NASA JOHNSON SPACE CENTER ORION ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

DONALD E. REED
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is July 18th, 2016. This interview with Don Reed is being conducted in Houston, Texas, for the Orion Oral History Project. The interviewer is Jennifer Ross-Nazzal, assisted by Sandra Johnson. Thanks again for taking some time out of your busy schedule to meet with us. Really appreciate it.

REED: Sure. I look forward to it.

ROSS-NAZZAL: Tell us how you became involved with Orion.

REED: I worked with Brian Anderson on X-38; Brian was the first Program Manager for MPCV [Multi-Purpose Crew Vehicle], CEV [Crew Exploration Vehicle] back then. He asked me to come work for him and lead up the Flight Test Office, so that's how I got involved.

ROSS-NAZZAL: What year was that?

REED: That was in 2005.

ROSS-NAZZAL: What sort of things were you involved in at that point? It was a fairly new Program in 2005.

REED: I was involved in the Source Board. We went ahead and downselected for the contractors. Then what I was asked to do was work on the abort flight testing, so I was not only on the Source Board but also was asked to lead up the abort flight test. Back then we had six abort tests on the books, so that was really what we did, lay out the plan on how we'd get all the abort tests that we felt were necessary to be done at the time to certify the design. We used Apollo as the basis for that and laid out the initial plan based on what Apollo had done for their abort system. That's where it all started.

ROSS-NAZZAL: When you refer to the abort system, you're referring to the Launch Abort System [LAS], the rocket on top of the [vehicle]?

REED: Yes, the Launch Abort System.

ROSS-NAZZAL: How robust was the design at that point when you started working on CEV? Have things changed dramatically since 2005?

REED: That's a tough question for me to answer: how robust the design was. The design has evolved over the last what, 11 years or so, 10 years. We had a boost protective cover back then, for example, like they did on Apollo. Then they wanted to carry I think it was the docking mechanism to the Space Station, so they actually extended the area underneath the Launch Abort System. That's when the Ogives came in to have a larger volume in which to carry a docking system to the Station.

As far as how robust, the vehicle has always had the mission to go on to Moon, Mars, and beyond. From the get-go it was designed to do that mission. It's not like the requirements for the mission have evolved. How you define how robust it is, I can't answer that.

ROSS-NAZZAL: You said you took a look at Apollo to come up with these ideas for these abort tests. How did you stray from their original plans? Were there differences, or was it very similar?

REED: I have a background in flight test. When you test, you hit the corners of the envelope. You look at the areas where the environment is the most stressing or where there's the most uncertainty in the design. We looked at those areas, and physics is pretty much the same as what it was for Apollo. Pad abort was the big one for your total impulse for the motor to get you high enough, further enough downrange.

Then you get into the conditions of max drag, where it takes the most amount of thrust to get away from the launch vehicle. That happens right around Mach 1 transonic. Then there's when the aerodynamic forces are the highest, which challenges the ability of the attitude control motor to be able to perform, have a good enough control authority. That was our third one, the max dynamic pressure. High altitude was another area where the size of the plume is larger, and thermal effects are more prevalent. We had two pad abort tests. PA [Pad Abort]-1 was like an engineering developmental unit if you would. Same with AA [Ascent Abort]-1. They were initial development units.

The run for record was PA-2, AA-2, AA-3, and AA-4. Budget became an issue, so we went and had several discussions on the risk in that and what the objectives were. The high

altitude abort was really the first one to drop off because very low dynamic pressure at that altitude. The technical community sort of agreed we understood that well enough that we didn't need to spend the money for that. The risk wasn't worth the cost.

We did PA-1. We learned a lot from that, a lot of design changes. In fact about every system on there I can think of had a design change after PA-1. PA-2 is where, in my opinion, they felt like they'd learned enough on PA-1 they didn't need to do a PA-2. That's really a risk discussion. It's a risk discussion of does your engineering analysis give you confidence that you understand what could potentially go wrong. They opted not to do a Pad Abort 2. We were going to do an Ascent Abort 1, which was similar in terms of the configuration as PA-1 in that we were going to use a government boilerplate crew module for AA-1. When they started looking at it, the cost of doing a separate analysis for those loads, [the Program] deemed that it was not worth the cost. PA-1 took a tremendous amount of analysis from a loads and dynamics standpoint. AA-1 was going to be a one-off design again. Lockheed would have to spend a lot of resources in terms of loads and dynamics, so AA-1 basically fell off the chopping block a couple years ago.

