for that directly, and, yes, we had people, not me personally, but people within that division that were working to be sure that we would get the expected performance and operation of that hardware. And we worked with the power team as well. We provided the fuel cells and electrical power, because the fuel cells were already down after the service module went down, but we were using the batteries. The Propulsion Power Division were responsible technically for the batteries, and they knew we had an awful lot of insight into how they would be used and how long they would last and so forth. Electrical power, if you remember, was a key parameter—having enough.

BERGEN: Right. As you said, you worked on the Apollo Program for so many years. How did you feel when it finally came to an end?

VAUGHAN: Well, it didn't end just abruptly. After Apollo 11, we had Apollo 12 and 13 and all the way up to 17. So we tapered off on the program. It wasn't as if we came up to a cliff. The coming up to the cliff was basically getting the first objective done, of getting people

there and back. Generally, by the time we'd actually done that, it was pretty well known or becoming to be known that the Russians were not really as much in a race as we thought earlier. We didn't know that for sure until after we'd done it, but it came out later, well, they really weren't trying too hard, or what have you, you know.

So it's certainly challenging to meet your goals, and that is to get them there and back within the decade. We just barely beat it. We'd hoped to do it a year or so earlier, but we were pleased with the overall objective. But the Apollo Program was continuing, and we were adding experiments on board and trying to learn more about the lunar surface. So it's not as if it was just coming up to a cliff and have an abrupt end. We were able to taper off.

BERGEN: After Apollo, did you work any on Skylab?

VAUGHAN: Well, really before Apollo. You know, most programs take a long time for the development, and to be honest, even in 1966 or '67 time frame, we worked on a space station and did some concept designs on a space station and what it might look like. That work eventually evolved in what was called a wet workshop, which was the S-IVB stage, if my memory's right, of the Saturn launch vehicle. The plan for the wet workshop was to launch it with propellant in it, and then to go up and use it as an orbital workshop and put in your equipment and so forth. Some of it would go in before launch, but most of it would go in after launch. Obviously, as we studied that more and became more realistic with the program, we eventually wound up launching Skylab, already outfitted and ready for human occupancy at launch time.

Yes, we worked on that, and even though it was primarily a Marshall [Space Flight Center] undertaking for the Skylab itself, the command service module, for instance, still had to have the capability to dock with it, to provide some control, and to get the crew up and back. The big new difference was on this on-orbit stay time, having to be there with the

command service module up to ninety days. If you'll remember, all of the Apollo missions were only fourteen days. So it was a pretty long extension of the capabilities of the command service module. And from my division's standpoint, we had to work those issues and be sure that the systems had that capability. Didn't want to be there for thirty days or fifty days or sixty days or ninety days and then find out you couldn't get home. So we needed to be sure to get them home before we started.

BERGEN: That's right. As the Shuttle era approached, and as you said before, all the programs seemed to overlap, but there was somewhat of a gap between ASTP and the first Shuttle flight. What was the mood like during that period of time?

VAUGHAN: Well, there was a gap in the flights; there was not a gap in the work. The development of the Shuttle started in, I believe, 1972. I believe we had the first contract and it actually started internal studies and so forth even earlier than that. We had the first contract, I believe, with Rockwell [International] to do the orbiter and to start on the overall integration for the Shuttle in either '73 or '74. My memory's a little hazy on when that contract was written.

Of course, we were very, very busy in the engineering world, of going through and scoping out what those systems—what the requirements were for those systems and understanding from preliminary design standpoint what kind of capability we required of those, and then what it would take to go and develop them, and to bring that gap, most of that gap, we were actually into what we called the design, development, and test verification phase of the Shuttle Program. You'd like to not have that much time between flights, but you do need a fair amount of time for the DDT&E [design, development, test, and evaluation] development, keeping in mind that the Shuttle, I mean, it was advancing the state of technology in several areas, so it was a big development activity.

BERGEN: And you were, in the early stages, still working in the RCS [Reaction Control Systems] area?

VAUGHAN: That is correct. Shortly after the Shuttle got going, I do remember going out to Downey [Rockwell facility in California]. Well, first of all, I worked with proposal evaluation on the Shuttle and worked with the proposal—I guess it's called request for proposal, getting the requirements squared away, and then worked on the Proposal Evaluation Team as the proposals came in, and I also remember going out to Downey and working with the fact-finding team, trying to understand what their bids were and what the costs were, and the development time and that sort of thing. So I spent a fair amount of time at Downey, California, doing that. I think that was probably in 1974. My timing may be a little bit off.

BERGEN: As you worked on the development of the Shuttle RCS, what kind of advances or differences did you have from what you worked on in Gemini and Apollo?

VAUGHAN: Generally in the RCS systems, the big new requirement was for reusability. With reusability, you have the issues associated with leaving the propellant in the system when it comes back to Earth or taking it out. And if you take it out, part of the issues with the hypergolic propellant systems is that when they get moisture in those systems, it creates some other bad chemicals and is very bad for us. We did some special work early in the seventies, some test work, that helped us decide that we could, in fact, reuse these propellants. A lot of people had assumed that they would be unable to do that. In fact, early on, there were oxygen-hydrogen systems baselined. Primarily because of the reusability, they also have a little bit increased performance from an engine standpoint. The overall

system didn't have any increased performance, but when you looked at it as a thruster, I mean, it would have a higher ISP.

In fact, during the Phase B portion of the Shuttle Program, the baseline was an oxygen-hydrogen system, but the type system we wound up developing was a what we call [unclear] hypergolic system. Similar—same propellants, basically, that we used for the Apollo RCS.

