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

DANIEL DUMBACHER
INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is June 21st, 2016. This interview with Dan Dumbacher is being conducted for the NASA Johnson Space Center Orion Oral History Project. Mr. Dumbacher is speaking with us today by telephone from Indianapolis, Indiana. The interviewer is Sandra Johnson. I want to thank you again for taking your time today to talk to us. We really appreciate it.

DUMBACHER: My pleasure.

JOHNSON: I want to start today by asking you to briefly talk about your background and how you first started working with the Orion Program. As we were talking about a moment ago, I know you worked at [NASA] Marshall [Space Flight Center, Huntsville, Alabama] most of your career with NASA. You were working with Constellation [Program]. You were the Director of Engineering for the Ares Program. If you can talk about that, and how that transitioned to your next position, and that whole transition between Constellation and Orion.

DUMBACHER: It goes back to basically the Return to Flight era for [Space Shuttle] *Columbia* [accident, STS-107] when at the time I was working in the Safety and Mission Assurance Office at Marshall trying to help with all the efforts we were going through to get back into flight after *Columbia*. Then in parallel with that, the Agency under [Administrator] Mike [Michael D.] Griffin at the time was doing a study to determine what we ought to be doing in exploration.

As we were getting close to Return to Flight, basically I got asked if I would go over and work on Ares as the Deputy Program Manager working with Steve Cook. That's when I first got involved with Ares and Orion, with Jeff [Jeffrey M.] Hanley and Mark [S.] Geyer and those guys. As I'm sitting here thinking, I just realized I skipped a step.

Back in the 2004 timeframe actually, under Sean O'Keefe when he was the Administrator, I was working X-37 [Orbital Test Vehicle] at the time. Admiral [Craig E.] Steidle was brought in to head up [Office of] Exploration [Systems], and the Agency was going through a lot of analysis to determine what the next steps ought to be. At some point, they stood up an early version of the Constellation Program. I was asked to help out with that at the Chief Systems Engineer level in addition to my X-37 duties, and that's when I first got exposed to Orion, back when they were trying to figure out what the spacecraft ought to look like. They were going through the phase of what should the requirements be.

At some point in all of that I got asked to go over to help Safety and Mission Assurance and work on *Columbia* Return to Flight, so I got out of that business and moved over to Return to Flight, until I got back to the Ares Program like I mentioned. Then from the Ares Program, I did that for two or three years, I can't even remember, and then Dave [David A.] King was the Center Director at Marshall at the time, asked me to come over and be the Director of Engineering at Marshall. That was the job I held until the fall of 2010, when Doug [Douglas R.] Cooke and Bill [William H.] Gerstenmaier asked me to come to [NASA] Headquarters [Washington, DC] to basically—I can't even remember what the title was at the time—but basically to come up and be the Program Director for SLS [Space Launch System], Orion, and Ground Systems [Development and Operations].

Really what that job was all about at the time was trying to get the strategy put together within the Agency following the budget that canceled Constellation. I came up to Headquarters. There was a little bit of an organizational change. They combined Doug and Gerst's organization into one. That's when they slapped the title on things of Deputy Associate Administrator for Exploration Systems, but the job content was all still the same. It was Program Director for SLS, Orion, and Ground Systems.

That's when I got engaged, but I had seen Orion from the mid 2000s up until 2007 when I got asked to go to Engineering Director, and then Marshall had a little bit to do with Orion, particularly on the launch abort system, working through [NASA] Langley [Research Center, Hampton, Virginia], so I stayed in touch with Orion, and then back to it at the Headquarters level. So, I saw it at about three or four different levels and different time phases, which is interesting.

That's probably the short version of the background as best as I can do it.

JOHNSON: Since you did see it at three different levels and different places and from different perspectives, can you talk a minute about the cancelation of the Constellation Program and the budget? February 2010 was when it was announced by the President that he was going to cancel it, and then it wasn't until April 2011 that it officially ended. There was a time period in there that people were still working on something that they knew there was not going to be any funding for as far as Constellation, and that whole process of moving to Orion from that.

