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

CHARLES W. DINGELL
INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is August 3rd, 2016. This interview with Charles Dingell is being conducted for the NASA Johnson Space Center Orion Oral History Project in Houston, Texas. The interviewer is Sandra Johnson, assisted by Jennifer Ross-Nazzal. Thank you again for joining us and agreeing to talk to us today.

I want to start today by asking you to just briefly describe your background and how you first became involved with the Constellation Program.

DINGELL: I worked on X-38 with Brian [L.] Anderson when Admiral [Craig E.] Steidle was appointed to the [Office of Exploration Systems] at [NASA] Headquarters [Washington, DC]. He came and visited JSC. He talked to various people including Brian about CEV [Crew Exploration Vehicle] which was being born at the time. He basically offered Brian the job. It turned out to be Deputy Project Manager starting CEV working under Charlie [Charles J.] Precourt. I worked very closely with Brian, so Brian asked me to do some work related to helping their team prepare the RFP, request for proposal, for a Phase 1 contract for CEV. Then after that there was an evaluation period for the RFP and I was asked to go to Headquarters, spend three months or so in Headquarters area leading a technical team that was evaluating those RFP proposals for the Phase 1 contract.

After doing that, and the Phase 1 contract was awarded to two different teams, we needed to spin up an engineering technical type of team to work with those contractors, evaluating their designs and their studies. Brian asked me to be the lead of that Phase 1 oversight activity, so I organized a team that evaluated the contractors' designs and their studies that they did as part of execution of that Phase 1 contract.

Then when a formal project office was assigned, Brian asked me to be his Chief Engineer. I've been in that role under various titles since 2005, 2006 timeframe, whether it was Chief Engineer or Project Technical Director or Chief Architect, Vehicle Design Manager. Now I'm Spacecraft Chief Engineer, been through four or five different titles and flipped between badged to engineering versus the program. But essentially doing largely the same kind of job as the spacecraft technical lead over the last 10, 11 years or so.

JOHNSON: Talk about those early days and some of the duties and how you worked with the contractors and what that relationship was like and what you can remember about that time period.

DINGELL: Of course we had two different competing contractor teams at the time, Lockheed Martin on one side and Northrop Grumman teamed with Boeing on the other team. Their work broke down into two fundamental areas. They had to put forward conceptual designs for a spacecraft that would do certain things per the criteria of the Phase 1 contract, and then they also were to perform what we called special studies.

The studies were related to helping the government figure out maybe what size spacecraft should we have, what type of launch abort system would be most appropriate for it. Propulsion system, should we stick to what we call storable or toxic propellants, which have their advantages, but they have disadvantages because they're toxic, or should we move to more what we call green propellants like LOX [liquid oxygen]/methane. There were probably 20 or so special studies that we assigned to each contractor to help us get educated and answer those kind of architectural level questions. We generated a list of the 20 or so studies.

We gave the same list to each contractor, and then of course we had almost daily dialogue with each contractor, but then we had formal reviews as I recall, quarterly milestones where they would in an organized, somewhat formal way present the status of their design. The other half was present results to date of those study results. We would have a chance, it would be normally a two- or three-day meeting with each one. It was much like a form of a Preliminary Design Review kind of a thing, without some degree of the formality, and without things like RIDs [Review Item Discrepancies]. But we would have two-way dialogue, we would give them perhaps some feedback related to what we were seeing in their design or their study results, ask them questions.

JOHNSON: Was there a lot of difference in the designs or anything significant?

DINGELL: They started out very very different, because no specific direction was given in the RFP [Request for Proposal] related to the shape of the spacecraft. One contractor proposed a capsule which is the model that's sitting right there behind you. That was the Northrop Grumman-Boeing team. Lockheed Martin was pursuing more of a lifting body type of approach that they disclosed publicly in some magazine articles. Then we figured out in working with the NASA Administrator [Michael D. Griffin] that we really needed to normalize between the two. NASA needed to decide do we want a complex spacecraft like a lifting body, or are we really more looking for a capsule.