Really came down to our transonic and our max dynamic pressure abort, AA-2 and AA-3, and what they opted to do was combine those into a single test that sort of split the difference between transonic and max dynamic pressure. That's where we're at today, just AA-2. Of course that was supposed to be flown with the EFT [Exploration Flight Test]-1 crew module, so it was closer to production design if you would, but then again we were trying to save money. Again, we looked at doing a government-provided boilerplate like we did on PA-1. Last March, not March of '16 but March of '15, the Program decided to go ahead and do AA-2 with the Lockheed production Launch Abort System with government-provided crew module and

avionics and ground support equipment, so that's where we're at today. We fundamentally went from six abort tests back in 2006 down to two today.

ROSS-NAZZAL: That's a tremendous hit to your budget.

REED: Yes, that's where we're at.

ROSS-NAZZAL: You mentioned the technical community came to this decision. Who was involved in those decisions to cut back on those tests and look at different ways of ensuring that the rigor would be there and that you were proceeding safely?

REED: We went through, and we discussed the risk with management. We've actually gone back and done a trace of how these decisions got made. I know AA-4, AA-1, as you went through and looked at the budget, the PPBE [Planning, Programming, Budgeting, and Execution] each year, you would see these things drop off. There wasn't really a formal Program Control Board that dropped those off until we finally got to AA-2. That was really the one that really got people's attention, because we're down to the last abort test now and not doing an ascent abort test at all. That went through a very rigorous, very formal review of all the engineering folks and the risk. We actually had two MPCV Control Boards addressing that issue back in March of '15 so there was a lot of rigor that went into that.

The engineering team, who really needs the data to certify the design, had to come in and show where they were confident that their analysis they were going to use, that they could get

information from a nonproduction crew module that would allow their analysis to be valid. They had to come in and show how they were going to do that.

On AA-2 we're actually going to do an acoustic characterization test so that we understand how the acoustics get transmitted through the boilerplate crew module as well as the random vibration, so that they can actually measure how those loads are transmitted through our government boilerplate and then go back and see how that compares to their models in terms of how loads get transmitted through that, so they have confidence that they're modeling the production crew module loads appropriately.

They convinced the Program that the risk is acceptable. The Aerospace Safety Advisory Panel is very interested in this topic, so they've weighed in. This topic has gone all the way up to [William H.] Gerstenmaier, to Human Exploration and Operations Mission Directorate. Right now we've got the approval from up at [NASA] Headquarters [Washington, DC] to proceed in this configuration for Ascent Abort 2.

ROSS-NAZZAL: Will you be testing here in the Vibration and Acoustic Test Facility or are you taking it up to [NASA] Plum Brook [Station, Sandusky, Ohio]?

REED: It'll be here. Over here in the old Apollo acoustics lab.

ROSS-NAZZAL: If I may, how much do these tests typically run? How much did Pad Abort 1 [PA-1] cost?

REED: Pad Abort 1 was roughly around, I think it was somewhere between $220 and $250 million. I think AA-2 is coming in right around $180 million.

ROSS-NAZZAL: Beyond coming up with these plans for aborts, what else is entailed to work on these types of plans? Do you have to set up a Mission Control Room? How many people work on these? How many people set them up? Can you walk us through all the things that you have to do? You started in 2005, Pad Abort 1 was in 2010, so obviously it takes quite a long time to put something like this together.

REED: These flight tests are done like most of your missions, where you've got to have the whole gamut of control rooms, people sitting on console monitoring the systems. You're flying out of a range so you have to coordinate with the range, all the safety aspects associated with that. All the networks required to pass video data to the control team, send commands. It encompasses all those things you need to do a mission.