DUMBACHER: That was a particularly interesting period of time. I frankly don't want to have to go through that again. It was rather stressful to say the least. I think we were all surprised when

the budget proposal came out that canceled Constellation. When that happened, we started struggling with what to do next, and I give Jeff Hanley and [Lawrence] Dale Thomas and Mark Geyer a tremendous amount of credit in that they were astute enough to figure out what they could best do to keep the hardware moving, what was the best way to keep the hardware available, and how much progress could we make given the overall environment in terms of hardware.

They did a tremendous job of doing that. As we worked through the transition from Constellation to what became Exploration Systems, their thought process and the basis that they laid for that turned out to be critical, because once the Agency went back and relooked at the strategy and relooked at the requirements and realized that Orion was still the right thing to go do, then we already had a jump on the hardware, we already had a jump on the design, and we were able to get a test vehicle built in the form of EFT-1 [Exploration Flight Test 1] that provided us a lot of good engineering test data for the overall Orion Program.

Those three guys, Jeff, Dale, and Mark, along with their teams, I don't mean to say they were the only—because obviously it takes a large team to go do this. They really did a masterful job of figuring out and sorting through the strenuous situation and keep the right things going. We got through it. The Agency came out in May of 2011 with we still need Orion and here's why. We got that approved up through the [presidential] administration and Congress and so that's when we reinvigorated it and got it going again at the level that it should have been. That led to the progress they're making today and EFT-1. We went through that valley, and I don't think many of us want to go through that valley again.

JOHNSON: Yes, I can understand that. While that was happening, budget obviously was a big concern. I know with Orion it's a different type of budget, it's not like the older budgets where the money is all given up front and it's a lot of money and then things level out. This is a pretty level budget from what I understand.

DUMBACHER: That was actually one of the overall constraints that was put on the Agency by the administration, namely the Office of Management and Budget, that basically said, "Here's the level of money that you're going to get. Oh, by the way, no inflation, don't assume inflation, it's going to be flat. Here's what you're going to get." We had to put a lot of work into figuring out what we could do and how we could do it under an annual cost constraint, which is different than any of our prior experience in terms of a development program where you have a funding level that starts out relatively low, it peaks around critical design review when you get the initial hardware built and tested, and then as you get into operations it comes down.

This was, "Here's a flat line, figure it out." In that flat line we had to get not only Orion, but we had to get SLS and the ground systems at KSC [NASA Kennedy Space Center, Florida] all developed under that flat line, which led us to making some rather difficult decisions. I think Mark and company, the Orion team, did a wonderful job of working through and figuring out how they could phase the work and how could they go about making things more efficient, particularly between the government and contractor, Lockheed [Martin].

Then we had to get SLS into that same flat line budget, and we looked at several options, but we ultimately concluded that we may not have gotten the highest-mass-performing capability launch vehicle, but we got one that did what we needed and it did it within the cost constraint.

Then the same with the ground systems guys. The folks at KSC, Pepper [Phillip E.] Phillips and his team, were working hard to figure out what needed to be done and how could we do it in a flat funding scheme. As you might imagine, that was a challenge among all of us. But, I think everybody kept their heads about them and worked hard to come to a reasonable conclusion for the overall team, so it turned out.

It is different than the way we ever managed a program in development before in our lives, although somewhat similar to the [International] Space Station flat line experience after the mid ’90s. But, they were further along in hardware when they had that limitation put on them.

The team has done well, the Orion team in particular. When Mark and company came to NASA Headquarters with the idea and the proposal to do Exploration Flight Test 1, at first we all wanted to do it, we all recognized the need of getting a flight test, but we had some higher level strategy issues we had to get addressed before we could approve EFT-1, and we had to see how the budget worked out. Once we got to a certain point and realized that the strategy is settling down, now that we have a better clearer understanding of the strategy, we have a clearer understanding of the budget, now we think we can get EFT-1 in the budget, and then let Mark and team go off and execute.

JOHNSON: I know part of what early on in Orion they were doing and also with the SLS, they were going back and looking at other technology that had been used before in Apollo or Shuttle and reusing or revisiting that technology. Was that for budgetary reasons mainly, or was it just because it was more practical to do it that way?