My group at that time, in addition to doing RCS, we had some new things on Shuttle that we didn't have to have on Apollo. One of those was the hydraulic system to provide controls, hydraulic power to control the surfaces of the Shuttle wings and to provide the energy to gimbal the main engines and that sort of thing. And we also had to have a system to drive the hydraulic system. On airplanes you either have the big jet engine that's going full time and it's easy to take a little shaft power off of the big turbine and drive the hydraulic pumps.

Of course, on Shuttle, while initially we had air-breathing engines, but they didn't last very long because they were so heavy and they were difficult to get to orbit and get back, but when we did away with those, we did not have a power source, so we had to have what we called an auxiliary power unit [APU] to drive the hydraulic system. We still call it an APU, an auxiliary power unit. It's really not auxiliary; it's a primary power unit for the hydraulics. My group was given the responsibility for those two additional activities as well as the RCS.

So we took on some new challenges, some things that had not been done before. The APU, if my memory's right, the state of the art at that time. We'd used them as energy power systems, generally having to last ten, fifteen minutes to get an airplane down, some of these military airplanes, from high altitude back to a landing, if they were to have a main power system failure. In other words, if the main jet failed. But we were looking at much longer operating times, plus reusability on the auxiliary power system and hydraulic system as well. So it was some new challenges involved.

BERGEN: Great. In 1975, you became deputy chief of the Thermochemical Test Branch and then, three years later, chief of that branch. How did your responsibilities change as you took on this new role?

VAUGHAN: Rather dramatically. I was still dealing with components of the same systems I had been dealing with before. There were some added systems. That branch was responsible for providing test support or testing of the kinds of components for the rest of the division. The rest of the division was also involved with the fuel cells, the batteries, the pyrotechnics, as well as the main propulsion system, although we didn't really do very much work on the main propulsion system in the thermochemical test area.

We used the thermochemical test area to understand how the hardware would perform, what kind of issues we might have with it. We eventually wound up doing the space qualification testing of the auxiliary power unit in those facilities in the ‘77-‘78 kind of time frame, but an awful lot of direct mission support.

Of course, when you're out testing, it's a little bit different from a theory standpoint, from the overall systems that you're dealing with in propulsion and power. The difference is that what you decide that morning, you may go implement that afternoon. So, you know, the timing of it was much, much different and we were dealing with high-energy propellants, and you had to be very careful. High-energy propellants, high-energy systems, pyrotechnic devices, of course, they do have a lot of energy and they require a lot of energy, but you have to be very careful with them and treat your procedures exactly right and have a lot of discipline in the test program.

So that was a new environment for me, but it taught me a lot and I learned a lot by doing that.

BERGEN: Do you have any particular instances, events that happened during that time period, that stick in your mind?

VAUGHAN: Well, yes, several. But one that probably would maybe be best to relate is that we were doing development testing on an auxiliary power unit, the APU that we talked about earlier. We ran an altitude simulation in an altitude chamber, and we restarted the unit, left it at vacuum, under vacuum conditions, so we'd run what we'd call an ascent profile; in other words, during the ascent portion of the mission. And then we shut it down and simulated an abort once-around [AOA] mission, which means that you shut the unit down for a short period of time while you're going around the Earth one time. During that time, the heat soak-back [phonetic] on the turbine heats up the injector rather high, and when we restarted the system about an hour, hour and a half later, it blew up. You know, we had done similar tests at the APU manufacturer.

The difference was that we had that test being performed at sea level, we had the exhaust products being piped to altitude, but the overall unit was under sea level atmosphere conditions, so the amount of heat soak-back during the test at Sunstrand [Corporation] did not result in getting the hardware quite as hot a temperature as it did in the real space environment, because we didn't have conductive cooling.

What happened was that the hardware was just too hot. It created a bubble or gas pocket in the feed lines for the APU, and when we started the APU up and opened the values and that gas ran out and then was recompressed very rapidly, it took us about a year, year and a half or more to figure out exactly what happened. But it turns out that we had generated a bubble, and when it got recompressed in starting this system—it's called adiabatic compression, and adiabatic compression heating, and it was enough to detonate the hydrazine and cause the system to blow up.

Turns out, had we not run those tests in that facility, had we had an abort once around, which we've not yet had in the program, but we are certified to do that, we would have lost our units. We grow bubbles in it, and it would have happened. It was just a difference in the way we simulated the environment that the hardware would see.

As a result of that, we put in a little cooling system, pretty simple. We didn't have much time to do it, but one of the ways to do it is we had a thermocouple in areas where it would get hot, and we developed a little water system, and actually just spray a little water on it to cool it back down. So we were able to fly the basic hardware that we had, but still be able to do the abort once-around mission if we needed to do that. And that one stands out, still.

BERGEN: Makes you realize how important that testing phase is.

VAUGHAN: No question. Of course, the first thing that happens is you have to justify your test set-up, and to be sure that we didn't do something different than what the manufacturer had done to cause the hardware to blow up. That's a natural reaction. "You guys must have screwed it up." And you're always concerned about that, because it's difficult to get everything exactly right.

Turns out, that was a very, very good test. We wound up doing an awful lot of work for Sunstrand after that, where they brought their engineers down and we worked together, trying to be sure we had a good system, and we worked all the way through the initial Shuttle missions.

I don't know if you remember, but we had a fair number of APU problems early on in the early portion of the Shuttle Program. In more recent flights—and I'm talking about since *Challenger* [STS-51-L] and since fixing a lot of the problems we had on APU—we've not

had any flight aborts for APU in a long time, and we're glad. But early on, we had several missions that were aborted because the APU was not performing correctly.