Back to PA-1, the attitude control motor and the loads and dynamics were the two items that created the most amount of delay. In the end it was the attitude control motor development that really pushed the critical path. It was a design that was used previously on missiles, so they felt like scaling it up to the size we needed. [They assumed] scalability wouldn't be an issue, but it was. When they scaled it up, they started having issues with the electronics and the control on the valves and all the environment this thing had to operate in. They had a lot of challenges in this design because of how it didn't scale quite like they thought it would. In the end it was that motor that pushed the flight out from 2008 to 2010, which was unexpected.

Now with AA-2, the attitude control motor is pretty well understood. All the things we learned from PA-1 have been incorporated. The LAS has been integrated a second time for EFT-1, albeit not with the active abort motor attitude control motor. But the fact is they've gone through that integration process again. They've stacked it on another vehicle. I don't think the Launch Abort System is going to be an issue in terms of schedule getting to the launch.

We have an agreement with the Air Force for them to provide a launch vehicle, so that's being done by Orbital ATK out of Chandler, Arizona. They've got a lot of experience in terms of doing these types of one-off flight vehicles. We're pretty confident that they're going to provide a good product. They've got a mission assurance contractor that they've used for decades now, so we're going to rely on them to do the independent mission assurance. So we think that's not going to be a problem getting to schedule.

I think where the big schedule risk on AA-2 is going to be is with the crew module, because they just came on less than a year and a half ago, so they're catching up. They've got a lot of responsibility in terms of the crew module, the loads, the avionics, the ground support equipment. They're new to this in terms of working with this Program with the loads that they have to deal with, with their structure and their avionics and the software. I think if we have schedule issues that's probably where it's going to happen.

That being said, in terms of again doing the actual mission, we're flying out of Launch Complex-46 down there at Cape Canaveral Air Force Station [Florida]. The crew module is being built up at Langley [Research Center, Hampton, Virginia]. The boilerplate, it'll be shipped down here to JSC—then integration of the crew module and the mating to the separation ring. Separation ring is what adapts the crew module to the abort test booster, the launch vehicle. That's all being built and fabricated up in Langley. It comes down here. The JSC engineering

team integrates all the avionics, does all the testing, and they provide it to us. We actually run the acoustics tests from our Office here locally. Bottom line is they'll deliver us an integrated and stacked crew module and separation ring, and then we'll take it, accept it, and then we'll transport it down to KSC [Kennedy Space Center, Florida].

Once it gets down there we've got an ops team that then is responsible for ground-processing it and getting it through all the different tests that have to happen down at the launch site. GSDO [Ground Systems Development and Operations] is supporting us in this effort. Once we get it to the pad then we'll go ahead and stack on the ATB [Abort Test Booster]. We'll do full-up mission rehearsals on that, test out all the range assets, the network, make sure we're getting all the data, that the radars can see the vehicle. We'll have a full-up launch control team integrated with Eastern Range and the KSC networks and go launch it.

ROSS-NAZZAL: Of course the pad abort happened after the decision to cancel Constellation. How did that impact what you were working on at that point? Did you just continue? Or was there some discussion about are we going to move forward with this, and how so?

REED: Yes. Mark [S.] Geyer, myself, we all went out to WSMR [White Sands Missile Range, New Mexico] at the time, which is where the team was, because the crew module and the Launch Abort System were physically at White Sands Missile Range when the announcement was made in February. We basically wanted to reassure the team that we were still going to continue to fund the test and conduct the test even though Constellation was canceled that February. Basically we told the team just to keep working. We still planned to do this test. Just wanted to make sure people knew that.

ROSS-NAZZAL: What are your memories of that day? You'd been working on this for so long. What sort of feelings did you have as things went smoothly?

REED: You mean on the launch day?

ROSS-NAZZAL: On the launch day, yes, for Pad Abort 1.

REED: I was just amazed that it went so well. It's a big relief. You work that many years and you work so hard. You just sit there and hope everything goes the way it's supposed to. I was Test Director, and I just remember sitting there watching the video. Other than the data, which everybody was looking at, it was the only thing I had to see was it going like it was supposed to. Just seeing all those motors firing and seeing the attitude control motor working, it's like, "Well, didn't blow up, and we're flying, so that was just such a great feeling." To find out that it did everything it was supposed to, achieved all its objectives. It was just a great day.