DUMBACHER: Most of it was driven by the budget and the need to stay under the budget caps. The classic big example is frankly not an Orion example, although there are Orion examples. Big one on SLS is the fact that we stayed with a liquid oxygen/liquid hydrogen core stage because we had 16 engines from the Shuttle Program we could use, and we didn't have to do an engine development program. If we went with the other options that we assessed, we had to develop a new engine, and we just didn't have the money for that. So 16 engines sitting on the dock ready to go more or less was more cost-effective than developing a new engine.

As I recall, and actually the Marks, Geyer and [Mark A.] Kirasich, could answer this question better, I know that they were making some decisions based on some of the subsystems in Orion to keep the cost down. Because of the progress they had made on Orion from the mid 2000s and the beginning of the Lockheed contract, they already had some things in place. Their effort was more around not so much how do we change the design, because the design in some respects was already set and it's going to cost us more to change it than it would to just keep going. Although in some of the details they found options where they could do things, use some older technology to keep the costs down, they were really focused on how do we phase the work so that we stay within the cost caps. Which led to, pure and simple, the budget drove us into the situation where we could fly crew no earlier than 2021 on EM-2 [Exploration Mission 2]. That was purely budget-driven.

JOHNSON: I've read that in several places that the budget drove the schedule.

DUMBACHER: Right.

JOHNSON: Let's talk about when they asked you to come back with the Exploration Systems Development Division [ESD] and that work that you were doing there. If you could just explain what your position was in that. You mentioned that you had three areas, the Orion and the SLS and then the Ground Support. Talk about what you were doing at the beginning when you moved into that position, and explain that position as you saw it at the time.

DUMBACHER: The first thing I was doing was saying, "How the hell did I get here?" There was an interesting thought process going. Even before I came up to Headquarters there was a discussion at least running around at Doug Cooke's level, the Associate Administrator for ESMD [Exploration Systems Mission Directorate] level, about how do we do things differently.

Obviously we knew we were going to get a budget cap. We knew that the budget squeeze was going to be on. We didn't know how much. We didn't know what. We didn't know how long, but we knew the budget squeeze was coming. The question was, "Are there ways that we could do things more efficiently?"

I very well remember this conversation with Doug. Doug asked me one day in a hallway conversation when I was still Engineering Director and actually Steve [Stephen J.] Altemus and I were cochairing the Human Exploration Framework Team, HEFT. It later became known as HEFT 1, because there was a second version that got started up. Doug stopped me in the hallway one day and he says, "What do you think we could do more efficiently?"

I said, "I don't know. I got some ideas. Let me go do some homework."

Next time I was in Washington he stopped me again, "Well, you got an answer to my question?"

I said, "Well, actually I do. Let's go take a look at the Apollo Program Management Manual from 1968." I don't know what he thought. He probably thought I was nuts. I said, "Doug, if you look at it, what we're trying to do is not that different than Apollo. It's a launch vehicle, SLS, like Saturn V; it's a spacecraft, Apollo like Orion, and we got to have ground systems to prep and launch all this stuff." I said, "If you look at this Apollo Program Management Manual from the '68 timeframe, it's clear. The lines are clear. There's not a lot of overhead. There is an integration function over this, but it's different than the way we've done Shuttle and Station." I looked at Doug and I said, "I know this is going to be different than what everybody is used to, but it got us to the Moon."

This is one of those times where opening my big mouth got me in trouble, because it was in that conversation that he looked at me and said, "How about you come to Washington to start taking care of this?"

I said, "How about I don't?" After a couple iterations of that, we all know what happened. That's really where it started from was a notion. There was another dynamic working in the background, which was from a congressional viewpoint whether you like it or not or agree with it—I'm trying to figure out how to say this nicely, and it doesn't really come out nice. But, to be blunt about it, there were legislative forces from specific congressional delegations that did not want to see their respective NASA Center reporting to another NASA Center on a program. They didn't mind reporting to Headquarters, but we were actually getting legislative pressure that did not want to have another Shuttle management or Station management setup.

