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

MARK S. GEYER
INTERVIEWED BY JENNIFER ROSS-NAZZAL
HOUSTON, TEXAS – 24 JUNE 2016

ROSS-NAZZAL: Today is June 24th, 2016. This interview with Mark Geyer is being conducted at the Johnson Space Center for the Orion Oral History Project. The interviewer is Jennifer Ross-Nazzal, assisted by Sandra Johnson. Thanks again for taking time out of your busy schedule to meet with us.

GEYER: Thank you. This'll be interesting.

ROSS-NAZZAL: We appreciate it. I wanted to start at the beginning, and that was November of 2005 when you were appointed Deputy of Constellation. Jeff Hanley was also appointed Program Manager. What were some of the key issues that you were working those first few months as you came on board?

GEYER: Maybe I can go back a little bit before that, if that's okay. In November of '04 Admiral [Craig E.] Steidle came to JSC. He asked me to go to Washington to run his system engineering and integration effort for the President's Vision for Exploration. When President [George W.] Bush announced that, they started a group when [Sean] O'Keefe was the Administrator under Admiral Steidle. Their job was to really put together an exploration vision, how to get beyond low Earth orbit. He started that process, and he asked me to go up and help him. I didn't want to go,

because I had a good job here. I was running the MMT [Mission Management Team] for Station, and I was wary of going to DC.

He was okay when I said no, or at least he seemed like it. In January General [Jefferson Davis] Howell called me in his office here, and he asked me to go to Washington. He was a little more convincing. It was up to me to go or not, but he really wanted JSC to be a part of that exploration work. He thought system engineering was a good part, so I agreed to go. I showed up, I think, it was March 10th of 2005. My intent was to move there.

If you remember, they had a fairly complex strategy for exploring. Orion actually started under Steidle and was called CEV (Crew Exploration Vehicle). It actually started under them. Phase One of the contract was actually let, sent out to industry, awarded in early April to Lockheed and to Boeing. There was no rocket really. The rocket had not been picked. It was probably going to be one of the current existing expendable rockets, but that part hadn't been selected. This exploration vision included not just the early part with CEV and this rocket but also eventually leading to exploration of the Moon. There was a big technology budget. It was pretty big. It was a fairly complex construct I would say.

Mike [Michael D.] Griffin, I think people knew he was coming in, but I think he showed up in early April of 2005. He began the process of replacing leaders at [NASA] Headquarters [Washington, DC]. There's a process if you're an SES [Senior Executive Service] where they have to send you a letter and you have, I don't know, a month to reply. They can't do anything for three months, and then if you get one of these letters you have to make a decision. Usually these letters tell you to move. You get to move to Alaska or here's this job at Dryden [Flight Research Center, Edwards, California]. You get a choice to either take that job or to leave NASA. A lot of those went out. One of those went to Steidle, so he was going to be gone.

He hadn't sent letters out I think till June, because there's a legal limit to when you can actually send those letters out. As soon as he got in he started three different groups that were basically study teams. One was for Station and Shuttle: what should we do with the Station? Should we build it out, should we finish it, and based on that how long should the Shuttle fly? Then there was one on basically exploration, Exploration Systems Architecture Study. I think it was called ESAS. A lot of people have heard that acronym. Those teams were stood up. Because of my background on Station they asked me to be on the Station and Shuttle study, so that's what I did. I was on that team for a couple months, so I was not on the ESAS study.

That team was basically set up on a floor. I can't remember if it was the fourth or the fifth floor, where they had locked doors, cipher locks. They were doing all these assessments. If you were in Steidle's team and had been part of that, you were basically shut out of this thing. You were still working, you were still producing products, but you knew there was this team down there figuring out what the real architecture was going to be. They were blessed by Mike Griffin. It was an odd time.

I was on the Station-Shuttle one, so I felt like I was at least on something that Griffin was looking for. We finished that team, made a recommendation to Mike to finish the Space Station, fly the partners on Space Station, and build out the Station. That was the recommendation we gave Mike, and eventually they did that.

I was never part of the ESAS team although I did get to sit in on a couple of briefings. I can't remember why; I can't remember how. I did not know a lot about what they were coming up with actually. [I] was not part of that. I guess in July of that year the Station and Shuttle study finished, and Mike asked me to be part of another team, which was basically an infrastructure team. You've got the Station-Shuttle part, you've got the exploration part. He wanted a NASA

infrastructure thing. Look at all 10 Centers, what can we do more efficiently across NASA? He asked me to be part of that with a guy named Mike [Michael J.] Benik who was from KSC [Kennedy Space Center, Florida].

