

NASA JOHNSON SPACE CENTER ORION ORAL HISTORY PROJECT

EDITED ORAL HISTORY TRANSCRIPT

JAMES M. FREE

INTERVIEWED BY JENNIFER ROSS-NAZZAL

HOUSTON, TEXAS, AND WASHINGTON, DC – 21 JUNE 2016

ROSS-NAZZAL: Today is June 21st, 2016. This telephone interview with Jim Free is being conducted in Houston, Texas, and Washington, DC, for the Orion Oral History Project. The interviewer is Jennifer Ross-Nazzal. Thanks again for taking some time to talk with us this afternoon. We certainly appreciate it.

ROSS-NAZZAL: I wondered if you could briefly describe your background and how you first became involved with the Orion Program.

FREE: My first involvement was back, I think, in 2005. The Orion Project, at the time CEV (Crew Exploration Vehicle) was going to have a liquid oxygen/liquid methane propulsion system on it, which required a good bit of development. At the time I was at the Glenn Research Center [Cleveland, Ohio]. Glenn was given the responsibility for doing that development of that entire propulsion system and all the technology development. The project was started at Glenn that worked for the CEV Project, and it was the LOX, Liquid Oxygen/Methane Project.

I was the Project Manager for that, so that's where I really became familiar with the requirements of the CEV mission and very familiar with the folks working the Project from JSC.

ROSS-NAZZAL: Can you talk about the original design of that service module that you were working on and how it evolved? I know, for instance, there was a design team activity in 2006 at

Glenn where you came up with four separate iterations, and you presented two to Constellation and the administration. Can you share with us some of those details?

FREE: There's a couple different efforts that happened at Glenn. Are you referring to what became known as the Smart Buyer activity?

ROSS-NAZZAL: No. According to your newsletter, which of course it's not on my desk.

FREE: There's a lot of evolutions in here. Eventually the LOX/Methane became not a baseline for Orion. Glenn and Marshall [Space Flight Center, Huntsville, Alabama] worked together to pursue the service module. What threw me was when you said presented to the administration.

We started working with Marshall to develop different options for the service module, and I transitioned over into leading the Glenn half of that for the service module. We did; we looked at a number of different iterations and designs and basically trading the capability that the service module needed versus the requirements that CEV had. Even after 2006 we had a number of different designs for different things. That's really I think what you're referring to, taking the requirements and what are the different ways in which we could meet those requirements.

ROSS-NAZZAL: Can you give some examples of the different iterations? Some of the major ideas that you came up with?

FREE: The driving case for the service module basically, because it was a support element to support the crew capsule, was really first around the propulsion system, so the main engine that

the service module had to carry and determining what thrust level we needed from that service module. That was a configuration change that we seemed to spend a lot of time going back and forth on what thrust level we needed. At the time it was Constellation architecture, and it was going to Space Station, which meant that it was going as far due north as you could out of Kennedy [Space Center, Florida] on its launch trajectory. It put it over an area, it was called the downrange abort exclusion zone. You had to make sure that you had enough thrust that, simply put, the crew didn't end up landing in the North Atlantic. That requirement drove a thrust level on the main engine for Orion that drove quite a bit of the design.

You asked me what we traded. That was one of the trades we did, what could we do with thrust level so that either we didn't have to develop a new engine or could use eventually what's used today, one of the old OMS [Orbital Maneuvering System] engines. Now that trajectory is no longer taken by Orion, but the thrust level is now used to get to and from some of the orbits that are being considered for the cislunar space. Actually just confirmed that last week at a service module meeting I was at, that we still need that higher thrust level, so that would be one of the trades.

Another would be the outer surface area of the service module is where the radiators are to get rid of the heat from the crew module. How much surface area do we need, which was going to size the height of the service module. The other trades were a little bit later than 2006, but those are two that I'd throw out from around the 2006 range.

ROSS-NAZZAL: This time period is more design and development period. At what point did you get to an actual prototype and start looking at hardware and building things?