In parallel some government-led study work was going on independent from the actual CEV team. I forget the actual name of that study that Dr. Griffin had commissioned at the time. And coming out of that study was a conclusion that for this particular mission really the capsule shape was the appropriate shape for that mission.

Not too far into the Phase 1 activity, the decision was made at the Administrator level that we need to normalize these teams and tell them both, "This is the government reference design that we want you to go put details to." At that point in time, basically Lockheed Martin had to change their shape pretty dramatically, but they were able to import the systems within the spacecraft into the different shape. It was difficult for them, but they had a pretty good recovery plan for it as well. That was some of the initial things I remember starting out working with them.

Of course just seeing the results, it was interesting to contrast the two teams together. I remember a lot of similarities but a number of differences as well in their approaches in terms of the design and in terms of how the team worked. It was a little bit of a touchy thing. We were coached quite thoroughly by our contracts people not to cross-pollinate between contractors, in other words steer one contractor to be viewed as goodness—you might look at one contractor and say, "Well, yes, he really has the right idea, he gets it, and this other guy doesn't." Since it was a competition we were not allowed to say, "Well, shouldn't you maybe be doing this instead?" Some degree of difficulty involved in keeping your mouth shut on certain things.

JOHNSON: I can imagine that it would be. It's interesting that Lockheed Martin, even though they didn't start with that initial design, they're the ones that ended up building the capsule.

DINGELL: It was.

JOHNSON: You mentioned that there were some differences in the teams. Is that part of what goes into picking a contractor, how the team works together and with the NASA people also?

DINGELL: It's definitely a part. I would say that by and large the selection was done to a great extent independent of that Phase 1 work. There was an entirely separate team working out in what we refer to as the bunker here at JSC. They were working the RFP for the Phase 2 contract, and they received the Phase 2 proposals from the contractors. Our contract folks intentionally firewalled off that team from other entities such as the Phase 1 team so that the contractor work process could remain pure.

As part of the RFP evaluation criteria we were requested by the Phase 2 contract team to come in and give a briefing related to our findings from the Phase 1 contractors. That was used by them as input data in making the selection. But you might imagine contractor one was better at certain things, contractor two was better at certain other things. So it was a balance between which issue you considered most important. In the end it was a fairly balanced evaluation.

JOHNSON: You mentioned those studies that you gave to both teams early on to help NASA figure out what was the most feasible. Is that what those studies were for?

DINGELL: Primarily for that. Some of it was to specifically get them to address certain details, tell us how you would do a certain thing. Certain things that we knew we wanted to know about what they would do. But I would say the majority of it was to help—we were still trying to establish the architectural type approaches. It was really to help focus. LOX/methane green propellant sounded like a really good thing to do, but it comes with certain other challenges, and the devil is in the details of understanding those challenges.

We said, "Let's get another level of detail and a prime contractor perspective on that level of detail. Let's direct them to do a study related to which propellant for this application makes the most sense." Primarily we used that to help us make architectural-level decisions, which we would then turn around and basically probably direct the contractor that okay, we want LOX/methane propulsion or we don't.

JOHNSON: Eventually Lockheed Martin was selected. Talk about those early days and working with the contractor as far as building the spacecraft and the teams and maybe how it was organized between NASA and them, and what that work relationship was like.

DINGELL: We had a close working relationship pretty much from the start. In fact I would say that was probably one of Lockheed Martin's strategies in trying to get selected as the Phase 2 contractor. They seemed to put special emphasis toward cultivating I wouldn't say a personal relationship with the government, but a very close working relationship, to where the government technical team that did oversight did not feel stiff-armed or firewalled or held in the dark about certain things. Their strategy seemed to be let's be very open, let's make these people comfortable, smart, educated about what we're doing, let's make them comfortable, let's get their buy-in along the way, and not keep them in the dark until major milestone reviews and then spring the design on them at a major milestone review.