BERGEN: During this time of the intermediate Shuttle development and later in the eighties, you were on several Accident Investigation Boards and special committees and things of that nature. I'd like to talk about a couple of those. In 1980, there was an accident involving the Shuttle extravehicular maneuvering unit, and you were on that accident investigation. Can you tell us about that event and your role in that?

VAUGHAN: Well, yes, I could do that. And they were interesting. I was sitting in my office one Friday afternoon, minding my own business, and things going pretty well. I was out in the test area, you know, and as I told you before, we have to watch our stuff pretty carefully or things can go wrong. Anytime you saw or heard the fire engines, you always went out back or went and looked to see which direction they were going. They didn't come our way all the time, but they came our way more than a few.

That particular afternoon, I had heard them, saw them come down, but they were going in the other direction toward Building 7. Of course, that was not my concern. About an hour, hour and a half later, I had a call from my immediate supervisor, Mr. "Guy" [Joseph G.] Thibodaux, and Guy says, "You're going to get a phone call from the head of SR&QA [Safety, Reliability & Quality Assurance], and he's going to ask you to take on a special job. You need to think about what you're going to answer, how you're going to answer that."

A little bit later, I did get that phone call, within ten minutes or so, and I was asked to head the Failure Investigation Board for that. And I agreed to do that, because it's kind of hard to say no. They had named the rest of the board members. We called an initial meeting later that afternoon on Friday. That Friday, instead of leaving early at two, three o'clock or so, I think we finally left the center at maybe eleven o'clock or so.

But there had been a fire in Building 7. There was an EMU [Extravehicular Mobility Unit]. The overall suit was laid out on the test bench. I don't know if you've see pictures or remember any of the photos. No one was inside the suit at the time, thank goodness; they would have been killed had they been inside. This was the last test that they were planning to run before someone would have been inside, so it was close. But an individual that was operating the suit, he had to reach over the suit and activate a mechanism on the EMU, and he got burned pretty badly, so he was in the Galveston Burn Center that evening.

When you looked at the pictures or looked at the suit itself, you see the helmet up there and the whole business laid out on the table, and then this big burn hole right around the stomach area of the suit. It looked very much like as if that was the person and someone burned in there. We were debating as to whether we should even release the pictures, because most people might believe that we had someone inside the suit. Thank goodness we did not at that time.

The other issue that we had to deal with is that that system had some high-pressure oxygen tanks, two of them. They're called a secondary oxygen [propellent]—SOP. Second oxygen propellant, maybe, or pressurant. We were not certain as to whether those high-pressure tanks had vented or not, so here we were with a system that had been involved in a fire, and we did not know the condition of the tanks. We wound up not knowing that till the next afternoon. I took some of my technicians from the thermochemical test area, in fact, and put them behind some shields, and they went in and looked, again just trying to be sure we didn't have someone hurt in a secondary event.

So it was an exciting six weeks, a long six weeks, but we finally got to the bottom of that and had good support from all the team members, and we were able to make improvements in the system that served us well.

BERGEN: Great. You also participated on an Investigation Board that looked at an incident in which a nitrogen tetroxide spill damaged Columbia's tiles. Do you remember that incident?

VAUGHAN: It's hard to not remember it, of that magnitude. That happened at the Cape, on the pad. What happened was, we'd flown the first STS-1 mission, we'd gotten the vehicle back successfully, we were preparing it for the second mission, and in loading the hypergolic propellants, the nitrogen tetroxide, as the oxidizer, when the team was loading the forward module—and that's up above the windshield and the nose area of the Shuttle Orbiter—when they got ready to disconnect the ground support equipment from the flight hardware, the quick disconnect failed, and it failed in an intermediate position. It's supposed to be either open or closed. When it's open, you can flow the propellant into the vehicle. When it's closed, it's supposed to shut off the flow path. It failed in an intermediate position, so the valve to the system was closed, but the flow passage from the ground support equipment, which also has propellant, was open, and so it continued to flow propellant that had no place to go except to the outside and get on the tiles.

They were able to detect that situation and correct it within a pretty short period of time, a minute or two, but by then we had spilled a fair amount of nitrogen tetroxide on the tiles. That overall event would have been almost a non-event had it not been that the tiles and the—I don't know if it's glue or exactly how—it's not glue, I know it's not, but the tile attach materials were not compatible. So in an hour or so, the tiles started sliding off the vehicle. So we had to go through an awful lot of work to be sure that we'd gotten all the tiles off that were affected and to replace those to be sure that they would be okay for the next flight.

The other thing we had to do, obviously, as part of the review team is to go in and understand exactly what had happened—it wasn't obvious what had happened—and

understand what corrective action we needed to do on that. I was not the team lead for that activity, but I did support it from JSC [Johnson Space Center], and I spent probably a month or so at KSC [Kennedy Space Center] during that time.

BERGEN: In 1984, you became deputy chief of the Propulsion and Power Division, and then two years later, chief of that division. Again, your responsibilities probably changed dramatically.

VAUGHAN: They did. And what I said earlier was that my work at the Thermochemical Test Branch was very important in terms of teaching me not only the test disciplines, but we were also testing hardware that were the engineering responsibilities of the other branches within the division. So by the time I came up to deputy division chief and, later, division chief, I already had a lot insight into the other systems that the division was responsible for. So that was very helpful in getting me ready for those jobs.

Of course, the Propulsion and Power Division is responsible and still—well, was until we turned over an awful lot of it to the USA [United Space Alliance] contractors that we had, the subsystem managers for all of the propulsion systems, the power systems, the pyrotechnics, the hydraulics, APU, and those things, most of them dealing with high-energy propellants and high-energy materials so that you had to be very, very careful. They enable you to do space flight, but they can also get you in real serious trouble in a hurry.