FREE: We weren't really ever going to build the service module in house, because there were two study contracts to industry. There was going to be the downselection to a single contractor. We were looking at design trades to see how the requirements that were being set in place drove the design and then also gave the government our own reference mission to compare against what the contractor was giving us. There wasn't going to be a time, as much as I would have loved to have done it, to build the whole service module ourselves.

ROSS-NAZZAL: Who were the two companies that were working on the designs?

FREE: Of course as usual, it's a group of companies. One side was Lockheed Martin, who eventually won the contract, and then the other side was a combined Boeing and Northrop Grumman team.

ROSS-NAZZAL: Contracts play a big role in everything that NASA does, for sure. You talked a little bit about heritage hardware in terms of that OMS engine. Were there other ways that the service module reflected Apollo or Shuttle hardware?

FREE: As we traded the propulsion system and control of the vehicle, it became clear we were going to need three levels of thrust. One of the levels of thrust was about 110 pounds of force, and that fit what's used today for pushing satellites into geosynchronous orbit, a 100-pound thruster that was used on Apollo actually, same design. It of course had evolved since the Apollo time but traced its roots back to the heritage of Apollo.

ROSS-NAZZAL: I wonder if you could tell me what were the initial requirements for the service module. You've alluded to them, but we haven't put them on the recording yet.

FREE: Sure, so the thrust level that I talked about, it varied, but it was up above 6,000 pounds of thrust. I think when I mentioned the LOX/methane engine, at one point we were looking at a 15,000-pound thrust engine for that. Then when the development went away, we figured out how we could fly the vehicle that we could get away with about 6,000 pounds of thrust. That was a critical driver.

The total Delta-v available for basically the energy you need to change your velocity, I can't recall what that requirement was now off the top of my head, but that was clearly a driver, because that set how far you could go in your mission and what you needed to come back on.

Then there were requirements for what we had to provide to the crew module. Eventually the crew module separates. It comes back. The service module just burns up in the atmosphere. We had to get rid of the heat, the radiators I mentioned earlier. We had to drop a certain amount of heat that came from the crew module. We had to carry water for the crew, oxygen for the crew. All that set volume within the service module and really set the size. That's what I would say. I'd say that thrust level, the total propellant in the form of Delta-v requirement, and then the services that we had to provide to the crew module, which were thermal systems to radiate the heat and then provide water and oxygen to the crew.

ROSS-NAZZAL: I've written down originally it was 15,000 pounds of thrust. Then you go all the way down to 6,000 pounds of thrust. Can you explain why there's such a huge variance?

FREE: It was really when the LOX/Methane Project drove the 15,000 pounds of thrust. We didn't really understand the mission that we were doing at that time. It was open-ended. We were doing technology development.

When you do technology development, you're trying to satisfy a lot of requirements that aren't really well understood. As the requirements become better understood, you can refine the development you have to do in the form of technology. In the grand days the CEV with 15,000 pounds of thrust was—I'm being facetious here—going to fly all over the universe. Then as we understood how our vehicle was developing, how the launch vehicle was developing, how much weight that could take to orbit, we refined that thrust level down to the 6,000 pounds of thrust.

If you think about it like designing your house—we're doing this with our kitchen at home right now—you start out saying, "I'm going to knock this wall down, and I'm going to put this here." Then you say, "I don't really need to do that. Here's really what I need. I need an island, I need new cabinets, and I need new floor, I don't need to knock the wall down." That's just refining the requirements. Some of it is affordability also. The two evolve together.

ROSS-NAZZAL: I was wondering how much budget was driving that change as well. In 2008 I read that you moved to Houston and became the Orion CEV Test and Verification Manager. How did that opportunity come about?

FREE: I did. Can I add just a couple things on service module real quick?

ROSS-NAZZAL: Absolutely, yes.

FREE: There's two things I just wanted to point out—really the evolution of the service module went through. One was the mass problem for Orion was very big. The vehicle was too heavy to be launched, and we had to drop mass from it. The service module team at Glenn actually came up with a concept. The service module is wrapped in a metal structure called fairings. It's three pieces. They envelop the service module. We came up with a concept of implementing those at Glenn, and what that allowed was as the vehicle was flying up on top of the rocket, these fairings would come off, and you'd be able to drop weight as you're going into orbit, so they could hold the weight of the vehicle under the thrust of the rocket, and then go away and not count against the mass going into orbit. It was a very critical design evolution that was actually developed completely by NASA, then handed over to the contractor to implement, and is still part of the design today. A big item there.