There seemed to be this daily working environment. We worked very closely together from the get-go. I worked and have been for the last decade working very closely with the Lockheed Chief Engineer, Bill [William] Johns. We've had an excellent working relationship from the very start.

JOHNSON: Between that 2006 and 2010 time period and in moving toward the Orion capsule and that whole concept, is there anything that stands out in your mind as something that is memorable during that time period?

DINGELL: There's no one particular thing. It was just a huge challenge to start to spin up a team from scratch. There were some complications involved in another entity was supplying the launch vehicle, and it was not an existing launch vehicle at the time. It was a parallel effort to design the Ares I at the time.

There are some complications that can be involved from that in terms of to design a spacecraft for example you need to know what is the loads environment that the launch vehicle will impart on the spacecraft. Those loads environments were not necessarily defined yet because the launch vehicle was in the same infancy of its design phase as we were. You had a prime contractor that was there ready to design, but maybe he didn't have all the input data that he needed in terms of, for example, loads definition.

You get into perhaps making them wait for that loads data to be developed, and maybe that causes their schedule to be delayed right off the bat. Who do you hold accountable for that? It's hard to hold the prime contractor accountable if they were waiting on a government product to do it.

There was also a complication involved in the Phase 2 contract was awarded prior to Constellation being born, or maybe Constellation was born but still in its very very infancy. We were the CEV Project at the time, then put under the Constellation Program when Constellation was born. Constellation spooled up their team, guys largely independent from the ones that had been working the CEV Project. They began writing certain requirements from the Constellation Program level that turned around and flowed down into new requirements that had to be imparted upon the spacecraft and the prime contractor. Now a very difficult thing programmatically, you've awarded a contract, you've got a schedule, you've got a cost to meet. Now all of a sudden six months or a year into your prime contract here's a set of new books that are now new requirements upon you.

You can imagine the square wave that that can cause. There was a large increase in the contract cost as a result of imposing these new requirements. That is I think perhaps a lesson learned by the Agency. That's not a good thing to do.

JOHNSON: During that time period also multiple Centers were involved. What do you think about that whole concept of having everything—again, it was the first time NASA had built a spacecraft in a long time. Then having the different parts of things being directed or involved at different Centers. Was that a good working relationship with Centers?

DINGELL: Yes, I view it favorably. It was a net win for us in my opinion, leveraging the talent and the resources I think relatively appropriately from the other Centers. It does create obviously difficulty. It is most efficient that everybody lives under as close to one roof as you can. It's most efficient to get the job done that way. In this case with the magnitude of the program I think it did make sense to leverage talent and resources at other Centers to get the job done.

For example the TPS [Thermal Protection System] development work that was to a large extent led out of [NASA] Ames [Research Center, Moffett Field, California], I view that favorably. The aerodynamics work that [NASA] Langley [Research Center, Hampton, Virginia] was a big player in, I view that favorably. The propulsion that [NASA] Glenn [Research Center, Cleveland, Ohio] became involved in, I think they brought a lot to the team, I view that favorably. Langley also helped us with advanced development work on the landing systems. They did outstanding work related to that.

In the end I don't have memories of viewing anything in a negative light that oh gosh, we were forced by the Agency to go leverage certain resources at other Centers and that was a drag on the system. I don't have memories of viewing anything in that way. I think expanding our work with other Centers was encouraged to us at a certain time, and I think in the end that turned out to be a good thing.

JOHNSON: Let's talk about the time around the cancelation of Constellation. Did you have any expectation that that was going to happen?

DINGELL: Prior to it actually happening, no. Was it February 1st, 2010?

JOHNSON: Yes.

DINGELL: Seems to be a date ingrained in my head. It came as quite a surprise. Perhaps I heard something in the hall maybe a week before that, but very nondefinitive. That came as pretty much of a shock.