BERGEN: In 1991, you had a pretty significant change in jobs. You became chief engineer in the Office of Space Flight at NASA Headquarters, and you were the first person to ever have that position. So you had to basically develop what roles that person, that job was going to have, right?

VAUGHAN: That is partially correct. Turns out that the job I went to was given a new title as chief engineer for the Office of Space Flight. Dr. Bill Lenewell [phonetic] was head of the Code M [Office of Space Flight] at that time, and he had had Hank [Henry W.] Hartzfield up earlier doing a similar job, although Hank did not have that title.

You know, the chief engineer for Code M is a pretty big title. I wondered exactly what you're supposed to be, because you can't be the smartest guy on everything. In fact, you know you're not. What you're trying to do is coordinate the activities and be sure that things are done correctly and to try to give the Washington program managers, like Dr. [William E.] Lenoir and others, the right perspective on engineering kinds of things as they come up.

So, yes, I enjoyed that year here. Bill Lenoir would have liked to have made that a more permanent job. I didn't want to stay that far from Houston that long, and he agreed that we would make it one year. We did that, and that was a big learning experience as well.

BERGEN: So you decided to come back to JSC after that?

VAUGHAN: Yes. Aaron Cohen was our center director at the time, and Aaron and Henry [O.] Pohl were gracious enough to leave my job as Propulsion and Power Division chief, and Ralph Taeuber ran the division as the deputy while I was gone, so I was able to also come back to the job I had prior to that. So they were both very, very good to me.

BERGEN: Great. Shortly after your return, you were promoted again to deputy director of the Engineering Directorate.

VAUGHAN: That is correct. You know, I hadn't necessarily expected that. The things that were happening in the interim was the Space Station redesign and the Crystal City activity,

so that there were a lot of things going on both at the center and at headquarters with respect to organization and that sort of thing.

Henry Pohl wound up, he had been director of engineering for the Johnson Space Center earlier than that. Henry was the design lead—well, was the lead for the Johnson Space Center, who had the lead on Option C for the Space Station redesign. If you'll remember, we had three different options that we were chartered to look at, and Henry basically took himself out of Engineering Directorate role and moved over to head up the redesign activities associated with Space Station for Option C. Henry elected to retire after that point in time, and it turns out that the deputy director had retired—Max Engert—and so Leonard Nicholson was appointed as engineering director, and shortly thereafter he asked me to come up and I served as his deputy for several years.

BERGEN: You mentioned the Space Station redesign. Can you talk a little bit about that and why it came about and what your role was in it?

VAUGHAN: Well, it's hard to know all of why it came about. Obviously we changed administration with the [President Bill] Clinton administration coming on board in 1992. And that was coupled with the fact that we were having some fairly major technical and management difficulties in the Freedom Program. My understanding, although I'm not sure if it's true, but my understanding is that President Clinton, as he came on board in his new team, basically had the Space Station on the chopping block; in other words, planned just to cut it out of the program and not have a Space Station.

As you know, Mr. [Daniel S.] Goldin was already NASA administrator, and as I understand it, Mr. Goldin pleaded with them and got them to agree to allow him to redesign the station as opposed to totally canceling it, try to get it under better control and to reduce the overall projected cost of the program.

As a result of that, there were a group of us that were called to NASA Headquarters back in probably February '93, and at that time we were going to do the work at Headquarters, or at least in this task force at Headquarters, and we were challenged to come up with three different options that would be available for the administration to select from. And we spent time on that from about February of '93 until around June '93. The Best Committee was set up, a blue-ribbon team, headed by Dr. Best from MIT [Massachusetts Institute of Technology], and he had an overall team, and we reported up through that team, and they reported through the administration and to the White House. Big-time activities during that time.

BERGEN: Did you work on several of the options or just on Option C?

VAUGHAN: Well, I was there at Headquarters during the total time. At Crystal City, not at Headquarters, but near Headquarters. Obviously I was exposed to all of the options, and there were certain parts of the program that would be constant, independent of which option was selected. But I was the lead for Option C, so I spent most of my time on Option C and dealing with Henry Pohl, who was making real work happen, he and John Aaron down at the Johnson Space Center. So we did an awful lot of design work very rapidly, trying to get that option defined and have it ready to present.

I did have the opportunity to present. I think we presented either two or three times to the blue-ribbon committee, in public. They were public hearings. So we went down to the big conference room and provided status for a couple of times, and then kind of a final briefing to them, end of May, early June '93.

BERGEN: So what was your opinion on the configuration of the station that was finally chosen?

VAUGHAN: Well, one problem with the station is that there's so many different configurations that are okay. I mean, you know, in fact, I've frequently told people that one of the difficulties we've had with the Space Station is there's so many options, we've not stuck with one long enough to get it going. So I believed, and still believe, that Option C would have been a better option. I'm sure I was biased on that subject.

I can tell you that our projected cost for it was less, and our projected flying time, getting it on orbit, was quicker. In fact, we went to the congressional hearings on the day that the selection was announced, and we got there before it was announced. In fact, the hearings were about an hour late starting, and there was an announcement sheet put out before the hearing started, and it indicated that they had selected Option A.

I can remember Congressman Hall asking Mr. Goldin, "Mr. Goldin, I understand Option C was cheapest, had more capability, and could fly faster. Why did you select Option A?"