ROSS-NAZZAL: There wasn't a decision to move forward on MPCV till May of 2011 by the NASA Administrator. What were things like around here? What sort of projects were you guys working on? Were you just continuing your work? Congress was certainly battling to keep Orion.

REED: I actually headed up the effort here to justify continuing with EFT-1. I worked with Mark Geyer down here, and we put together a plan to brief Doug. He was the head of the

Exploration Mission Directorate, Doug [Douglas R.] Cooke. I helped pull together the presentation, and we went up there and briefed Doug Cooke on what we can continue to do in this gap in terms of getting a commercial launch vehicle.

In April is when Obama basically made his speech at KSC that said, "Hey, we're only canceling the launch vehicle. Orion is still intact, so Orion is still going to continue." We were looking at ways that we could still get a flight test done on the Orion system spacecraft. That's when we presented the benefits of what we could achieve if we used a commercial launch vehicle. That happened in 2010. I think it was August of 2010 when we went up there to present the case. I think at that point in time is when they said, "Continue to move out in terms of putting together a strategy for doing a flight test like that." That's eventually what EFT-1 became.

That's what we did at the time when Constellation was canceled, figure out a way that we could still fly the Orion crew module, get some good flight test data, instead of having to wait for the Agency to formulate a new strategy for a launch vehicle and morph itself. We wanted to try and keep moving ahead and making progress, so that's what we did. My Office here, once EFT-1 was approved, there were some things that Constellation was doing that we had to fill the gap.

The other philosophical change that Geyer wanted to do here is just give Lockheed the responsibility to do the mission. The government provides the flight test objectives. Lockheed provides the data back to the government based on the flight test objectives. It was basically make it a commercial launch, and FAA [Federal Aviation Administration] license; Lockheed, they go do the mission. That was the original plan, but then the whole network thing was an area that really NASA had more expertise in. That was one of those gaps, because the office at Constellation that did that went away, and so my Office actually stepped up and said we'd take

care of that. Working with the people at Jet Propulsion Lab [Pasadena, California], we came up with a network working group. We basically made sure all the ground network, space network stuff was all coordinated and requirements were established.

The other interesting thing that happened is Astrotech [Space Operations, Florida] was where Lockheed was going to integrate the LAS, stack it on the spacecraft, and then transport it to the launch pad. Just so happens there was a bridge down there that was going to cost over $1 million to get certified for the load for transport from Astrotech out to the pad, so that's when it was more cost-effective to have the government provide the integration facility. Again that's where my Office got involved working with [LSP, Launch Services Program] to provide the Payload Hazardous Servicing Facility down there, [KSC]. That's where they actually serviced the EFT-1 crew module in terms of ammonia and hydrazine. It went there, and we did that in a government facility with GSDO's support. They provided the ammonia cart to service the ammonia, and then we transported it from there to the Launch Abort System Facility where Lockheed stacked the Launch Abort System and then took it out to the pad from there.

The government picked up a little bit more of the work, just because of expertise. We had more expertise in network, because we owned the Space Network, NASA, and the ground network, a lot of that is owned by NASA. Just seemed to make more sense to let NASA integrate that. Then just a cost saving thing to have the government provide the facility to do the hazardous processing.

ROSS-NAZZAL: It sounds like morale was never really low here.

REED: We had plenty to do, believe me. Of course I was on the recovery team. Tom [Thomas E.] Walker, we had the responsibility for the recovery. GSDO provided support, whereas now it's GSDO's responsibility on EM [Exploration Mission]-1. With EFT-1 that was another thing that the government did; it was led under MPCV for the recovery, and GSDO provided the support. Then I helped with the air operations out there to get the helicopters in the air and get all the imagery to meet the flight test objectives. That kept me very busy working that. Griff [Griffin P. Corpening] next door here, who was my Deputy, helped work the LCC [Launch Control Center] and the mission management team. He sat in there in terms of flight test objectives, and what do we do if certain instrumentation goes down. They worked through a whole thing of what's acceptable if we have failures in the data system.