Then also with the closeout of the Shuttle, the ability to take larger pieces of cargo into orbit was gone, specifically some of the large cargo that Space Station could need in the future. We did a design concept where we actually were able to accommodate inside the service module some of these big pieces of hardware that when Orion got to Space Station could be taken out by the robotic arm and then installed on Space Station. Two big design evolutions that came out of the work done at Glenn and are still part of the vehicle today.

On my move to JSC, I got to know the project managers quite well. Brian Anderson is the original one and then Skip [Caris A.] Hatfield and then Mark [S.] Geyer. In working with Mark—he was the Project Manager in 2008—he asked me if I would be willing to come down there to take the test and verification job. What led to him asking me I'm not sure. It's probably a good question for him. Hopefully it's not one he regrets, asking me. I think he was comfortable with the work that I had done on service module and saw it as an opportunity for me

maybe to contribute in another part of Orion with some of the things he thought I did well leading the service module.

ROSS-NAZZAL: Can you share with me some of the numerous tests that were going on at that point? Or was that still too early? Were you just thinking about some of the testing that would be going on?

FREE: No, we were doing some testing then. The abort testing—basically if something goes wrong and you have to get the crew away from a hazard, that's an abort. That work was under me. We were heading towards the first of the abort tests, which was called Pad Abort Test-1. If you're on the rocket on the ground before you launch and something goes wrong with the rocket itself, you need to get the crew away. You fire this basically post on top of the crew module, [it] has a rocket in it, and you fire it. It pulls the capsule away, parachutes come out, and the crew lands some distance away from the hazard. We were heading towards that test. We were assembling the vehicle, the capsule that was going to go through that testing, while I was the Test and Verification Manager. We were doing a lot of the subsystem tests of that pad abort test.

Parachute tests were going on at the time. We were putting together the laboratory where a lot of the electronics boxes were going to come together to be tested before they were installed on the flight vehicle, the boxes and the software with them.

It was really at the early stages of a lot of the testing on the vehicle, a lot of rocket tests going on at the time for a variety of the systems on the vehicle. It was probably more at the formative time or the really early testing, as opposed to more of the testing that you saw leading up to the launch of EFT [Exploration Flight Test]-1 a couple years ago.

ROSS-NAZZAL: What was your role in overseeing the tests? Obviously there are technicians that work on these tests, prepare for them, and monitor things as they're going on. What is your role overseeing all of those?

FREE: There were folks who worked for me that managed those day to day. My role was working on developing two things. First, the plan, the test and verification plan, that we had to have for the entire vehicle. So when the vehicle popped out ready to go on top of the rocket, we knew how it performed. It met all of its requirements. Then the other piece was getting the test facilities ready that the vehicle was going to use to be tested once it was all put together. So a lot of setting the plan in place was my responsibility and then making sure the facilities were going to be ready on time to do the testing.

ROSS-NAZZAL: Can you talk a little bit about coming up with that plan? Were you looking at previous programs to determine what sort of tests had to be done? Or were you just simply starting from scratch saying, "We need to do the following tests to ensure that this vehicle is man-rated?"

FREE: Absolutely. I'm still in awe of the documentation that was done for the Apollo Program. We relied heavily on the testing philosophy that Apollo had. Of course it was a little bit different era. They had quite a budget. We didn't have quite the same budget that they did. It was absolutely looking at things that were done for Apollo, things that were done for Shuttle, because number one, that's what we knew. We had found success with it. It's very difficult to test large

systems, let alone large human-rated systems, so we'd be foolish not to look at that. So we relied quite a bit on that.

We did push the team—I won't say we, it was probably more me—to look at how things were done for uncrewed spacecraft, because there's a lot of lessons to be learned as technology has evolved over the years. Robotic spacecraft were much more robust in this timeframe than they were perhaps when Apollo and Shuttle were being developed. It was trying to rely on things that had been used previously.