And Mr. Goldin's response was that he would let Dr. Gibbons answer that. And Dr. Gibbons, of course, was the White House scientific advisor, I believe was the right title at that time, and Dr. Gibbons' comment was that it just wasn't the right time for Option C. Some of the internationals were very much opposed to it. They felt like it diminished their contribution toward the program, and there were some other difficulties with it that they were concerned about as well.

So, you know, again, we had three options on the table from our standpoint, and, in fact, we were encouraged to—not encouraged, but—I don't want to say "lectured to" either, but basically told, "Hey, let's just lay it on the table, what this is, and not try to do any selling of the various options." This was for the last presentation we did to the blue-ribbon team.

And I think each of the three leads, in fact, laid the best facts on the table that we could. From a NASA standpoint, we were chartered with being sure that either of the three

options were okay. And I'm okay with the option that was selected. You know it was modified rather dramatically. It started being a U.S. option—not a U.S., but it did not include the Russians. And later, the Russians, later in '93, in fact, the Russians were brought into the program, and it changed the program some, but not dramatically, the most dramatic part being the use of the Russian hardware, including propulsion, in the way we build the station. We would have assembled it in a little different configuration, had we not had the Russians involved.

BERGEN: Did you play some role in bringing the Russians into the Space Station?

VAUGHAN: Not directly in terms of deciding to bring them in. Once that decision was made, in fact, during the redesign, each of the three leads did brief the Russians on what we were doing several times.

Turns out, even though the Russians were in the Washington, D.C., area during the redesign activity and we had some discussions with them during that time, either the Congress or some part of the government had not cleared us to involve the Russians in the program at that time, and it was after the decision was made on Option A in the August or so time frame, maybe September, that the Russians—we were looking at bringing the Russians into the program much more heavily.

I did go back to Crystal City after coming back to Houston in June. I went back to Crystal City in the August-September time frame, helping to find what roles the Russians might play and how the hardware configurations might go together, and I did go to Russia in early—not early, but in about September-October '93, again exploring ways that we might be able to use the Russian hardware.

BERGEN: Your last position that I'm aware of at NASA was as chief engineer of the Space Station. Was that your last position?

VAUGHAN: That was my last position. I had the opportunity to do one another job in the meantime, and that was in about the '94 time frame. The center director at the Marshall Space Flight Center, [G.] Porter Bridwell, had decided that he wanted a rotating acting deputy center director, and he'd had a guy from Langley come down and do that job with him first, and after the Langley guy's six months was up, I was asked if I'd go do that, and I did that for four months. It turns out that there was some other changes at Marshall and my tour was cut short, but I did spend four months at Marshall as the acting deputy center director working with Porter and with the Marshall people, and I thoroughly enjoyed that. I knew a lot of the people already, but, you know, we formed some bonds that still exist today.

So when I came back from that one, Dr. [J.] Wayne Littles, who had been announced as Code M chief, asked me if I would come and be chief engineer for the Space Station. If you'll remember, at that point in time, that would have been late '94, maybe early '95, I think it was actually early '95, the centers had not been very involved in the station. In other words, the blue ribbon Best Committee had said, "Hey, you centers get too involved in these programs, you inhibit them too much. We want a very small program office and not bring the centers into it very much."

Well, the chief engineer's job in trying to bring the strength of the organization, technical strength of the organization, back to the program, I think was started with the set-up of the chief engineer's job. I was still assigned to the Engineering Directorate, but I was working very, very closely with Mr. [Randy H.] Brinkley and his team. There were a lot of people who were skeptical about that, because they weren't quite sure what responsibilities I would be resuming that they had had all on their own previously. It turns out that what we were really trying to do is bring some of the technical strength of the centers to bear on the

program to make it a better program, and I believe Mr. Brinkley and others would believe that we were successful doing that.

So, I enjoyed it, and that was my last position working with NASA. It was very enjoyable. Mr. Brinkley is a tremendous individual and a great program manager, and I enjoyed working with him.

BERGEN: So, when exactly did you leave NASA?

VAUGHAN: I left NASA in—let me get the year right here. Must have been February '97. So, from about early '95 until a little over a year. I may be off a year. Sounds like I'm off a year. I spent a little over a year as Space Station chief engineer. And I've been with Boeing [Company] for, what, a little over two years, two and half years now. So we're '99, three years from that would have been '96. Maybe I left NASA in February '96.

BERGEN: And what do you currently do at Boeing?

VAUGHAN: Well, it's a lot of the same things I did as chief engineer for NASA. I'm not the chief engineer by title for Boeing, but I do an awful lot of troubleshooting. My job title says "independent assessment," and I report directly to the vice president and program manager for the Space Station on the Boeing side. Doug Stone says, "Well, you know what it is you need to do. Go figure out what it is and do it." So he gives me an awful lot of flexibility, and I try to work with, from an engineering standpoint, what trouble spots that we have.

What I do more than anything else is try to help with the communication and getting the right people together, getting the right dialogue going so we can solve the problem at hand. And there's always a problem at hand, so no lack of work.

BERGEN: So, looking back at the achievements that have been made in the Space Station in the last few months, even, can you give us an overview of the positive and maybe some negative of what you see in the Space Station Program and its future?

VAUGHAN: The negatives—and I'll cover those first just to get them out of the way—the negatives are, we should have been flying a long time ago with Space Station. Most people think of the Space Station as our first Space Station. Obviously, if you think back, Skylab was really our first one. We should have figured out a way to keep it up and to use it, and we did not do that. It's taken us much too long to get the station flying, for some of the reasons we've talked about.