JOHNSON: What was it like, the atmosphere and the people you worked with, with the teams and also with the contractor, during that time period? I know for about a year or so until it was actually canceled it was still funded. The work was still going forward even though you knew the President was canceling the program. Just talk about that time period and how it was working with everyone during that.

DINGELL: It was a negative time period obviously. I think some reaction on the team was gosh, here we are again with the government canceling yet another project for us. For me personally I had spent seven or eight years working X-38, which I was a strong believer in, only to have that canceled when we were pretty far along, I think canceled in favor of Orbital Space Plane Project, which in turn was canceled a couple years later in favor of CEV. And here we were now, CEV as part of Constellation, being canceled. It really reflected negatively on our government, I think. There were some views along that line.

But that said, we still kept our head down and worked. It was a little bit awkward in terms of well, if we're really canceled should I work to try and organize and preserve knowledge and work that we've established to date, so that we can use it in a positive way on whatever project similar to this that lives on, should we put our effort into that, or should we put our effort into still building the spacecraft? We actually did our PA-1 [Pad Abort 1] flight test in May of 2010, so we were very far along on that. Should we complete things like that?

We kept our head down and basically we did complete things like that. It became apparent in a fairly short amount of time that Congress was going to put up a fight and maybe there was some chance that in the end we would live on, so I will hand it to Mark [S.] Geyer for very skillfully managing and leading the team through that timeframe, and keeping the team working with positive outcomes, and in the end keeping us alive because he did that. A lesser person in that role, we might have had a different outcome.

JOHNSON: I know the idea to do EFT-1 [Exploration Flight Test 1] was floated relatively early during that time period. And as you said, the pad abort test, was done, even though there was some controversy whether that should be done or not. Then NASA decided to go ahead and do that and then keep working toward the EFT-1 flight.

DINGELL: Yes, as I recall—getting canceled projects mixed up—but it seems like there was a sentiment of well, yes, let us go do this Pad Abort 1 test. Even if this vehicle doesn't live on, whoever lives on can use the knowledge gained from that. We're so far along. The test article is built. We obviously flew it three months later.

Then there was the move to streamline our first vehicle we created, seems like in the summer of 2010, what we called the Block 0 vehicle, which was a scaled down vehicle. Then I remember going on vacation that summer and coming back in August of 2010 I think, and an idea had been cooked up related to taking Block 0 to even more of an extreme, where OFT-1 [Orion Flight Test 1] that then became EFT-1 was born. It was a little shocking, but after the initial shock at least for me I very much got behind the idea. It was very refreshing to just clear the deck of as many inefficiencies as you could and cut straight to the chase of let's go build a vehicle as fast as we can. That was a refreshing thought. It turned out to be I think one of the reasons that we lived on.

JOHNSON: Proved a point, that you could work toward that and make it work. Then of course the MPCV [Multi-Purpose Crew Vehicle] was announced in 2011. So after that announcement I assume that things started moving a little, the feeling was a little more positive that things were going to live on and the work was going to be completed at that point.

DINGELL: It was good to be formally recognized as real again.

JOHNSON: That's an interesting way of putting it. You mentioned earlier when we were talking during the Constellation part about the budgets and how things increased. Then with Orion of course the budget is a flat budget. It's not one like normally happens where you have a lot for development and then it flattens out. It's pretty much flat across. How has that affected the development of the Orion vehicle?

DINGELL: It stretches it out quite a bit because the natural thing that you want to do is you need more people in the design phase of a spacecraft than you do during the sustaining or even the production phases. Once you've got the design under your belt now you can put your work into producing that article. People that were used as designers can move on to other projects. If you're flatlined and you're stretching it out more, then fixed costs, overhead type of costs, start to become more dominant and reduce your efficiency. So just to put it simply, if you need a factory floor, there's a certain dollar amount, and it's not insignificant, to keep the factory doors open. When you add up all those fixed costs, if your marginal budget over that is small, it takes you a long time to do it, but meanwhile those fixed costs are still there year after year after year. It's much more efficient if you can have a surge in budget at first to get that design work done, and once you get the design work done then you ramp back down to a lower cost. It has created inefficiencies in terms of how to get the project done.