ROSS-NAZZAL: Some of those facilities that you were getting ready to prepare, were those NASA facilities or were there also DoD [Department of Defense] and contractor facilities?

FREE: There were contractor facilities and NASA facilities. Our DoD facility usage was very focused. What I mean by that is if we needed to do a test on acceleration and the crew seats, we wanted to go on a rocket sled that was owned by DoD, basically a sled that you put whatever you want to test on. They fire a rocket and it gets it going really fast. We used DoD facilities but we didn't necessarily build or modify their facilities. We just used their service.

The contractor facilities, we did some big upgrades to Lockheed's facilities out in Colorado. We did some work at facilities at Glenn and work at facilities at JSC.

ROSS-NAZZAL: Can you give a couple of examples of those upgrades that you mentioned?

FREE: Sure. The one that I'll give, I don't know if it's the biggest one done. It's probably one of the bigger ones done by Orion, the upgrade of environmental test facilities at NASA Glenn's

Plum Brook Station in Sandusky, Ohio. There was a large vacuum chamber there that could simulate the vacuum and thermal conditions of space. The Project did a trade of different facilities across the country to upgrade, and that facility was chosen to add an acoustic test chamber basically to blast sound at the Orion vehicle like it would see at launch and then also a vibration table to shake Orion like it will see at launch. Those were major major upgrades. Orion is an incredibly big vehicle, under extreme environments. We spent a fair amount of time and money upgrading those facilities, and actually they're in use even as you and I talk here today to do some vibration testing for the European service module.

ROSS-NAZZAL: Yes, I believe I saw an article about that. I'm just curious, and I think I know the answer, but here at JSC there's a Vibration and Acoustic Test Facility. Too small for Orion?

FREE: No, it could have been used for Orion. It would have needed a major upgrade also. The Project did a trade study, the trade study I just mentioned. They ask each of the Centers, "Please respond to these requirements and tell us which of your facilities could meet these requirements and how you would propose building new ones." The Project decided that Plum Brook Station was the place to build versus JSC.

JSC Chamber A would have been the chamber used. Chamber A is now dedicated to James Webb Space Telescope.

ROSS-NAZZAL: Were you there long enough to see some of these tests and then have them result in any changes to the vehicle or service module?

FREE: I was there a year. I left just before the pad abort test. That's the one that probably had the most profound changes on it. I wasn't in that position when the changes were made. I like to think I was the one that set a lot of the plans in place that are being used even today to understand the operation of the vehicle, and some of those that have required design changes based on the testing. I don't get that kind of credit. That part of the program is always tough to work on, because it's not always the big fun tests, but it's got to be done in order to get to the big fun tests.

ROSS-NAZZAL: What changes were made as a result of those abort tests?

FREE: The pad abort test, that validated some of the parachute design. It helped understand the acoustic environment, so when the rockets fire right above the capsule they create a pretty significant acoustic environment. There were some changes made to how you protect the crew from the acoustics with blankets or shielding, which are pretty significant.

A lot of the electronics testing is actually probably still—that electronics lab where you test the boxes, that always leads to changes because you're dealing with software. It's like dealing with your computer at home. Trying to get it set up the right way and operate the right way. I know there's been quite a few changes to the software and the boxes and even some of the hardware.

ROSS-NAZZAL: In 2009 you returned back to Glenn, and you were overseeing the Orion Office itself. Then you became Director of the Space Flight Systems. Can you talk about that in relation to the Orion Program and the activities that you were responsible for that you oversaw?

FREE: Sure. So when I went back to Glenn in the Orion Office, that was where we really had oversight over all the different elements that Glenn was supporting. At the time we had the service module element. We were doing work on the propulsion system for another abort test called Ascent Abort-2, which is actually going to be an abort while you're on a rocket. You simulated getting off the rocket quickly, and you had to use the propulsion system for that, the propulsion system that we were developing at Glenn.