That is so foreign to the thought process at JSC [Johnson Space Center, Houston, Texas] that they struggled as much as anybody with it, if not more so. Frankly, Kennedy and Marshall

struggled with it also, because everybody figures you go to Headquarters, as soon as you get to Headquarters you got a lobotomy because there's no technical expertise whatsoever up there.

Fundamentally what we were trying to do was look at how could we get the same job done more efficiently. It wasn't a whole lot of science to it. It was basically going back and taking a look and saying, "If this worked for Apollo why can't this work now?"

A couple of us went off and had some conversations with George [E.] Mueller, who was the AA [Associate Administrator] during the Apollo days, and then I talked to a couple of my other colleagues. I'm drawing a blank on names right now, but they had all worked Level 2 integration for Space Station and other things. As you might imagine, George Mueller was one of the ones who actually put me on the idea with, "What you're describing and what you need to do is not that different than what we did in Apollo. Why don't you go back and look at how we did it?" We spent some time, George and I. In fact a couple of us flew out and spent a day with George Mueller, just getting his input on things. Then we went and did a little bit of other homework and came back and said, "If this worked before, why don't we try it again?"

One of the things it did do was it allowed in theory—and I think it did work this way out in practice—that it didn't put a program office located at a Center in a bad place about having to make a tough decision concerning that Center. We ended up down this road in this model. It's still the model that they're using today as near as I can tell. But it was driven by two forces. What can we do to be more efficient? Two, we're getting help from a legislative perspective on how they want to see the management between Centers lined up, so how can we address that? That's where the Apollo model came in and served needs.

JOHNSON: These congressional forces that you were hearing from, were they satisfied?

DUMBACHER: Yes. As much as they get satisfied.

JOHNSON: As much as they're ever satisfied?

DUMBACHER: The truth is every congressional delegation wants all the money sent to them.

JOHNSON: Right, and that's why they're elected.

DUMBACHER: We're like, "Wait a minute. No, that's not going to happen." We had an interesting debate—well, not debate. It took us two or three years to finally just get the Alabama congressional delegation to realize that all of the money under SLS cannot just go to the launch vehicle and the Marshall Space Flight Center. Some of it had to go to Kennedy Space Center to be able to be ready to launch a rocket. What good is it to build a rocket if you're not going to have a place to launch it? I'm not kidding. The discussion was at that level with some people.

JOHNSON: You are talking to elected officials and not engineers. I'm sure that has something to do with it.

DUMBACHER: They certainly come at it from a different perspective.

JOHNSON: Yes. I can imagine. Probably quite an education.

DUMBACHER: Trust me. My last five years, Sandra, at Headquarters was quite an education.

JOHNSON: It usually is, going to Headquarters after working at a Center, I think.

DUMBACHER: What was interesting is this was actually my second or third trip through Headquarters. You got inklings of it before, but boy, not like this last time.

JOHNSON: You mentioned that they didn't necessarily understand that you had to change things at KSC. Can you talk about some of that ground support and those changes? I know we hear a lot about the SLS and a lot about the Orion, but what was going on at KSC and the changes that had to be made? I know the launch pad was changed and some other things. Of course I think they had to refigure buildings for the stack. Can you talk about some of that for a few minutes?

DUMBACHER: Yes. The KSC guys had—and they still have, and they're actually doing a really good job with it—two problems. Number one, they as much as anybody else had to get the cost down. The typical past experience of Shuttle level budgets and Station level budgets was not going to happen again. Yet we still had to figure out a way to do exploration under a lower budget. All of us felt we basically had a choice. We either figure out how to do it within budget, or there wasn't going to be any human exploration. That second option was not acceptable.

The KSC guys had to start figuring out how to do things with modifying facilities, not building a new facility. They had to figure out how to make launch pads more efficient, how to design things. They actually had to get into more of the design and development mentality and less operational mentality. It took them some time but they got there.

The other thing that they were trying to do at KSC, which is extremely important and is playing out—I think over time we'll see how strategically intelligent this decision was—is to actually make KSC a spaceport that could address more than just NASA launches. The Blue Origins and the whoevers come to Kennedy Space Center, and it's treated as a spaceport able to launch multiple different vehicles and support different systems.