The good-news part is that we've already got it started. We have a long way to go. And some of the good-news parts of it are that we took the hardware that was designed and developed in Russia, other hardware that was designed and developed all over the U.S., and we're putting that hardware together and it's working. We have a long way to go, because we've only got two elements up in that mode at the moment, but we've got many other elements that are already at the Cape and being prepared for flight.

We've got the service module, which will be shipped to their launch facility, I think it's in mid-February or so this year. In fact, I'm going over to Russia later this week, and we'll work with the acoustics team, trying to be sure that we're running the right tests and understand what the acoustic noises are inside the vehicle, because if they're too high, we have to take some measures to quiet it down some.

But that hardware is also getting ready to fly. Once we get the service module up and operating, we'll have the course systems that we need to really support station, not independent of the Russians, but if they didn't bring any other hardware except for the resupply vehicle, the *Progress* vehicle, it would not inhibit us from finishing out the build on the U.S. side and providing the capability on the U.S. side. Now, obviously we hope that

they bring their research modules and power tower and those things to the program, but we will not be dependent on those as we are with the service module.

So we've got a big milestone coming up, hopefully in July, that that vehicle will be launched, the service module will be launched, and once we have it on and operating, we'll have made a big, big step. I think if you take a look a year, year and a half from now, we'll have us an operating station that has a tremendous amount of research ability. And as we complete the build, it'll have capability that will not even have been close to anywhere in the world in the past. So it's still exciting, and it's good to be a part of that.

BERGEN: Great. You've been in the space program for many years and seen many programs go by. Looking back at the past few Presidents, [Ronald] Reagan made a pledge of a space station within a decade in 1984, and then, next, [President George] Bush came along and announced initiatives to finish Freedom and establish a permanent base on the moon and then later go to Mars in thirty years. They didn't seem to get the public backing that [John F.] Kennedy got in the sixties. What kind of change have you seen in the American public with regard to the space program?

VAUGHAN: I think the American public still supports the space program, very much so. A primary difference is that we didn't have the Cold War emphasis associated with the country, you know, the Soviet Union at that time, who had supposedly declared that they would take over the world. I mean, and that was not a secret. They announced that as often as they could. I think when the Soviet Union put the first unmanned spacecraft into orbit first and then the first human in orbit, it showed that the U.S. could potentially, at least, be far behind them, and they were making an awful lot of, if I can say hay, or at least positive propaganda on those events toward world opinion and toward their objectives for being able to control the world, it woke a lot of people up in the United States.

When President Kennedy realized what we needed to do to get our energies focused and to be sure that we were, in fact, foremost in the space technology, most people believed that whoever ruled space would also rule the world to a very large extent, particularly if they were going at it trying to rule the world from a military standpoint.

The Space Act of 1958 did put the space and with some worldwide agreements that we would not use space for military operations, we all know that even though we've not attacked from space, it has been used for espionage and for understanding what's going on around the world, and the U.S. has done an awful lot of that, too. I think it's that atmosphere and the fear of the American people, and the challenge, of beating the Russians to the moon and being foremost in the technology is what gave us the kind of support that we had from a Congress and from the American people standpoint.

I think the American people still support it. It's just that it costs a lot and there are other priorities. I don't think there was any lack of belief from President Reagan's standpoint that he could have the Freedom Program flying in the decade.

VAUGHAN: It's just because of all the difficulties that we ran into, both management and technical, along the way, and funding, we were not able to do that, but I believe those guys thought we could. I think the same is true with President Bush. And who knows what we'll have in the next thirty years? They're not up yet.

I will say that an awful lot of people, including the general public and a lot of people who are in the space business, don't totally appreciate what it takes to get beyond Earth orbit. I mean, it takes a lot to get to Earth orbit, as you know, but it takes a lot more to get beyond that. I can remember Dr. [Robert R.] Gilruth saying more than once after the Apollo Program, is that people will understand how hard it was to get to the moon the first time when they try to go back. They'll find out how difficult it really was. Of course, we've not been back in a different program yet, so that's still in front of us.

BERGEN: We have a few minutes left, so I wanted to see if Kevin has some questions for you.

RUSNAK: While you're reflecting back, you've commented on changes in the American public's perception. How would you say NASA has changed from the inside in the past forty years? We're celebrating the fortieth anniversary [of NASA], or it just ended.

VAUGHAN: Well, it's hard to know. I mean, organizationally, the organization grows up and becomes a bureaucracy, and then it reinvigorates itself. Most organizations go in cycles like that. We wind up with a lot of people thinking back and looking at a new program and deciding what we need to do is put things in place to keep us from making the mistakes we made in the last program, and you do enough of that and it puts a lot of bureaucracy in place.

But for the most part, it hasn't changed all that much. We've had a lot of new people coming into the program. I think most of them—I know most of them are much more capable and have better tools that we had in the sixties, from the computers and the analytical capabilities and so forth, and an awful lot of enthusiasm throughout the program.

The challenge is not quite as great as it was because of the national defense and the national survival that we had when we were in a mode of survival and competing with the Soviet Union, but I think that the scientific exploration and the engineering achievements are still something that a lot of people get excited about. I know a lot of people still work just as long hours or are just as excited about the jobs now as they were during the sixties.

So, changes, yes. Some better, some not so good, but overall the program's still strong and doing well, I think.

RUSNAK: A lot of the people who worked on Apollo, for instance, such as yourself, have left NASA. What impact do you think that will have on efforts to essentially repeat going to the moon or more advanced projects?

VAUGHAN: It's hard to say. Again, the two sides. One is that when you go back, when we get ready to go back, the technology will have changed so dramatically that we wouldn't want to use the same systems that we had last time, so it's not a matter of coming back and reengineering those systems. So you want to take advantage of the new technology, you don't want to be hampered by the things that bit us during the Apollo Program, and you wind up with a little bit of both of that.