Then Joe [Joseph B. Voor] next door here, my ops guy, he was working all the different requirements for services and support at the launch site. We were taking all Lockheed's requirements and then getting them into what they call the Universal Documentation System, particularly the program requirements document, which is how we request services from all the different organizations, from KSC, from the Cape, from the Air Force. We were basically just plugging holes when we went from this Constellation cancelation to trying to get EFT-1 done. We just all pitched in and filled in where we could. There was plenty of work to go around.

ROSS-NAZZAL: You mentioned working on the recovery, so you were working on EFT-1?

REED: Yes, EFT-1, I was out there on the recovery ship. Tom Walker, who works in this Office, was the recovery lead. He cochaired the recovery panel with Jim [James S.] Hamblin down there

at GSDO, so it was a co-led effort on the recovery. MPCV was the lead, and GSDO was supporting, where now it's reversed for EM-1. GSDO is the lead, and MPCV supports them.

ROSS-NAZZAL: Would you talk about your involvement?

REED: Yes. Fundamentally I had to make sure that we had the clearance for the helicopters to take the NASA-provided imagery gear and carry it on board the helicopters. It was an interesting experience. It's not that doing that is any different. Working with the Navy, they call it NAVAIR [Naval Air Systems Command], Navy Aviation out of Patuxent River, actually going through their whole flight clearance process was very interesting and done in a very short amount of time.

Bottom line is we got through all that and got certified to fly our equipment on their helicopters, then going through all the training. We were in pretty close. There were hazards we had to worry about, and there's tools we used to avoid that hazard. Doing all that training and getting the aircraft in the right position so that we could acquire the spacecraft coming back from orbit. That's a pretty tricky task to be able to pick out a spacecraft at 70,000 feet without having any autotracking aids if you would.

We had two Navy helicopters. We had the same crew in terms of the pilots and the people that operated the sensor on board the actual Navy helicopter. A lot of our guys from NASA had experience, so we basically took what we did at Yuma [Proving Ground, Arizona]. I do the Yuma operations also for the CPAS [Capsule Parachute Assembly System] testing. We use helicopters there. We use the same NASA still photographer, videographer that we'd use for quite a few drops. It's the same tools that we use. Fundamentally we took the same operation

that we used with the CPAS testing at Yuma and then we just transferred that capability and adapted it to the Navy's helicopters in capturing a vehicle coming back from space as opposed to one being dropped out of an aircraft at thirty some thousand feet. We'd learned a lot at Yuma and then we just applied that to the EFT-1.

We brought the actual aircraft over to Yuma, and that's where we did some training in terms of letting the Navy crew actually see what the crew module looks like, what the sequence of parachute deployments look like, what the forward bay cover looks like coming off. That was a good test for them to actually look through their cameras and see what they were going to see on EFT-1, so they knew what they were seeing and what to follow.

One aircraft followed the forward bay cover down, the other one followed the crew module down. It was just a good opportunity for them to actually see what they were going to see for EFT-1. They learned a lot. I was really shocked that both helicopters picked up the crew module well before we expected them to. They both got it and tracked it all the way to the water.

ROSS-NAZZAL: What was your role during EFT-1?

REED: I had multiple roles. Again, we were responsible for the network, responsible for recovery. We were responsible for the ground processing once the crew module left the O&C [Operations and Checkout Building], and then specifically on the recovery side I was the air ops lead out there on the recovery ship. It was our responsibility to get the flight clearance, to get the crew trained, to make sure we had our operations integrated with the other operations going on on the ship, which is a very interesting experience.

This surprised me, but the Navy apparently never had experienced helicopters cranking their engines on the flight deck at the same time they're trying to do operations inside the well deck. The first time that we cranked the engines to take off, they told us to shut down, because it was so loud in the well deck they couldn't even communicate with each other. What we had to do was go deconflict all the helicopter ops from the well deck operations. Getting all the sequencing of all the different activities that had to happen on the ship and the helicopter ops, getting that all integrated in a good timeline so that we could work without interfering with each other.