We started that study, and actually it was based in Florida, so I was temporarily at Headquarters but based in Florida. My family was in Houston. It was a weird couple months. That study went through the fall. I had heard that Mike was going to announce this Constellation Program. He was going to stand up this Program which would be based on the ESAS results, and he would name a Program Office. I did hear Mike say he was going to send the Program Office back to JSC. I was interested in working on that Program and coming back to JSC, because my family was still here. We couldn't move because of all the churn that had happened, and there was really nothing to move to, based on his decision to stop the Steidle stuff and move the Program to JSC.

So in that fall timeframe I'm working on this other study. I'm in Florida, but I don't know what my job is going to be in the future. I kept asking. Doug [Douglas R.] Cooke was up in Washington at the time, and I asked Doug if he could give me an idea, "Is Mike interviewing for Program Manager, Deputy Program Manager? Is there some process that I should know about, because I'm interested in working on the Program." They were pretty vague about it. You never know how to take that. Do they not want you to do it, or they just don't know what to do yet.

I actually called Mike [Michael T.] Suffredini, and I said, "Look, I need a job." Mike was still the Program Manager of Station. "I don't want to do the study stuff anymore. They're not sure what they're going to do on Constellation, and I want to come back to JSC." He offered for me to be his Deputy, so I was his Deputy I think for a week because then Jeff Hanley called me one night.

I was in the La Quinta Hotel in Cocoa Beach [Florida]. Jeff calls me and says, "Hey, we're standing up this Program." Mike wants Jeff to be the Program Manager, and he wants a Deputy. "I want you to be my Deputy." So that was interesting. It was a surprise to me, but I said, "Yes, let me think about it a little bit." Only because it was a new idea to me, and it came out of the blue. Here I hadn't heard anything, and then suddenly he offers me this job. I knew Jeff though before. He's a really good guy, though I had not worked for him or with him very much.

I discussed it with [William H.] Gerstenmaier. "Where do you think I ought to go?" Because Station was under him, and this new Constellation would be under someone else. I don't know if "Doc" [Scott J.] Horowitz had been announced as the AA [Associate Administrator] for Exploration or not yet. I asked Bill, and Bill Gerstenmaier said, "Hey, you should go do this exploration thing." I think I accepted the job in late October, early November, somewhere in that timeframe.

I came back here, actually drove my car back Thanksgiving weekend, and started setting up the Office here with Jeff. At the time I think it was Jeff and I and Brenda [L.] Ward and Deb [Deborah J.] Neubek and a couple of admins trying to make selections. What does the Office look like? How do we fill those spots? Really starting from zero. We had to define the Program Office structure, then we had to go figure out how we were going to select people. We had to make decisions on how many of these people would actually be based in Houston and whether some of them could be done in other places. Then we had the big programs too like Orion, Ares was the rocket, and there was the ground system. There were choices to be made on those program managers too. By the time I showed up Steve Cook was already named as the Ares Launch Vehicle Manager. I think that was really a Mike Griffin decision. I think "Tip" [John J.] Talone had been announced as the Ground Ops Manager, I think that was Mike's decision too at the time.

The first thing was: what the hell does this Program look like, how are we going to organize it, and who are the right people. That was really the big thing. Jeff asked me to go to be the person to go make recommendations on the key personnel for the Program. Who's SE&I [Systems Engineering and Integration] Manager? Who's Safety Manager? What should we do about the Orion Program Manager?

We had a CEV Manager. Brian Anderson was the CEV Manager at the time, a holdover from Steidle's work. We also had a contract that had been let before Mike came in, which had Boeing and Lockheed doing work on CEV. What do we do with this contract? Do we keep it the way it is? Do we downselect? Do we start over? Those were a lot of the things that were in the mix.

The Center was very supportive, and we got a lot of support on selecting people. Mike Suffredini was especially helpful. If we'd say, "Look, I need this person to come over here to help us with this," he was very supportive. He knew that he had a lot of leaders that could help us put this Program together.

Shuttle was actually very very busy getting back to flight. They'd had the one flight that didn't go that well, and they had to continue to fix the ET [External Tank]. They were very busy. We didn't get a lot of people from Shuttle on the Program. It was hard for them really to let go of people at the time. I understood that; that was not an issue. That was a big thing, hiring the people.