We were doing a little bit of the instrumentation work to go inside the test capsule, and we had this major work out at NASA Glenn's Plum Brook Station where we were upgrading the facility for the environmental tests. So I literally walked out of JSC to finish my job as the Test and Verification Manager, got back to Glenn, and they told me, "Hey, this facility is in real trouble. You got to go back to JSC and ask for more money in your new job," which was interesting. I did go back, and actually then spent a number of months on getting that Project out at Plum Brook. I became the Project Manager on that, because the JSC folks trusted me and I turned that Project around to get it back on course.

September of that year, I was selected to be the Director of Space Flight Systems at Glenn, which oversees all of the spaceflight work that we do, from things on the Ares I, Ares V launch vehicle, up through the work we did on Orion. All of that work fell under there. Everything we did on Space Station, everything we do to support satellites that fly. Orion was just one element of the Office which I took over.

ROSS-NAZZAL: In 2010 the Obama administration made the decision to cancel Constellation. How did that affect your work at Glenn?

FREE: Other than devastating me personally at that point? It affected us quite a bit. We had large roles on the Ares I and Ares V. Then of course in the end Orion survived, but it still went through a tumultuous time. We downsized our contractor workforce quite a bit. We moved people around within the Center for the launch vehicle work, and we shut down some of the facilities that had been built to support the Ares mission.

ROSS-NAZZAL: Ouch.

FREE: It was a tough day.

ROSS-NAZZAL: In addition to that were you guys still working? I remember for a while there, especially being at JSC, everybody was in shock as well. I think everyone was surprised. There was still this fight. Congress was like, "No. We can't get rid of it." There was still money to be spent. Were you guys still doing some Constellation work at that point until things really got ironed out?

FREE: Yes, Orion still continued to press on. We were still supporting Orion, still getting the facility ready out at Plum Brook. The Ares stuff took a little while to close out, so we were still doing some things that were still funded as part of that Constellation Program closeout.

ROSS-NAZZAL: You went on to become Deputy and then Director of the Center. What role did you have with Orion once you became a manager for the Center?

FREE: It remains actually very near and dear to me. I just spent two weeks in Europe with the European service module team. It's still in my job jar, even in my new job here at [NASA] Headquarters [Washington, DC], which is great, because—well, we can talk about that later.

My involvement was just like all of our projects. My responsibility as the Deputy and then as the Director was making sure that we're delivering on the commitments that we've agreed to with our customers. Orion was one of those customers. It was all about making sure that we met the milestones, and we were doing well customer satisfactionwise.

Knowing Mark Geyer, the Project Manager, it was easy for me to really understand from him hey, it's not Center Director and Program Manager, it's Jim and Mark. How are we doing, what can we be doing better. Formally it was about making sure we delivered on our milestones and our commitments.

ROSS-NAZZAL: The next couple set of questions that I have are more general to everyone we're talking to on the Program. You mentioned earlier how you did some work with Marshall and, of course, with Johnson. I'm curious if you could talk about how the multi-Center program management model affected the Program, or if it did. NASA has had programs before where there are many Centers who work on various components, like the Shuttle Program definitely had that. I wonder if you could talk about that in the structure as well.

FREE: Actually this is one of the Constellation lessons learned that bothers me the most, because it really talks down the inter-Center relationships and says that management model needs to

make sure it has all the right assumptions, which I agree with, but it talks about it very negatively.

I saw it as a great benefit. It's 11 years now that Glenn has been involved with the service module, a significant involvement on a major element of human spaceflight. The ideas and rigor that a Center like Glenn brings to the table have shown great benefit to it. It takes a ton of work though to make it happen. I think from 2005 until I was down at JSC doing that test and verification job in 2008 probably three weeks out of every month I was at JSC on travel in some form or another. In order to instill that confidence in Glenn, the program management team at JSC needed to be able to see that the Manager of that group wasn't just sitting back at Glenn trying to run the show or trying to take an element away from JSC. That wasn't going to happen.

I think it was incumbent upon me to realize that we were part of the bigger vehicle, that I worked for the Orion Program Manager. These multi-Center teams in all areas bring a great set of ideas to the table and help really break down a lot of the barriers and stovepipes that I think drive a lot of cost and inefficiency into the way that we do things at NASA. So I thought it was very good. Everybody's got a different opinion on it, but that happens to be mine.