Communications was the other thing that took a lot of effort. It was flight rules development. What happens if the crew module is not where it's supposed to be as it's coming back on its reentry? Because where are our tools and where are we [depended] on the crew module being where it was supposed to be. We had to go back and look at all the credible failure modes that could affect the navigation state of the crew module. Then work with the people over here in the Mission Control Center [MCC] that had the data coming off the vehicle to know whether or not the nav state was credible and that the vehicle was actually where it was supposed to be, then working communications. When we got calls from the MCC on the control tower on the ship that relayed information to us out there flying around.

That took a good bit of effort in terms of generating those different conditions and then convincing everybody that we could actually implement that, that we had sufficient time to implement it, and to convince the safety community that we weren't putting anybody in harm's way and we had a good exit strategy.

ROSS-NAZZAL: Did you witness the launch from where you were of EFT-1?

REED: Yes, they had the actual feed from the launch site on the ship. We were all down in the chapel. That's where they congregated. We sat there and listened to the countdown. Of course the first day it didn't launch, it scrubbed. It's like oh. It's actually fortunate that it didn't, because the weather on that day was not very good for a helicopter. We had a lot of low-hanging clouds. It's overcast. We probably wouldn't have got what we actually ended up getting if we'd gone on the 4th of December. By delaying a day, the weather the next day was just beautiful. That allowed us to get some really good shots.

ROSS-NAZZAL: Were you in the helicopter for the recovery?

REED: Yes.

ROSS-NAZZAL: Can you share those details with us?

REED: Yes. What better place could you be, talk about a front row seat. Yes, it was pretty amazing. We could actually see the imagery in the back. They had a repeater of the display that the pilots were looking at. We could actually see them acquire the crew module and then see all the chutes deploy. It was really something to see all the main chutes come out and actually look out there and see it coming down.

To actually fly up to it just after it splashed down, be the first people there to actually see it, that was pretty neat. The crew module came within four miles of where we were. It's probably the closest anybody's ever been to a vehicle coming back from space.

ROSS-NAZZAL: There were some problems with the uprighting system. Was that a challenge for retrieval?

REED: That was a good lesson learned, because at the time one of the things that we try and do is recover as many of the pieces, parachutes and stuff, as we can. When we're at Yuma that's one of the things that we do with the helicopter. After the crew module lands and all the chutes come down, we go around and we go get coordinates of where everything lands so that the recovery team can go out there and recover the parachutes and the hardware to get it back so they can analyze it.

We applied those same techniques to EFT-1, not thinking that there could be a failure of the CMUS, the Crew Module Uprighting System. The plan was as soon as the crew module splashed down and the parachutes cut away, we would refocus and try and pick up the drogue chutes to follow them to where they splashed down so we could go see if we could mark them and get the recovery crew there to pick them up.

We had that whole plan orchestrated. We had smoke grenades and sea dye and communications set up to talk to the RHIBs [Rigid-Hulled Inflatable Boats], the small boats, to get them to where they could pick up these items. We refocused our imagery sensors to the drogue chutes, and we should have stayed on the CMUS because of the failure. The initial failure we captured, because the failure happened right away. But had we been more aware that that failure might happen, we probably would have focused on the CMUS bags and not gone to look for the drogue chutes and the pilot chutes. That's a good lesson learned, and that'll definitely be an objective we make sure we get here on the EM-1, now that we know that failure.

It's there, they didn't get root cause, only probable cause. That's one thing we're going to do, make sure we keep some cameras on the CMUS so we don't miss anything.

ROSS-NAZZAL: You've talked about working with DoD [Department of Defense] and some of the other NASA Centers. My understanding is that Orion is very much a multi-Center approach. You could probably say a multi-Agency approach. Can you talk about how that's affected the Program in your perspective?

REED: I guess there's different ways to look at this. There's the production program, all the coordination that goes on there. I don't get so much involved in that. Having worked PA-1 and now AA-2 with all the different Centers and different organizations, we work with the Air Force, the Eastern Range, GSDO, Lockheed, different contractors.

Working with the different Centers has been a great experience for me. We really work well together. It's been a good experience from where I sit working PA-1 and AA-2. As far as the Program, program-to-program, we watch that from my Office standpoint. We have a separate agreement with GSDO to get support from them. There's some challenges there. They have a certain mindset, and we have a certain expectation on how we want to do things. It takes a lot of communication, coordination with GSDO. Nothing bad against them, it's just it's an educational thing.