Another big thing was, so what's the budget for this Program. The ESAS group had done a budget projection. This small group that had worked at Headquarters had done a projection of the budget as part of their study and as part of Mike saying, "This is the Program I want." There was what we called the sand chart that basically showed total budget and showed all the pieces of CEV, Ares, ground ops. Then of course Constellation the Program was much bigger, so we had a

lunar lander and we had lunar surface systems. All those had been projected in the budget and phased over time, and Headquarters had actually tried to allocate some of that money.

Some of the hard work in the first six months was to trace that budget guess into a real PPBE [Planning, Programming, Budgeting and Executing] budget. In other words, these guys guessed a lot of things. Now you actually have a Program, and you actually have program managers, project managers for the hardware. You had to say, "This is what these guys guessed. I need a real budget formulation. I need a real budget estimate from you guys." Big part of that first year was them actually saying, "Now I have a design. I have a team. We have estimates on what the contractors are going to charge." We had to build bottoms up really an estimate for what Constellation was going to cost. That was a big part of that first year, doing that trace. Where is the money that was supposed to be available, and how do we allocate it to the different people?

Right off the bat—I wasn't in those meetings—according to Mike Griffin, OMB [Office of Management and Budget] did not give us the money they promised they would give us. In fact, when Mike went back and showed how finishing Station required—I can't remember the total number of Shuttle flights, but it was some number. He showed them that that meant that the Shuttle couldn't retire on the date they wanted, and we needed more Shuttle flights. They were fully supportive of finishing the Station, but they didn't give any money to fly enough Shuttle flights to actually do it. The only place for that money to come was out of the Constellation budget, so that's the beginning of had a plan, now we got to take this money out to finish flying the Shuttle out. Almost within the first year or so we had to change our plans and push the schedule to the right because the budget was not per the projection.

I actually have some charts we made that I could give you, because I've actually pitched them at a conference, that shows the budget history of CEV to Orion to MPCV [Multi-Purpose Crew Vehicle] and talks a lot about these requirements changes and things that happened.

ROSS-NAZZAL: That'd be great. We could put it in the history.

GEYER: When people say, "Gosh, they've been working on CEV since 2005," well, yes, but this is the third rocket. We never got the budget that we requested any year, and from '10 on we've had a flat budget. Not to whine about it, but people need to know that the requirements changes have changed significantly. It's not like they've been working on the same thing from the beginning. Let's see. What else would I say about Orion?

ROSS-NAZZAL: Could you just go back? You said you had to choose how to organize, create the structure. What did you do? Did you look to Shuttle and Apollo or did you come up with an entirely new organizational scheme?

GEYER: That's a great question. We actually looked at all the previous organizations. We looked at the Apollo structure, a lot of that led from here, although there was an SE&I group in Washington for Apollo. The Apollo Program was really led here, but they weren't the detailed let's say managers of Saturn V. That was really [Wernher] von Braun and the guys at Marshall [Space Flight Center, Huntsville, Alabama]. It was an interesting Program structure.

We certainly looked at Shuttle. Shuttle has changed quite a bit from its initial Program, but we looked at that structure, because it's actually more similar. It's more applicable than

Station, because at the beginning it's CEV on a launch vehicle. That's more like Shuttle kind of work. We said there should be a bias toward that function, more like Shuttle.

But the fact that Constellation had a lot of pieces, it's got a lander, it's got a surface system, it had a lot of other pieces that had to be integrated together well, so that actually was more like Station. Station is a lot of individual elements, but there's a very strong Program that ties all those together, and it has partners and everything else. We actually leaned more toward a Station model, which had a strong SE&I group, the safety group, and then advanced programs. That's what we did. Test and verification—I have to remember all the offices. It's been so long. Let's see. I think there was safety, SE&I, test and verification [T&V], advanced programs. Trying to think what the other one was. Oh, PP&C [Program, Planning, and Control], the budget. Then we went out and found the leaders for those. I'm sorry. That didn't answer your question.

ROSS-NAZZAL: If you want to talk about selecting those leaders; how you put forward those names and determined they would be the best people for those positions.

GEYER: Again we looked at what we thought was the complexity of Constellation, which had all those different elements. That biased us toward a Station model. I looked for leaders that had been involved in the Space Station, and so actually we looked for a month or more, maybe two, three months for an SE&I lead who would have the right skills, can understand the complexity but also know how to make hard decisions and move forward.