JOHNSON: I was talking to someone from Langley and it was on the launch abort system. They were talking about how after the Constellation was canceled and then Orion went on in 2011 that Mark Geyer made some changes as far as the way the engineers were working in teams. He wanted engineers to be embedded with the contractor so that it was more of a side-by-side effort. Was that part of it?

DINGELL: Yes. That kind of thing was going on. As I mentioned earlier, we worked very closely side by side. I don't remember the exact numbers. But let's say like two-thirds of the technical team budget or resources were being used for oversight work. Working side by side, but in an oversight role. One-third approximately was for direct in-line type of products or GFE [Government Furnished Equipment] projects like the parachutes, the advanced development work on the TPS and the landing systems.

In 2011ish there was more of a push to, "Look, we can help the prime contractor by having government guys actually do some of the products that Lockheed would normally do themselves, and that could reduce Lockheed's budgetary needs." In the process of doing that work, not only do you develop a product, but you get oversight in the process of doing that product.

That's only good really to an extent. If you put 100 percent of work into in-line products and said, "Well, you're going to get oversight as a result of that too," I don't think that model would quite work. I think where we landed, which is probably roughly one-third of our resources pure oversight, one-third doing government GFE projects like parachutes, and one-third doing more of what we call MODE [Multi-Organizational Design Environment] team or in-line tasks where we share with Lockheed, I think that model has worked very well. I was comfortable with the outcome when it came time to approve the EFT-1 vehicle for flight. I was quite comfortable with the level of knowledge that our folks had, even having executed the model with quote reduced oversight for three years at that point. I was still quite comfortable with the level of knowledge that our guys had. I think it's a good model.

JOHNSON: In your position did you work closely or at all with the Exploration Systems Development Division out of Headquarters and that cross-program system integration initiative that came from there?

DINGELL: Me personally, no. Our organization, we have Julie [A.] Kramer-White is the Program Chief Engineer. I work for her as the Spacecraft Chief Engineer. There's some overlap between our roles, but in terms of up and out type of work and program-to-program integration from the engineering side, that's more in her camp than it is mine. I'm more of the down and in spacecraft guy working more closely with Lockheed to get the spacecraft done rather than working more closely with other programs to integrate the spacecraft.

JOHNSON: Let's talk about some of the technological advancements. We've had people especially in the press comparing it to Apollo, that it looks just like Apollo. But obviously there are a lot of things in the Orion spacecraft that are nowhere near anything like Apollo. So let's talk about some of those differences and some of the new technology.

DINGELL: The most notable would be the avionics. Obviously we all as users of personal computers realize how fast technology moves today. You can think back. Gosh, electronic devices, computers, and so forth 40 years' difference, obviously that is a completely different universe in terms of the design of the avionics system.

That said, physics is physics. So yes, the shape looks the same. Some people were surprised about that, other people were not surprised. I think I remember a quote from Jeff [Jeffrey M.] Hanley in the meeting we were having where this subject came up. He noted that boat hulls have looked the same for millenniums. Physics doesn't change. That being an optimal shape for our particular mission is no surprise. In terms of the structure, although there's some differences in the structural design, strength of materials is still strength of materials.

The core skeleton of it is not dramatically different than Apollo. The parachute system is obviously all different parachutes, but it's still modeled after what the very very wise Apollo guys did. The biggest significant changes are in regards to the avionics, and the propulsion system architecture is different. Even though we did not step up to different propellants, we did not step up to the green propellants, for good reasons, we still have the same basic chemicals that were used in Apollo. We have an enhanced guidance, navigation, and control system. We can do more capable reentries of that vehicle because we can fly it better now than the Apollo guys actually had computing power to do back then. We can fly what we talked about, like we call a skip reentry, which allows us to rather than fly 1,000 miles downrange, perhaps fly 4,000 miles downrange. With those kinds of capabilities and lunar return speeds, in a way you can get winged vehicle capability out of a capsule.