In fact we had a meeting in June to sit down with their management just to talk through: who's in charge, who's our interface, how the decisions get made, so that we could understand who does what down there in terms of making decisions. We sat down in May of 2015 with their systems engineering and integration lead Phil [Philip J.] Weber and some of their safety

people, and we walked through the whole flow down there, all the different things that we're doing and what GSDO is going to do. We have a memorandum of agreement with GSDO specific to AA-2 because this gets into funding issues; who's going to fund what activities. We've been working very closely with GSDO in terms of program-to-program coordination. We actually have an individual that's assigned to my Office that's matrixed here that is from GSDO, so we have a direct line into their Program.

We've got the people in place. We understand the processes. We've got agreements in place, and we just continue to morph those and update them as we get closer. I have no issues working Center to Center. Everybody's been great working together. Working with DoD, you just got to know the process and how to get their support. I think all in all, it's worked pretty well.

ROSS-NAZZAL: We talked about some of the budgetary issues and its impact on the Program. I wonder if you could talk about policy decisions or operational decisions that you think have impacted the Program or testing in particular, your area.

REED: That's a heavy question. What it ultimately comes down to is it's a risk acceptance. What's an acceptable level of risk that you're willing to take by cutting out content in these tests? I'm retired military, and I keep going back and telling people that when I was in the military, the program managers would have control over these large tests. What the military realized is that when there would be budget problems these program managers would cut these big integrated tests. [They'd] be the first thing to go, because they're the most expensive thing. If they're running short of money, they cancel the big tests.

What the Army in particular did is they took that away from the program managers. They put all the testing under a separate test organization so that the budgets couldn't be cut for these big integrated tests. What I see in NASA, NASA is doing that same thing that the military was doing. When they get into budget problems, what do they do, they go after the big tests. Like I said, we started out with six tests, we're down to two. At what point is the risk no longer acceptable?

I've got to caveat this by saying that the analysts have done a pretty good job. PA-1 was an extremely stressful test. The analysis was pretty darn good. I think that our tools these days, our computing systems, allow us to model things much better than we could do 10, 20 years ago. It's just at what point do the unknowns get you. Are you putting the right things into your models to really model the physics the way it's really going to happen?

When you start cutting these tests, at what point do you cross the line between actually getting data from the real flight tests to anchor your models versus trusting your analysis? It's a very fine line. I've always been a believer that these big tests don't necessarily help you certify the design. What they will show you though is where your analysis was off. You're outside what your uncertainties were and your predictions. That's where you really benefit, where you just totally missed something that you didn't expect. As we cut back these flight tests we're adding a lot of risk. Do we really understand that risk? Do we really truly understand it? It's the unintended consequences, the unknown unknowns. There's a line there. Where is that line?

ROSS-NAZZAL: Is that something that you've talked with Mark Geyer and Mr. [Mark A.] Kirasich about? Have you been an advocate for keeping those tests on the books?

REED: Oh, I certainly have. But again what it comes down to, it's the engineering team, they ultimately have to be the ones that stand up and say, "This is acceptable. We're getting enough data to certify the design."

We're more of a service organization. I have a flight test background. I understand that there's certain risks you take. It's really the Engineering Directorate that has to really stand up and say, "Here's why we're confident that we can certify the design." They certify the design. Safety and mission assurance [S&MA], sure, they've got a big role in that. But those are the people that decide whether or not the design is going to be certified, not me.

I can only say from a philosophical standpoint this is why you don't want to cut these tests. Ultimately they've got to accept the risks based on what the safety and mission assurance and engineering ITAs [Independent Technical Assessments] tell them.

ROSS-NAZZAL: Everybody's on board? Or there are people who disagree with the assessments?

REED: They had a reclama when they went to make the change from using the EFT-1 crew module to a boilerplate. S&MA had a reclama. They had a person that reclamaed. The reclama went all the way up to Headquarters to Gerstenmaier, and they did the process. They listened to what he had to say but didn't change their decision.