ROSS-NAZZAL: You said you spent about three weeks out of every month at JSC, obviously doing a lot of planning meetings and things of that sort. Can you give me an idea of what some of your days were like down here as compared to at Glenn when you were on the floor with your guys?

FREE: When I was at Glenn and not at JSC, there were a lot of planning meetings, attending the planning meetings in person, as opposed to being back at Glenn being an active member of the

team face to face. The face-to-face element is really important when you're trying to build trust, so that was where the time investment for me came from. It's planning meetings from requirements development. It's budget meetings. The number of budget meetings we had I probably don't want to really think about how many, as budgets were changing and the Program was developing and we were going through some of the early milestones in any project development cycle.

It was really like I was on the team, like I was a JSC employee. Maybe the way I should say it is I spent a week at Glenn every month as opposed to three weeks at JSC. It was taking things forward. I talked about the fairings before, the pieces of structure that fall off intentionally as you're going uphill. It was working through that design, making sure that we got the community on board with that was the way to go. It was a lot of bringing Glenn into the fold of human spaceflight by showing my commitment to the Project by being there.

ROSS-NAZZAL: Obviously you had a deputy that was back at Glenn who was keeping you apprised of things going on?

FREE: Yes, and then I would dial back into things at Glenn. The inverse scenario of being back at Glenn. I'd dial back into things there. Or I'd try and kick the team off on Monday and go to JSC for two days, three days, and then come back and spend the balance of the week with the team at Glenn. We had a lot of people at Glenn going down to JSC too for the same reasons I just gave you.

ROSS-NAZZAL: It sounds like a big challenge, probably didn't see your family very much at that point I would think.

FREE: Yes, now I'm at Headquarters, and my family is back in Cleveland.

ROSS-NAZZAL: Oh my gosh. Oh, that's tough.

FREE: Yes, it's a little bit challenging right now.

ROSS-NAZZAL: Yes, I can imagine. It's tough living in DC.

FREE: Yes, those were long days. I'm sorry, didn't mean to interrupt you.

ROSS-NAZZAL: Oh, you didn't interrupt at all. You did mention something though that I wanted to ask about. That was budget. I know that Orion has a very tight budget. Can you talk about issues of affordability and moving towards a lower cost development model and how that was handled and implemented from your perspective?

FREE: The initial part will be editorial; the other part will be fact. The editorial side for me is it's crazy the way we do things in this Agency: changing budget three times a year, four times a year, living on continuing resolutions. Having to change contracts, to change funding levels, to push back milestones. To me what drove cost into our system is the inefficiency of our

government and Congress and the administration fighting with each other all the time. So that's the editorial part.

The fact part for me is we had initially a pretty well gold-plated set of requirements that we needed to drive down to drive cost out. I know we spent a lot of time doing that. I know the Project still works on that today, especially now that they're getting towards production and operations.

I think that we had to really take a look at how we did business with our contractor, Lockheed Martin. The Project spent a lot of time saying, "How can we do oversight the right way of the contractor but still have knowledge of the design, but not drive the contractor's cost?" I'm not sure if folks have brought it up to you. There were oversight models put in place.

ROSS-NAZZAL: No.

FREE: What levels of oversight and insight we had into different systems. The Project didn't just do a blanket, "We're going to have this many people working on every subsystem," because eventually they're just going to go find things they don't like, and then that drives cost into contract changes. So the Project did a good job, I think, of applying resources to the critical areas and letting the contractor run in other areas.

ROSS-NAZZAL: Can you give an example from the service module perspective of that gold-plated requirement and then you decided no, we need to restructure?

FREE: I'd give that thrust requirement as the number one, just because that drove so much, because the thrust drives the size of the engine. The bigger the engine, the bigger the service module has to be, the heavier it is. Which means you have to design more into the rocket to lift it. You have to make the service module longer, which drives more cost into the system. To me that was the gold-plated one that jumps right to mind.