Because you're returning so fast, you get enough lift out of the capsule. You're returning so fast, there's a lot of energy to use in terms of lift. We can fly very far downrange and we can fly pretty far cross-range with just a simple capsule shape that most people might think you need a winged vehicle to fly that far. I would say principal advancements have been in the computing power, the avionics architecture, as well as the guidance, navigation, and control.

JOHNSON: I've read there's a lot more redundancies too than in some of the earlier programs, and it's built to be upgradable as opposed to some of the other programs or spacecraft that we've built.

DINGELL: Yes. In terms of redundancy, I wouldn't say that we have more redundancy than other spacecraft. I would say we've maybe perhaps more judiciously established where we believed that we needed redundancy or maybe dislike unsimilar systems that provide crew survival type of capabilities. We started out originally with what stemmed from a [International] Space Station and Agency level requirement to be two-failure-tolerant, which means you need three of all of your critical things. That was a bit impractical thought considering the limitations we had to build the spacecraft within.

We set that requirement aside for rigid two-failure tolerance and said, "Our floor is one-failure tolerance, let's start with that as a floor." We went through a very large effort in the 2007 timeframe beginning with that as a floor to figure out what specific areas we needed additional redundancies over and above that floor. We put a lot of effort into—we called it risk-informed design—to establish the specific areas where we needed that extra redundancy.

JOHNSON: Working toward EFT-1, I think that not long before that flight, the thermal protection system, there was a problem with the Avcoat. But it was fixed and EFT-1 flew. Then of course things were changed for the next flight. Did you actually see the launch of EFT-1?

DINGELL: I was out at KSC [NASA Kennedy Space Center, Florida] for the launch. I was actually working in the [Launch] Control Room. In addition to the launch control team we had an engineering team, what would be the equivalent of Shuttle and Space Station Mission Evaluation Room or MER. That MER function was put by design out at KSC to be very close at hand to the program management team, who wanted and needed to be there at the launch site for the launch. We had an engineering support team out there in the O&C [Operations and Checkout] Building at KSC. It was led by Bill Johns, the Lockheed chief engineer. At each console position we doubled that up with a NASA guy on each console. So I sat there, was co-lead of the team with Bill, as the NASA representative. I was there, and I was part of the launch, but I didn't get to go outside and actually see it.

JOHNSON: That's a shame. I know a lot of people have talked about how impressive it was seeing that launch vehicle. But speaking about those issues at the beginning, what was learned from EFT-1 that is being applied for EM-1 [Exploration Mission 1]?

DINGELL: Gosh, that is a poster child for the priceless value of experience in building a spacecraft. I remember naively back early on when we got going in 2006, 2007 timeframe. Of course we had already started the TPS Advanced Development Project and originally were working with PICA [Phenolic Impregnated Carbon Ablator] and then changed over to Avcoat, very much focus being on the TPS material itself, and very little if any focus on the underlying carrier structure that the TPS would be bonded to. I remember naively thinking well, how hard can it be, just need a dish kind of structure, you glue it on there.

That was a very very naive thought. Of course as it turned out we started talking about potential cracking of the TPS due to thermal stress. Even in those early days I was fairly naive to the causes of that. Of course in the end it turned out to be—I don't know if incompatibility is the right word—between the underlying structural material and the TPS material itself with its characteristics of expansion due to changes in temperature. CTE, or coefficients of thermal expansion, between the two materials, one material would expand a lot more than the other, and so as you changed temperature you would induce a lot of stress in the Avcoat material. It's not real real strong as a structural material. So in the end it was at least a contributor to the cracking that we experienced in the test that was done in the production of the heat shield.