That can actually be competing demands. Get cost down on SLS and Orion processing, but oh, by the way, we want you to be flexible enough to handle other systems and be able to support the commercial launch vehicle market.

The KSC guys worked it pretty hard. They figured out ways to use some of the launch pad work that had already been started for Constellation. They figured out how to use that for SLS. They did things like we're not going to have two crawler [transporter] systems for SLS, we'll have one. They actually did that in a lot of ways. A lot of redundancy that we were used to under Shuttle went away under SLS and Orion simply because of the cost constraint. It drove us to a single system, so one crawler, one pad, one high bay in the VAB [Vehicle Assembly Building], as opposed to two high bays in the VAB. Right now they couldn't stack two vehicles at one time without having to refurb [refurbish] one of the other high bays, because we just had the money to refurb one high bay to get ready for the first couple of flights. The crawlers, the same thing, and they limited themselves to one pad, 39B.

JOHNSON: They went to what is referred to as a clean pad approach. The processing for the Shuttle was around 30 days, but they can do it much quicker now.

DUMBACHER: Yes. That was the whole idea. That was part of the efficient and be flexible was that SLS is going to come up on a crawler on its launch support structure with everything it needs. We're going to set it down. We'll launch it, and then be able to move that stuff and get it out of the way so that the next customer coming in can put their own system in.

JOHNSON: That is quite a change in the way we're looking at things. Also the Orion itself was developed to make it more flexible and to be able to go to different destinations and not just one, as opposed to pretty much everything NASA has built up until this point.

DUMBACHER: Right. That's an excellent point. We went to a lot of work with Orion to make sure that we had flexibility but yet were able to do it within the cost constraint. The good news here is that from the beginning they had a little bit more of a multimission mentality on Orion, because they saw this coming in that it had to be able to link up with habitats. It could be the only habitat for some missions, like EM-2 or an asteroid redirect mission. That's what drove the 21-day crew of four life support requirement, the ability to go do some missions only with Orion, recognizing that if we were going to need a crew module or a habitat longer than 21 days, we were going to have to build something else in addition to Orion, because Orion also serves that absolutely necessary function of getting them home safely on reentry.

One of the key trade discussion topics that we had to work ourselves through before the final approval to continue with Orion in May of 2011 was there was a concept of just leave Orion in Earth orbit, and as the astronauts are coming back from Mars, or wherever they're coming back from, they just go into low-Earth orbit and meet up with Orion, and then they come home from low-Earth orbit in Orion.

We had to show people that that was actually going to be a more expensive operation. More expensive in terms of just the technical needs, because we now have to be able to slow down. I got a vehicle screaming back at high velocity from Mars and now I got to slow down the vehicle, and that takes propulsion, that takes propellant, and that's propellant and propulsion hardware and tank hardware that I got to take all the way out to wherever I'm going and all the way back.

Once we walked everybody through all that analysis the reentry function that Orion provides, people understood it better that you're just not going to slow it down and stop the crew in low-Earth orbit, let them change buses, and then come on home. Whatever bus they're in on the way back from Mars is probably the bus you want them in, because that's the most efficient way to do it.

JOHNSON: I was reading, it's actually your testimony before the House Science, Space, and Technology Subcommittee on Space in October of 2015. It was just a statement in there that struck me. You said that "The team is dedicated to building all systems as safely as possible, as soon as possible, and as cost-efficiently as possible." When I read it, it reminded me of Dan [Daniel S.] Goldin's famous faster, better, cheaper philosophy. I don't know how familiar you are with his faster, better, cheaper idea, but can you just talk about that for a minute? What would be the differences between what you were talking about and the idea he had?

DUMBACHER: From me you're going to get a little bit different answer than you get from most people on this faster, better, cheaper thing. I actually did live firsthand that faster, better, cheaper, because there was a time where I left the Shuttle world and went over to the reusable

launch vehicle world, and did things like DC-XA [Delta Clipper Experimental], X-33 [rocket plane], X-37. Certainly the DC-XA stuff was all in that faster, better, cheaper mode.