ROSS-NAZZAL: Along those same lines, if you could think back about any decisions that were made during your time with Orion that really impacted development, policy, operations, or cost. Anything that jumps out to you in one of those or all of those themes.

FREE: This'll probably be one that I'll think about. When you give me the transcript I'll have more. I think the number of crew that we were going to carry, when we went from six to four, was a big deal. I think six was just a big number. I think it drove the size of the vehicle significantly. It put a lot of load on the systems. When we went from six to four I think that backed off a lot of the requirements. I think that was a huge decision that the Project made. For me that's got to be the biggest one. That's technical requirement.

Policy requirements, I think Orion, ironically, has stuck with this multi-Center model. They had an out. I believe much like when Ares I and Ares V turned into the SLS [Space Launch System]. The SLS turned very internal to Marshall. I'm speaking now from the other roles I had at Glenn where we went from 70, 80 people working on Ares V to fighting to get 6 people working on SLS. We didn't lose our capability at Glenn. It was circling the wagons, I think—I can't say that I blame them—on the SLS side of the equation. Orion has stuck with the

multi-Center model. I don't know that that's an active policy decision that was made, but it's certainly a policy that has stayed with the Project now for 10 plus years.

ROSS-NAZZAL: Curious what the astronaut or Flight Crew Operations thought of that movement from six crew to four. Was there any pushback from them?

FREE: I don't recall any pushback from them, no. I don't know that the number of crew really affects them. They're very focused, and it's great to learn from them and watch them. They're very focused on the systems. Do the systems perform the way that they want them to and keep them safe?

Now if you got to three crew versus four, I don't know then if they have worries about "Hey, I always have to have somebody that's my buddy," even though Soyuz flies three, "we need to always have four. We always need to have somebody looking out for us." I don't know if they get to that. But I don't recall them really having a concern with going from six to four.

ROSS-NAZZAL: Any other significant decisions that you recall when you were working with Orion?

FREE: I think we talked about one, the decision to go to Plum Brook I know still really makes people mad at JSC today. Even as we sit here today, there's people, if you brought that up to them, at senior levels at JSC, that still bothers them. They still would like to see that reversed. I think that was a significant emotional event for them, and a significant decision by the Project based on the investment made at Plum Brook.

ROSS-NAZZAL: I wonder if you could share with me how the Exploration Systems Development Division Cross-Program System Integration—that's a mouthful—initiative impacted Orion.

FREE: Wow, this is a loaded question. Who put you up to this, Jen? Just kidding.

ROSS-NAZZAL: Yes, the Orion folks came up with that question, I did not.

FREE: I don't know. For me, we're talking about significant emotional events, having lived Constellation Systems Engineering Group, which was like 400 people, I think they outnumbered the Project. What we have today just in numbers in the Cross-Program I think is better. I think the fact that Orion is now doing more of the integration helps out Orion. The problem is they're not getting more resources to do it, so it puts additional load on the people already doing it, but they're driving their own ship. I think we always have to be wary of going back to the Constellation days where we have 400 people doing the integration, and that just goes to no good end.

ROSS-NAZZAL: Too expensive?

FREE: Too expensive, and the anecdote I always give is I went to a Constellation meeting. Constellation had thousands of requirements. We had this meeting on a specific set of requirements, and this gentleman stood up when we talked about two of the requirements, and he said, "These are my two requirements. This is what I come to work every day to worry about.

You can't take them away." Clearly it had driven the system too far. I don't want to get back to that.

ROSS-NAZZAL: So you think Orion is much more flexible, able to maneuver things more easily?

FREE: I think so. I've seen them do it. I've watched them do it. I think their fate is in their hands, which is much better than leaving it in somebody else's.

ROSS-NAZZAL: Can you give an example or two?

FREE: I think just working interface issues directly with SLS. Before, there would be an issue with the electrical interface between Orion and SLS, and Orion would have to go to somebody at Constellation systems engineering who owned that interface. That person then would get information from Ares and then feed that back to Orion. Orion would react, it'd go up to Constellation.