At that point in time we knew that this difference in CTE was an issue that had to be addressed. We thought we could manage that issue successfully for EFT-1 because it was a more limited environment that it had to go through, but we knew that changes were going to be required for EM-1 and on. It did take us by surprise that we had the cracking during the test. There of course were a lot of reasons as to why we experienced that. Principally that the TPS material turned out to be half the strength of what it had been shown to be capable of in smaller level type of tests. There were specific reasons that turned out for that.

But gosh, if I ever personally was involved in building another spacecraft, I would know a lot of smarter questions to ask early on in the design phase related to what material are we building that structure out of that's going to hold that TPS, what is that going to look like, let's talk a lot more about that while it's still in the formulation phase rather than getting into production.

JOHNSON: Were there any other lessons learned from the EFT-1 flight that you can think of?

DINGELL: Yes, there were so many, it's hard to name specific ones. I think Mr. Geyer had said it very well in communication with some people maybe even after the flight. Just the fact of having to actually produce the article even before you even fly it, you learn so much about issues encountered in the production of it.

Maybe a very notable one is we had some pretty significant contamination that was found in the propulsion system after it was welded up. We had believed that the pseudo clean room environment that we had built the vehicle in was satisfactory for processing that. Long story short, it turned out to not be. That led to some pretty gross contamination in the system.

There were some significant changes made for processing of the EM-1 article such as creating a real clean room out in the O&C Building for the processing of the vehicle that involved cleanliness-sensitive activities like welding up of the propulsion system.

JOHNSON: I know the flight went great, and once it landed, the only thing that didn't work quite the way they expected was the uprighting system.

DINGELL: That was the only really even mentionable anomaly that we had. We knew there were some concerns with that system, but I think most people still expected that system to work. Yes, it was a surprise. There were problems with three out of the five bags. I think like anything, once you go put a magnifying glass on that particular design—you don't have time to put a magnifying glass to that level on everything in advance of knowing that you have an issue. Once we really shined a light on it, there were some pretty glaring issues associated with how that system was done.

Maybe the most notable for me was these bags packed into a small volume inside what we call a gusset in the forward bay. They have to deploy out of a very narrow opening. In that opening basically there were not smooth walls, there were fasteners protruding into that that acted almost like teeth, that this bag was to inflate and deploy itself out of. You had these fasteners protruding into that like teeth that were trying to keep it from deploying, and then the bag had to rake across those teeth coming out. There was a list of a lot of things we changed, but that was maybe the single most significant change that we made was to put a smooth-walled container in there.

JOHNSON: Let's talk about working with international partners. Again this is the first time NASA has worked to build a spacecraft with an international partner, working with ESA [European Space Agency] for the Service Module.

DINGELL: It does create unique challenges. First of all right off the bat this very comfortable and close working relationship that I mentioned that we had with Lockheed as a practical matter you don't have with an international partner. You're an ocean apart. You can't have communication on a daily basis. You rely more on milestone reviews, formal products, to get your data relative to your oversight function. Right off the bat there's discomfort created because some of the mechanisms that we used to be comfortable with the design on the Lockheed side we did not have with ESA.

I think it's a little bit perhaps of a culture shock for lack of a better way to put it for ESA related to how much we feel we need to know about the design of the spacecraft, and certain safety implications that result from that. It's much different than something like an ATV [Automated Transfer Vehicle] where although Space Station depends a lot on the functionality of the ATV, at the end of the day if the ATV fails and doesn't make it to the Space Station, the program can recover from that and nobody loses their life as a result of it.

Here with the Service Module joined at the hip to the spacecraft, we are completely dependent on the functionality of that module to get the crew home. If that propulsion system for example in the Service Modules fails, we will not get the crew home. So we've had a lot of discussions related to certain specific design features, most notably in the propulsion system. I think to an extent our level of penetration with ESA has been a little bit of a culture shock for them.