We found one person here already at JSC, but that person was not interested. They had a job they liked. They were doing a critical job on Space Station, so we couldn't convince them to come. We got a lot of inputs that there was a guy outside the Agency that had done some really

good things on Space Station from Boeing, a guy named Chris Hardcastle. We talked to him, he was interested, and we recruited him; actually got him to come to NASA.

Safety, we had a few different safety leads. I'm trying to think who the first one was. I can't remember if it was Lauri [N. Hansen] or "Beamer" [Robert L. Curbeam]. I can't remember. Lauri Hansen had a bunch of experience both with Space Station, and she had been working on Shuttle for a while with her stint in engineering. She'd also had some time in safety, so we thought she would be really good as a safety lead. Her experience was really mostly Station.

Then we got the Space Station program planning and control lead, Barry Waddell, to come over. Like I said, Mike really helped us out. We had these people, they really knew what they were doing, and we needed them to come in and set up an organization.

For the test and verification we also got a Station guy named Bill [William] Arceneaux. Bill had been head of vehicle integration or vehicle hardware as part of Space Station for a long time. He was one of the key guys that got the U.S. lab off the ground and into space, and so we thought he'd be perfect for T&V. We brought him in to do that job.

It's also important to remember what the time was like back then, because we weren't very far removed from *Columbia* [STS-107]. We were only a year removed from return to flight. In fact, I think the first return to flight flight was in'05, and then [they had a problem during that flight. They] had to go fix those [issues before the next flight].

So this was right about the time where there was a lot of culture around making sure everybody is heard. Also any time you have a new program it's like any beautiful idea somebody had for the last 10 years needs to be heard, because if we don't do it on this Program we'll never do it. We had a lot of help. We had a lot of input on not only how to organize but then how to do

system engineering, how to do modeling. Everybody's genius idea we had to look at and make a decision on.

Again we set up the structure assuming we were going to have a lot of elements, the lander and then surface systems. Frankly, with all that I felt like Jeff and I didn't really get much help to streamline this process. What I mean by that is I felt like any time someone had, like I said, "I've got the most brilliant idea of how to do logistics," these people would talk to Horowitz or Mike, and they would send them to us. Or anybody at any Center, these ideas would flood in. In general that's good, except when you think about it. You're starting from nothing, you're supposed to fly in four years, and now you have to deal with all this, not just the normal work but all these ideas and requirements. Frankly, it was too much, it was a lot. Our SE&I lead, I thought he did a very good job. He was a little more process-oriented than maybe would have helped us, but we didn't really help him filter this stuff. It was overwhelming. I would say it was a problem.

Given that, a lot of that stuff flowed down to the projects, things where it's a beautiful idea. We go, "Well, I don't know, has anybody done that before?" Then it would flow down to the projects, and we'd say, "Well, tell us if that's hard." Which from up here [demonstrates] that sounds good, but when you're actually building something and you go, "Wow, I got these 300 things I got to go assess and tell you whether they're hard or not," pretty soon they locked up too. That made that year I would say very hard. In hindsight—it's one of those things if you had to do it over again—I think we could have done better in fighting a lot of that, although I do feel like we tried to keep the Program as lean as possible. But it was hard; it was very hard.

For example I felt like there was an overemphasis on independence after *Columbia* too. It was almost a hypersensitivity to independence. The safety panel was at the Program level, and the panel chairs were not from CEV. They were supposed to be totally independent from CEV, even

though Lockheed was actually building CEV. It would cause this process where Lockheed would create these hazard reports, and they would come to this panel who had no idea about the CEV design. It was just horrible. It was just so much time spent educating people as opposed to really talking about what the hazards were. It was just really burdensome, and it was that kind of environment. I remember arguing with the head of safety that this is so independent that it's worthless. We're getting people who don't understand the design. It just takes so much time.

That was the environment we were in. Big tent, everybody gets to say their thing. Remember the MMT was a circular table. Don't want anybody to be intimidated. All good stuff, but when you're trying to stand up a program and you're trying to get stuff out the door and you've got all these ideas and all these new things and you're supposed to listen to everybody, it was too much. It was too much.

ROSS-NAZZAL: It sounds overwhelming.

GEYER: It was, a lot. These guys worked really hard, but in the end it was very difficult. That actually impacted the flow of what I would say were the actual critical requirements. We ended up getting new requirements to Orion and Ares about a year after we started this process because it took that long to get the thing to settle down.

ROSS-NAZZAL: Was that the RFP Phase Two?