Now, it's Orion and SLS, those two people in the room trying to resolve it, directly. I think that's much better than anybody being the arbitrator, because you can get it done faster. There's an efficiency. I can tell the person across the table this is what I need. I can hear what they have, and we can move through that much quicker than trying to work it up and through the Constellation Office.

ROSS-NAZZAL: It sounds like a lot of bureaucracy is what you're describing.

FREE: Oh my gosh, it was awful.

ROSS-NAZZAL: We have about four minutes left, and I have about seven more questions. So I guess I might have to [re-]schedule, but they wouldn't take very much time. So I'll schedule some more time with your admin. I can't imagine maybe more than 20 or 30 minutes. But I wonder if we could just touch on one.

The focus that Orion is really interested in is that successful launch of EFT-1 in spite of all of the challenges that came up over the years. I know that at that time you weren't necessarily working in Orion, but what do you think were some of the more memorable moments or events that you recall as say Glenn was working towards that launch?

FREE: Towards EFT-1? I think the one that's at the top of the list are those fairings that I talked about. So those fairings that come off during launch off the service module hadn't been tested in flight. They'd been tested on the ground. First time through, they had some problems on the ground with the testing. They redid the test. They worked.

I can tell you for the Glenn folks, because I watched proudly as that happened with a lot of them, seeing those come off and validating that hey, Glenn contributed a significant element, a risky element, and it worked well, worked properly, that's probably the top moment from that mission from a service module perspective. That's got to be the top one. I know it brought a tear to my eye when that came off, that's for sure.

ROSS-NAZZAL: That was your baby. How were they tested on the ground?

FREE: What you do is you put them together like they're going to fly, and then you put them under different conditions. The way they work is they're clamshell vertical, and then the crew module sits on top of them. Then you simulate the weight of the crew module on top and the interface to the rocket below, so they're sandwiched in between there. You'll test them.

Basically you deploy them by firing explosive charges that cut the metal or cut the interface. They'll test them like they're nominally supposed to work, meaning they'll fire all the explosive charges, they'll apply heat, so that the mechanical conditions are different. They'll only fire a certain number of the explosive charges, like the minimum you think you can get and make sure that they still deploy. So there's a number of tests that they go through to test all the conditions or as it's put, corners of the box.

ROSS-NAZZAL: Do you have a test area at Glenn where you did that?

FREE: No, those were actually done out at Lockheed Martin. We could do it at Glenn, but the test was performed at Lockheed Martin. Or they could do it at Glenn. I'm not a Glenn person anymore. I still say we. It's only been three months.

ROSS-NAZZAL: Well, you spent a lot of time out at Glenn, so I can understand that. I want to keep you on schedule. So I will contact your admin, because I'm sure you have another meeting to go to. Unless you don't have anything on your calendar, and we can finish up.

FREE: No, I do have another one. I'm sorry. I feel like I talked too long if you have that many questions left. I must just be droning on. I really apologize.

ROSS-NAZZAL: Oh, absolutely not. No, and actually the more information we get, the better. Like I said, we're not looking for any sort of quote for the newspaper or just this little quip that we're going to put on the local news: "Glenn Research Center Director says the following," and it's all out of context.

This gives people the opportunity to better understand things like decision making and hardware development and things of that sort. That's what I always tell people. People always say when I turn off the recorder, "God, I must have been boring you." It's like oh, no, it's really fascinating to learn so much more about this. Because the other complication with this Project is we went out trying to find information, and it's such a young program, such a new program, that there isn't a lot out there that's been documented. What has been is on social media, and that really isn't preserved very well. All these details I think are important for the future, keeping that history of the Program alive. I will schedule probably no more than 30 minutes with your assistant. I sure appreciate your time today.

FREE: Thank you very much. I appreciate it, and you have a good rest of your day, and I'll talk to you sometime soon.

ROSS-NAZZAL: Well, hopefully next time the phone will work. I apologize that you had to call me.

FREE: I don't know what happened. It's no problem at all if it happens next time. I'll just call you right back.

ROSS-NAZZAL: Sounds good, thanks so much.

FREE: Thanks, Jennifer.

ROSS-NAZZAL: All right. Bye-bye.

FREE: Bye-bye.

[End of interview]