My interpretation of faster, better, cheaper when those words were used was not go cut corners that don't make sense. I think some people misinterpreted faster, better, cheaper as they were allowed to go further on the risk acceptance scale than they should have.

In the DC-XA arena, we were able to accept more risk, simply because it was a flight test program sitting out at White Sands Missile Range [New Mexico] and we didn't have astronauts on board. We were allowed to do things a little bit that the Shuttle guys would not be allowed to do, nor would we want them to go do it.

I think the faster, better, cheaper got misconstrued. Maybe that's not fair. It got perceived and some people implemented it, and they implemented it in a way that they took too much risk that ended up costing them, like MSL, Mars Science Lab, and those other things. All true. I don't deny the failures that occurred under faster, better, cheaper. I also know from my own Shuttle experience that I treat systems that have people on board with one level of risk tolerance, and I treat flight test systems with a different level of risk tolerance. I actually think faster, better, cheaper if appropriately implemented is actually looking for a proper balance and allows the program management engineering team to be able to try things that they may not be able to try under a strict human spaceflight risk tolerance model.

My statement to the House Science Committee was meant to try to get a point across that this is all a balance. It's not about skewing the equation in one of the three directions or the other. I think it was a recognition, at least from my perspective, that certainly when we send humans to Mars or even to cislunar orbit we're taking on risk that frankly we've never taken on before, and it's actually in some ways riskier than Apollo. EM-2 for example, assuming they

stick with the current plan, or something similar to it, will have astronauts in a situation where they will be a minimum of nine days away from home if an emergency occurs. That's a whole different thought process than an hour and a half away on Station or three days away from the Moon. We have to think our way through that. We have to be able to make sure that we prepare for that.

At the same time, and this is where I have a little bit different perspective than a lot of people that live their lives completely in human spaceflight, we have to figure out ways to do things more efficiently. Over NASA's history we have been limited by budget. Shuttle was certainly a budget-limited design, no doubt about it. Over time we did things and requirements crept in, but we never—well, we did once, and we actually went a little bit too far. Sometimes it got us into the *Columbia* problem. We have a hard time on the human spaceflight side figuring out what risk tolerance we really are willing to take, and how much money we're really willing to spend to go get that risk reduced. We will sometimes—or a lot of times—spend a lot of money for very minor gains in risk tolerance or risk acceptance, when we could be using our resources better.

There is a history within NASA that basically over time it has been mitigated, but I used to hear these words when I was at Headquarters. "Well, listen, Dan. Your job is not to tell us how to do it more efficiently. Your job is to go up to Headquarters to get more money so that we get what we need."

That's all fine and dandy, but in Washington, DC, where NASA actually has to compete with everybody else for federal funding, you better think about being cost-conscious. You have to have some level of cost-consciousness about it. What we were trying to do, and the message I was trying to get across to the House, is this isn't an easy job. We're doing stuff that nobody's

ever done before, and it's risky, and we're doing it with people. Number one, it has to be safe, but we also have to recognize that we are stewards of taxpayer money. We have to be able to think through and make reasonable assessments of what resources are required, and then how are those resources utilized to keep the risk level at what the Agency would consider acceptable.

That's a tough thing to do. It's not easy. It requires all the best technical talent, best risk assessment talent, best cost estimating talent, to try to sort through those trade studies. They're all subjective. I can guarantee you that never will everybody be happy.

JOHNSON: Spaceflight is a risky business.

DUMBACHER: Spaceflight is fundamentally a risky business. One of the things I think is hard for the Agency—and I think it's coming around to understanding this. I think the planetary science people understand this actually better than the human spaceflight people understand it. That is there's only so much money to go around. As long as we are funded by the taxpayers, in the United States democratic system, we have to answer to their representatives in Congress. They have the right as representatives of the taxpayer to hold us accountable for how we spend the money. We don't get to play the card of, "We're NASA, we're special, give us more money." That worked for a while, but that doesn't work in today's environment.