GEYER: No, sorry. That was actually before. I think it was awarded for CEV. Steidle's original vision was you would have a flyoff. You'd pick two companies, and it'd be like F-22. They'd

build all the way to flight, and they'd fly, kind of like the Commercial Crew guys are doing today, although the requirements are more complicated. That was his vision.

We started where we awarded this first set of the contract to Lockheed and Boeing. They started doing design work. Then Mike came in and he said, "I do not want to spend two years having these guys getting ready for a flyoff." He felt like NASA really already understood the fundamental design parameters of the capsule system. He didn't think he needed two companies to come up with two different ideas and fly them off. He also felt like it was taking way too long. This was Mike's opinion.

We restructured that next phase and actually downselected to Lockheed toward the end of that year. Even with that downselect, the requirement set had started under Steidle: CEV, expendable rocket. We tried, because we were still standing up the Program, to give the team that was doing the evaluation as much as we could updates to the requirements that we expected to see. A lot of them were white paper level things as far as standards and specs. It was still very nebulous.

They awarded, did a good job; we actually downselected to Lockheed. It wasn't till the next year when those requirement sets had firmed up enough that we actually had the whole specs and standards. That was another CR [Change Request] to Lockheed. "Hey, we got to go impact these, make sure they're in the design." That was at the same time where Mike said, "Well, I don't have enough money per the plan. You're going to have to push the work out to '14." Both of those were on top of each other as part of why. It's very inefficient. If you've already awarded a contract, you change requirements, and then you tell them, "By the way you're not getting the money we said you would, so you've got to rephrase your work," so the contractor has to figure out how to split all those subcontracts. It was a real mess. That was a big impact. Part of that is

the risk you take. You want to move fast. You had already awarded a contract, and now you're changing the requirement set. That was hard.

ROSS-NAZZAL: It's costly too, isn't it?

GEYER: Yes, it cost us a year, and the money that goes into a year for that amount of work. Especially when you're still fiddling with the requirements you probably shouldn't have awarded. Because once the contractor gets on board and once they've been awarded, they're starting to build to that set of requirements. You say, "Well, I didn't really mean those. Here's the other set that I really meant." They have to go back and change all that. They're being paid to be rigorous, and they're being paid to have some inertia because you want a highly reliable quality produced system. Now you're telling them, "I need you to change this." It's not the way you would normally do it.

ROSS-NAZZAL: What changes had to be made? Can you give some examples?

GEYER: A good example is—and this is in that presentation I can give you too—when ESAS was done and when the first white-paperlike set was given to the contractor team, the rocket was going to be basically a four-segment solid, almost identical to what Shuttle was flying today, with an upper stage. The upper stage was going to use an SSME [Space Shuttle Main] Engine. Everything existed other than the fact that the SSME is not normally lit in space as opposed to being lit on the ground, so there were some things relative to that. Very simple rocket, and actually most of it heritage. You were updating it for a new use, but it was a heritage system fundamentally.

Then Ares V, which would have been the next step that goes to the Moon, was going to basically require five-segment solids and a J-2 engine for the upper stage, because that's what's required to do the job. You needed that much oomph to get off the ground and then you needed a J-2 to actually push the system to the Moon.

Eventually Mike Griffin, and Jeff was part of that, looked at that system and said, "I know why we're doing this four-segment because it's quick, but there's really no link to the future here. We're building something one time, and then we're throwing it away." Actually that system would fly to Space Station, but there's no linkage between those two developments really. Mike said, "I don't want to do that. I want this rocket, this first launch of CEV that'll eventually take people to Space Station and then on to the Moon, I want to use a five-segment. I want to use the same five-segment that Ares V is going to use, and I want to use the same J-2 on the Ares I rocket as you're going to have on Ares V."

So you do this development up front, and then it's an easy transition to the lunar architecture. That's what he was biasing toward. It's harder to get to the Station one, but it's easier to get to the lunar one. Remember Constellation, the idea was Orion would go to Station first. That's how we would get crew to Station, and then we would use that same capsule system to go to the Moon. You synergize those two missions, that was the idea, so that's why you had two rockets. One was for Station; one was to go to the Moon. I understood what Mike wanted to do. It makes sense if you're worried about cost of transition to the Moon. It made the job of getting the first launch harder to do, because now you had to develop a five-segment. You had to develop a J-2 engine update in order to do this mission, and now all that having to happen before your first launch.