Then when you hit the point where you decide some sort of change is needed here, there's not a single boss. Like on the Lockheed side at the end of the day the NASA program manager can direct certain changes. It may cost money, but he does have authority to direct those changes even if they cost money. With the ESA relationship, it's a partnership, so there's no unilateral direction. In the end even things that you have to change become a bilateral negotiation to get done. It increases the complexity there.

JOHNSON: What would you consider your most significant challenge since you've been working on this since 2005?

DINGELL: Yes, gosh. It's hard to put your finger on the most significant ones. We've been dogged for a decade related to vibroacoustic loads, most principally from our launch abort system. We have a fairly large and fairly heavy spacecraft by necessity to meet the requirements that we have, and our launch abort system has upwards of 500,000 pounds of thrust, and it's arranged in a configuration that basically puts the vehicle in its plume, and that creates a very large acoustic field, which imparts very very extraordinarily high vibrations on the spacecraft. That's been a struggle for the better part of a decade to understand what those loads are and to design and build and certify components to be capable for that. That would be one systemic type of challenge that comes to mind.

It's been a challenge that there have been changing rules along the way in various forms. We talked about one earlier with Constellation being born and new requirements that were imposed. Then there was the cancelation and being reborn again and the leaning down of the team that represented certain challenges. There's the flat budget challenge. There's the international partner challenge. There's the challenge of a new rocket involved in what we started out with.

There's the challenge of it's difficult to understand past EM-1. Still even at this date we don't specifically know what our mission is for EM-2, what our mission profile is. Although we are designing by definition a generic spacecraft, there's still mission-unique issues that need to be addressed, and it does create challenges at certain times when you're trying to make sure you have a good spacecraft for EM-2 but you have not locked down to what specific mission you're going to fly.

Those are a few things that come to mind. I should not fail to mention TPS as a challenge and that whole discussion we talked earlier about, when you saw the challenge from EFT-1, and then basically a bit self-inflicted but for good reasons, we increased the challenge by going from what we call the monolithic Avcoat architecture that we flew on EFT-1 to the block Avcoat architecture approach for EM-1, and there were good reasons to do that. In part it helped with that CTE issue I mentioned earlier, and it was a big aid in terms of efficiency of production to do that. Yet that created new technical challenges to go to that block architecture and the verification of the bonding or the gluing of the blocks to the structure. More uncertainty involved in the integrity of that bond with the block architecture than with the monolithic architecture, and that's been a major technical challenge to overcome to convince ourselves that we're okay with that architecture.

JOHNSON: What about anything that you would consider your most significant contribution?

DINGELL: Me personally?

JOHNSON: Yes. Or anything you've worked on that you feel like made the biggest impact.

DINGELL: There's not one that sticks out. There's just been a slew of incremental changes. That's all part of daily life of getting the job done. I influenced certain changes that created additional burdens in terms of getting done, but I viewed as increasing the reliability and safety of the spacecraft. Were those necessary to have a successful EFT-1? Nobody really knows. It was successful. Would it have not been successful if those certain changes would not have been made? Nobody knows the answer to that. So I don't know that I can say—no one particular contribution sticks out for me personally. I try and take every day a day at a time, and for the issues that come up on a given day try and make the best decisions, do what I can to help the team make the best decisions possible.

JOHNSON: Mark Geyer has been quoted as saying, "The Orion Program learned to persevere." Is that something you would agree with?

DINGELL: Absolutely. The comment that I made earlier about if Mark personally would not have been in that role, we may not be here having this conversation today, and there may have never been an EFT-1 or a PA-1. I think a less skillful project manager may have not been able to lead us through that turmoil and come out on the other end in a successful way. Yes, we've gone through a lot, and have adapted and lived through it.

JOHNSON: Is there anything we haven't talked about that you'd like to mention before we stop?

DINGELL: No, I don't think so. We covered a lot of ground, so nothing immediately comes to mind. I would probably think of something after you leave.

JOHNSON: That's fine, and you can add it later. We thank you for doing this today.

DINGELL: You're welcome.

[End of interview]