All of us engineers, we like to think things in terms of black-and-white, right or wrong, yes or no, this'll work, that won't work. There's a lot of gray area in all this. There's much more subjectivity to it than we'd all like to admit. The laws of physics I can't argue with, nor do I intend to, but, when it comes down to those hard decisions and those subjective decisions of

what risk level is acceptable and how much am I willing to spend for it, that's the hard conversation that requires everybody's input.

JOHNSON: The risk level, like you said, is what you can accept changes when you put humans on board.

DUMBACHER: Right, it definitely does.

JOHNSON: I know when EFT-1 flew and now for EM-1 and then EM-2, some of the systems that maybe people would like to see on EM-1 aren't going to be there, because they're not ready, or because of the schedule and the cost. Some of them will be flying for the first time with the astronauts on board.

I know you're not with NASA anymore, but is that something that your comfort level allows you to accept as one of the risks of spaceflight in today's budgetary climate?

DUMBACHER: I tend to take these things one step at a time. If I look back, the big reason that we decided to go try to figure out how to put EFT-1 in the budget was because of the big risks that it was going to reduce or mitigate or give us a better understanding on for Orion. Is the heat shield going to work? That heat shield is tied directly to the structure. The more we understand that earlier, the better off we all are. I'm one of those who's a firm believer—and I know this is why Mark and the Orion team even put EFT-1 forward, because test data is worth a lot more than a bunch of expert opinions.

JOHNSON: Exactly. Yes.

DUMBACHER: We timed EFT-1 so that we can get the data back and give the engineers time to assess it before Critical Design Review for the EM-1 vehicle. That's what set the timing of EFT-1 was when do we need the data so that we can impact and influence and get that knowledge into the design process where it can do the most good, and that's before the Critical Design Review. That's what set the time for EFT-1.

That's step one. EM-1 is uncrewed so that we can go test out a bunch of other stuff, the next round of things, before we put crew in it. We do have the problem I think from what I remember of the program plan where we have some of the life support system—not all of it, because actually we're going to test as I recall the thermal management part. The thermal management part I know is going to get tested on EM-1. There are elements of the life support system that weren't going to get tested till EM-2. Then the debate was going to be what checkouts do I need to do before I leave low-Earth orbit and make sure we have everything working before we leave low-Earth orbit, because obviously we don't want to commit to an orbit where we're nine days away from home if we don't have confidence that the life support system is going to work.

All of that work is ahead of those guys. They're still going to have to sort all that out. But, I think if they're allowed to think it through in a step-by-step fashion and people recognize that this is a learning process along the way, they'll get there. There will be differences of opinion, but that's okay. It's in those differences of opinion and perspective that as we work our way through them we get ourselves to a better answer.

JOHNSON: You were talking about the Service Module and now we have the agreement with ESA [European Space Agency] where they're building the Service Module based on their ATV [Automated Transfer Vehicle]. I know that was happening right at the end of your time at NASA, but maybe some of the agreements or some of the conversation if you were involved in any of that with bringing ESA on board.

DUMBACHER: I was certainly involved with that. I think that was an interesting idea. I'll be honest with you, when I first heard the idea, I was worried. What I was worried about was you guys are holding me accountable for a schedule for EM-1 with SLS and Orion and now you're putting extra risk into my ability to be able to meet that flight date and budget. But, as we worked our way through all that there was no doubt that from the beginning, from a strategic perspective, getting international partners involved in Orion and actually doing it in a way where we were able to take advantage of the Space Station barter agreement to get some value for exploration was a wonderful strategic move. It got the international partners involved, made them part of the team, and all the benefits that go with the international partnership.

There are costs associated with that. The integration job is now a little harder. I've now taken on some more programmatic risk because I am now reliant on the Europeans meeting our schedule. The first flight of any system like SLS and Orion is obviously very important. You're taking on more programmatic risk, but as we worked our way through it, we realized that the benefits far outweighed the cost.

We had to work through the agreements and get all that in place. Had to make sure we understood the design that the Europeans were coming up with. Did it meet all the

requirements? How were we going to do the interfaces? That was a big challenge. In the end I think it's all going to play out extremely well.