ROSS-NAZZAL: What do you think has been your most significant challenge in working towards EFT-1?

REED: My most significant challenge was PA-1, just because that was really the first test that I had done in terms of being in charge of. It was a very challenging test because of the environment that everything had to operate in: loads and the avionics and the structures.

EFT-1, again it was providing the support that I mentioned. You don't realize how huge the Ground and Space Network is and trying to get all these different facilities all stitched together, meet everybody's requirements. The Program Office was in the mindset, "We've done this, and we know how to do this." That's years and years of flying the Shuttle. You fly a new spacecraft with different ways of transferring data, it's different routes, it's totally different. You basically have to start connecting all the dots. That was a huge challenge. I think the biggest thing there was just getting the Program Manager's attention that this really needed some good people working it and resources thrown at it.

I got a lot of pushback on having to pay JPL to do that work. But in the end they got the Systems Engineering Award of Excellence for their model-based systems engineering that was used to do that whole requirement set for EFT-1. In the end they got recognized the way they should have. The Program finally realized the importance of their role. That was a bit of a challenge getting through that.

Working with the Navy, NAVAIR, it's just getting up a learning curve on their process to get the flight clearance. The time pressure was tight because we started November and we needed the clearance in February, which wasn't really enough time. That was a real time crunch getting that all done.

From the hazardous servicing, just working with GSDO to get the ammonia cart certified. They pretty much were off on their own, did a great job getting that thing ready, getting the facility ready, getting all their support needs. Wasn't a real big thing.

Working through the flight rules and working with the MOD [Mission Operations Directorate] over here and those folks, getting the safety clearance for all the helicopter ops took a big effort. We got through it. That's really it.

ROSS-NAZZAL: What do you think is your most significant accomplishment?

REED: PA-1, to date. Probably got some of the best imagery you'll ever get of a capsule coming back from space. Just look at some of the pictures up and down the hallway. All the ones of the crew module and the parachutes, that was from our helicopter. Just supporting EFT-1 in general. Put a lot of work into it. Everybody did. It took everybody's effort to make it a success.

ROSS-NAZZAL: A lot of long days and weekends, long nights.

REED: Yes. By far the most rewarding was PA-1, just because we had total responsibility for making it happen and executing it.

ROSS-NAZZAL: Mark Geyer has said that Orion learned to persevere. Would you agree with that statement?

REED: Yes, definitely. Just to persevere in terms of the political environment, the funding environment. All the things. Compromises that had to be made in order to continue to move ahead. Personally, it's my opinion that it's a very inefficient way to do things. We're going to

spend a heck of a lot more money in the long run because of those compromises that we had to make. When I say compromises, let me just give you an example.

On the EFT-1 reaction control systems, the material they used to hold those reaction control system nozzles wouldn't survive abort loads. Basically we had to certify that design for EFT-1 from a loads standpoint. For EM-2 where we could do an abort with crew on board, now you got to recertify that whole system there because of a new material. You have to use a different material, now you have to go back and test it again.

That happened on quite a few components on EFT-1. They didn't qualify it to abort loads. You go certify it to what loads you expect to have on EFT-1, now you got to come back and recertify all those and test them to abort loads. If you'd just been given enough money to certify everything to abort loads, it'd be done with. But now you've got to test things multiple times. It's very inefficient.

ROSS-NAZZAL: NASA has an agreement with ESA [European Space Agency] to build the ESM [European Service Module]. Has that impacted your Office in any way in testing?

REED: No, because we don't use their hardware for AA-2. There isn't anything really that we touch, no software, no hardware. We're not involved in that.

ROSS-NAZZAL: Knock on wood. Unless you have anything else you'd like to talk about, I think we've covered most of the topics.

REED: Yes, it's been a great experience the last 10, 11 years. There's days when you get really frustrated, but in the end what keeps you coming back is knowing that you got a super job, you're making a huge difference, really helping our country and the space program to succeed. Human exploration, there's no better place to be. That's what keeps us going.

ROSS-NAZZAL: Thank you very much for your time.

REED: Yes, you bet.

[End of interview]