The main difference that I see is that the country does not have as much work going on as I'd like to see in the propulsion area, with the big propulsion systems, the high-energy systems, and what we need to do is to be sure that we don't let that technology and that capability die on us. There is some very special analyses and development things that you need to do to make the big engines, like the Space Shuttle main engine that's a real model in the world, still today. An awful lot of people that worked on the development of that engine and understand why it happened and how it happened, and what to watch out for, certainly won't be with the program. What we need to do—and I think what we are doing, to a large extent—is keeping enough activity going so that we do have a core of people who understand and can do that type of work for us.

In terms of avionics and structures and so forth, the big airplanes that we've got going now and the other things that are happening in the computer and the overall avionics world, I mean, including GPS's [Global Positioning System] and all that good stuff, you know, that ought to just make things easier for us. So I'm more concerned in those areas that don't have other commercial application.

We do have an awful lot of commercialism going on, as you know, in the unmanned space business right now, particularly with communication satellites and those kinds of things. Boeing has the Sea Launch Program going. Boeing also has the Delta IV Program going. And I know that there are several private initiatives looking at two-stage fully reusable systems. So hopefully there will be enough overall activity to keep both the spacecraft and the propulsion systems technology in hand and enough capability to really implement that when it's ready to go.

RUSNAK: Also, last time we talked, you mentioned some people who had been important to you as a co-op at Langley. In the years since then, who would you say some of the key people had been, from your perspective, who have influenced you or who you regarded as role models or like that?

VAUGHAN: You mean in my career?

RUSNAK: In your career, yes.

VAUGHAN: Henry Pohl would be one of the first ones I'd say, Guy Thibodaux, a second. I think I mentioned both of those quite a little bit. Our organization in the division was stable for an awful long time. Henry and I started working together as co-engineers back in about '62, and we still get together and talk. Of course, I worked for Henry throughout that career. We both moved up together. Guy Thibodaux, another one. Max [Maxime A.] Faget certainly had a big, big influence on what we were doing throughout. And, of course, Dr. Gilruth, as a center director and remaining center director, I believe, what, until about 1970? I can't remember the timing exactly. But had a big influence. Dr. [Christopher C.] Kraft [Jr.], obviously. Aaron Cohen. So, different people we worked with.

One of the nice things that I found in my career is that all of my supervisors and management teams, and I'm including up to the Washington area, we would also deal frequently with Washington in our areas, would generally provide us with enough flexibility to go do what it is we needed to go do. And yet they provided us some very good direction in terms of limits on occasion, too.

One of the things that probably didn't show up in my resume, but I had the opportunity to work on, was the hydrogen leaks of 1990. You know, the Shuttle Program was down almost the year. It was like eight or nine months without any flights in the 1990 time frame, because we had hydrogen leaks on the pad. We couldn't get it to leak during checkout, but when we'd load the tanks and load the systems for flight, we'd find excessive leakage. I was on the team that finally went to Florida and tried to—in fact, we found the leaks finally and got them corrected.

But part of what was happening in the meantime is that we were taking various components off and taking them to various test facilities around the country, and Aaron Cohen, who was center director at Johnson at the time, finally said, "You know, guys, this leak happened in Florida. Let's find it in Florida." And what he was meaning by that is, "Hey, let's quit tearing the vehicle apart and go find the leak." I mean, that was pretty specific direction, and we took it, and we found it. Because that was the kind of guidance that we frequently got from my management teams, at least in my view.

RUSNAK: Did you still have time?

VAUGHAN: I'm not hurting real bad. I need to be back by 10:30.

RUSNAK: I just had a few specific questions, if you did have the time.

VAUGHAN: All right.

RUSNAK: Going back to the station redesign, the station Option C bore similarity to the Shuttle C concept. Did you draw any on that design heritage?

VAUGHAN: Some, obviously. I can't remember. Shuttle C, if I remember right, also brought the engine pods back.

RUSNAK: Right.

VAUGHAN: Yes. So it was a big payload, delivering big payloads, but bringing key elements of it back to the Earth for reuse. The space flight—I mean, reusable vehicles bring a down side with them as well, you know. I mean, the down side is, you don't have the production capability or the production line running that provides you the capability to build new items. The up side is that because you're able to reuse them, you don't need that production. But it does take away from your overall ability. Of course, when we don't have the Saturn V anymore and we've not had it for a long time, and if you're putting things in orbit 40,000 pounds each, and if you're wanting to go to Mars with a human exploration, it takes an awful lot of Shuttle launches to do that. So we know we need some heavy launch capability, and that's what we're trying to get with the Shuttle C, hoping to be able to reuse the engines and the more expensive avionics portions of the system.

In Option C, we were doing a similar thing, except we were going to take the oldest vehicle and just use the propulsion modules and the avionics associated with that, and not try to bring them back, but to put this large payload, the overall station into orbit with one single launch. So there were a lot of similarities, but an awful lot of differences.

We spent most of our time trying to describe the structure and the internal portions of Option C to make it into a good Space Station. It would appear a lot like Skylab, but be updated with the system racks and payload racks and have the flexibility that we're currently looking at, and updated with the current state-of-the-art other equipment and materials. So it was a much different approach to it, even though each of them we used the components from Shuttle and trying to get a heavy payload into orbit and recover. Shuttle C, the emphasis was not on the payload itself, but on what you had to do to get the recovery of the hardware that you'd want to reuse. And I'm talking about the main engines and the pods and the avionics. In Option C, we decided that would be too big of a hit. We would just not try to recover that, but get the overall vehicle launched in one launch.