I can tell you this. For the second year in a row now I've taken 15, 20 students over to Europe after the end of the spring semester. Of course with me setting up the trip it is space-related. When you talk to the Europeans, the pride that comes out, the recognition that now they are part of the overall human exploration and they're more engaged in human exploration, is not only a point of pride for them, but it's a recognition that they're part of the team. Yes, that European Service Module costs us a little bit in terms of integration cost, but in the end I think from a strategic perspective and building a sustainable exploration program, it was exactly the right move to make. I was nervous about it at the beginning. It took me some time to come around.

JOHNSON: I'm sure you're not the only one since it was the first time NASA has ever teamed with another country or another space agency to actually build the vehicle. I'm sure it was a little bit of a sales job to get everyone comfortable with that idea.

DUMBACHER: Actually the way the sales job worked is it was really just let's go through the process step by step. Understand what needs to be done and what our risks are. As we understand things, let's continually assess those risks against the benefit. If at any time we think that the cost or the risks outweigh the benefits, we'll pull the plug on this. But, we never got to that point because even when the risks and the costs seemed a little bit on the high side, when you stood back and looked at the benefits, you said, "It's still worth it."

JOHNSON: It's always a balance, I'm sure. Let's talk about some of the technological advances that have come from this new generation of spacecraft. Do any come to mind and stick out in your mind?

DUMBACHER: Yes. There are a couple but the problem is they're not obvious when you just look at the vehicle on the outside. It's all buried inside. I think on the Orion side they're using gigabit Ethernet to be able to process more data, have better communications capability within the vehicle and with the ground.

Mark and the team had to figure out how to do heat shields to withstand reentry velocities from the Moon and Mars and not be able to use asbestos just like the Apollo guys regularly used. With all the latest panels I think one of the things that Mark and the Orion team is certainly working hard to do is to get the electronics so that they're upgradable over time as new electronic capabilities come into the marketplace that they can incorporate those. As opposed to the Shuttle, where we put ourselves into a box where it cost us so much to make a change that we were still flying late '70s early '80s technology by the end of the program.

From an SLS perspective, the new technology is frankly buried in the manufacturing with friction stir welding and some of the things they're doing to get the tanks built, where we'll have higher quality tanks, less defects to process. It's buried in the manufacturing part. John Q. Public does not see it. A rocket looks like a rocket. It's in the details that the technology is coming in.

This is where you get into an interesting discussion. There are people out there that will point to lifting body designs and other things as this is the new technology. Yes, it is, but just because it looks the same on the outside as it did in the 1960s doesn't mean that there isn't new

technology buried inside. New manufacturing technology, new communications technology, new computer technology is all buried in there.

One of these days we'll have laser communications based on some of the experiments that people have run. That's all going to come to pass. The external shape basically is shaped by the physics, and the physics hasn't changed, that any of us can determine.

JOHNSON: Nor is it likely to, right?

DUMBACHER: Nor is it likely to. If it does, we got some interesting other problems to deal with.

JOHNSON: More than spaceflight, that's for sure.

DUMBACHER: I know Kirasich could give you a long list of the new technology that's in Orion and the SLS guys could give you a long list of the new technology in there. I think those teams are done a disservice when the simplistic view of well, if it looks the same there's no new technology.

It looks the same because the physics are the same. The new technology is inside. That simplistic view that I hear out in the press and other places every now and then bothers me. You probably could pick up on that.

JOHNSON: Yes, I think so. Yes, they can't see what's inside the cockpit or the digital changes and everything that's happened like you said.

DUMBACHER: What they don't understand, friction stir welding for example, we started using it on External Tank. We refined it for SLS. SLS is actually using the largest friction stir welding machine in the world. That technology is starting to make its way into the shipbuilding, aircraft manufacturing, other places, because they see that it's successful. NASA has figured out how to use it and has worked out a lot of the technical kinks. Now it starts to show up in other industries, which you don't hear a lot about.

JOHNSON: They're not the things that people want to read about. They're not all that exciting to the normal person.

[Interview scheduled time ended and second interview was scheduled.]

All right. I appreciate it. I will talk to you then.

DUMBACHER: Okay, glad to do it, Sandra. My pleasure.

JOHNSON: Thank you.

[End of interview]