RUSNAK: Earlier I think you mentioned that you had some exposure to the early Shuttle proposals and evaluating some of that. Do you remember any of the other proposals that weren't selected for the Shuttle, and would you have any comments on those?

VAUGHAN: Well, I remember the Lockheed [Corporation] proposal. I can't remember who we—we had, I think, three bids. I know Rockwell had a bid, Lockheed had a bid, and I can't remember for sure. There were a lot of things on the Lockheed proposal that we wound up implementing in the Rockwell plan, to be honest. I mean, we didn't copy them from there, but as they evolved, they looked a lot like it. But, you know, either one of those systems could have been made to work, and it was a combination of factors. I'm not sure what the overriding factors were and the overall evaluation. I was looking at it primarily from a propulsion and fluid systems standpoint. Either one of those companies could have done that job at that point in time, from that standpoint. Not but so many ways you can do that job.

One of the big discussion items is whether you have a straight-wing vehicle or the Delta-wing vehicle. Of course, Dr. Faget was always in favor of the straight-wing vehicle,

you know, and I think either one of those could have worked. It's a matter of choices, again, and by the time you get around to implementing it, you've got to decide which one you want to implement and then go do it.

As I said earlier, with the Space Station there were so many options, and when you're putting things together in Tinker Toys—"Tinker Toys" is the wrong way to say that—but in a modular fashion, launching 20, 30, 40,000 pounds at a time, then that gives you a lot of flexibility. That flexibility also creates an opportunity for a lot of people to change things around, and when you change them around, it sets you back and keeps you from getting up and getting it flying as quickly as you would if you didn't do that.

RUSNAK: Going back to Apollo, at the beginning of the interview and beforehand you've discussed the anniversaries, the thirtieth anniversary of Apollo 8 and Apollo 11. Which of those do you think was more significant, at least personally at the time?

VAUGHAN: Oh, they both were, particularly with 8 and 11. Apollo 8, you know, was the first time we had taken humans beyond the pull of the Earth's gravity. So that was the significance of that mission. Watching the vehicle as it slowed down velocity-wise, moving from the Earth toward the moon, and it continued to slow down, slow down, and slow down velocity-wise until it got to the neutral point. I don't know exactly how the—I mean, there's a special word for that. And then when the moon's gravity starts taking over and starts speeding up again. But that's the first time we'd seen that type activity with a human space flight.

The other thing that happened is that we wound up getting continuous data, essentially continuous data, once we started going to the moon and not in Earth orbit, simply because you had a line of sight to three big antennas that we had looking toward the moon. In all of the flights, including the Apollo flights that were Earth-orbital flights, we didn't have

the teachers that we have today for the Shuttle, so we wound up with short periods of coverage and short or long periods of no coverage. So, you know, the amount of data that we were starting to look at was significantly different on the Apollo lunar programs than they had been on the Mercury and Gemini Programs and the early Apollo Programs.

So, seeing the people escape the Earth's gravity certainly was big, not as big as landing on the moon, which is what our real objective was, and you've got to say that that had to be the biggest one, but they were all big. Each one of them, each of those flights, dramatically stretched what we had done the previous flight.

Even the Apollo 10 was a full dress rehearsal for Apollo 11. We did virtually everything except actually land on the moon. We did separate the lunar module, we fired the descent stage, we got within pretty close range of being landed. We didn't actually do that. We fired the ascent engine, went back and rendezvoused. Almost everything except the actual landing itself. And we would run into difficulties on each of those missions, and you had to deal with those before the next mission.

If my memory's right, I believe Apollo 10, we had some oscillations, pressure oscillations in the fuel cell system that we had to deal with before we could fly Apollo 11. So, always some challenges between missions, being sure that we understood what was going on and what the effect was or to find a modification for it if need be. And, you know, two months—we were flying every two months. Pretty rapid.

RUSNAK: Do you remember what you were doing during key points, referring to those missions such as the Genesis reading on Apollo 8 on Christmas Eve or during the landing and such?

VAUGHAN: Yes. During the Apollo 8, with the Genesis reading, I was in Building 45, in what we call the mission evaluation room. That was where engineering groups were sitting,

monitoring the flights, supporting the flight controllers. There was a little bit more of a barrier between that group and the flight controllers, the fear always being that the flight controllers would get interfered with by the engineers if the barriers were too low. And we still have to watch that. But that's where I was during that one, and I was also there during the ascent phase of the liftoff from the moon.

The landing, I was home with my wife and two kids, and we watched it on TV. So I was not in the center at that time, but I was watching it quite carefully. And what it amounted to was we had different people and even the mission evaluation room filled up very rapidly if you allowed everybody to be in there. Even management might like to be. But I was there pretty often.

RUSNAK: That's all the questions I had. Thank you.

BERGEN: I just have one final question. Your career spanned basically the whole manned space program. As you look back, what of your accomplishments are you most proud of during your career?

VAUGHAN: Being a team member, I think, and being a part of NASA, and not just NASA, but the overall aerospace, now that I'm not NASA. I mean, the aerospace. And I knew long before I was not NASA that it's the total team that counts and being able to work in a team environment and make things happen. And we've been on the cutting edge most of that time.

BERGEN: It's been very exciting.

VAUGHAN: Yes, and still is. It still is.

BERGEN: We thank you so much for coming and sharing with us.

VAUGHAN: You're welcome.

BERGEN: It's been very enjoyable.

VAUGHAN: Thank you. I appreciate the opportunity.

[End of interview]