It also changed—the rocket now was much more energetic, meaning it's a lot faster off the pad. It's five segments instead of four. The acoustics at launch on Orion were much higher. The acoustic energy on Orion. In fact, the current design didn't work, so they had to create a shroud in a sense. The Orion guys had to create a shroud on top of Orion, which is the same shape you see today. That's where it came from, in order to deal with that acoustic issue. That was an example. That drove some mass into the system that we then had to take out of other things. I know there's some other things but that was the biggie. That's the simplest example. It was a strategic decision on Mike's part.

The other thing, I described it, but I didn't describe it well. When we did not get the money in '05 that we thought we were going to get, that pushed the CEV launch from 2012 to 2014. Because we had this plan coming out of ESAS, we laid it in the budget, and we thought we could launch CEV on the original Ares I to Station by 2012 with that budget. Then we didn't get the money because they needed it for the Shuttle. That pushed everything to '14.

Then Mike said, "Since we're not launching till '14," it made more sense then to do these upgrades, go to the five-segment and the J-2, because you got more time. In a sense it makes more sense. Of course it costs you more money too. He knew that. That's part of why he was interested. Since it's taking longer, let's get the right Ares I that helps getting to Ares V. That was part of the discussion.

This is another thing. When you award a contract, you're motivating the contractor to do a certain thing, and then when you change your mind, it's okay. It's our job if we feel we need to change our mind, but that can cost money like you said. The original contract that we awarded, starting under Steidle, and then Mike awarded, had a clause in it where we asked the contractor to go, "What would you do to fly in 2011 to Station? What would you have to do in your hardware

to fly?" I think it was a clause or an option in the contract; I think it was an option. Of course clearly we don't have the money to do that. One of the unintended consequences is the contractor then biases their design, because they're trying to win the contract. They're going to bias their design to go fast.

Some of those designs were not maybe as elegant or as cheap long term as you would like, but they biased to win, to go fast. Now we're not going fast. Right, now we're going slow because the budget got cut. Now Mike starts playing with the design, I would say. Playing is the wrong word. He would ask good questions. "I'm going to fly this thing for 40 years. Why does this power distribution architecture look like this?" Because we're trying to go fast.

He pushed us to actually come up with I would say a more elegant—what is the word Mike used? That made more sense long term. This started driving changes into the Program. Again, they're reasonable. If you're going to fly a long time, then let's be biased toward cheaper and higher-tech so that it can be more capable. But it was a change to what Lockheed had proposed, which was to go fast.

There were a lot of things like that. The whole power system changed from 28 volts to 120. It's like okay, that'll be easy, 28 volts made sense when you're going to Station, Station is 28, but 120 makes more sense when you're out at the Moon. It's better for the surface systems to be 120 because it's more efficient for long [distance] cables. We decided to make Orion 120 volts. Some of those parts are hard to find, and Lockheed had to do updates to the avionics to make it a 120-volt system. Again it's reasonable, more time, more money. There were things like that.

Again caused by not enough money, moving to '14, Mike saying, "I want more of a legacy vehicle. I want a better long term design." Again, it can be done, and we did it. It just took longer. That's one of those things where people go, "Why did you take so long?" We decided in the

middle to go, "I don't want to do that anymore. I don't want to be on that rocket, and I don't want to go as fast, so I want more [robust/elegant designs]." Again, all reasonable. Those would be the best examples of things that we changed in that timeframe.

ROSS-NAZZAL: You guys were going to use liquid methane originally for the service module.

GEYER: That's a good example of a study team having a concept that looks good—I won't say just on paper, because they would have models. They had CAD [Computer-Aided Design] models and other things. I felt like the NASA team was really good, but we had not built a capsule system in—let's see, this would have been 2005, and the last time we designed one would have been mid '60s, so it was 40 years. We'd built Shuttle, and we'd built Station, but we hadn't built a capsule system to send people, so we really didn't have much expertise. I'd say we had advanced development guys that could scope things and do mass properties and lay things out, but they didn't have a lot of experience in some of the details.

What I remember was the methane system—it's nice because it's a clean fuel, so you don't have to have [hazmat] suits and everything else—[but] we actually had a volume problem in the service module. We just didn't have the volume to actually lay that system in with all the other things we were doing. That's one of those we had to take back to Mike go, "It just doesn't work." It turns out that these hypergols, while they're dangerous, we know to work with them, and they're very safe [and efficient] once you know that's what you got.

This impacts the ground, but it's actually a much easier system and much more efficient system for going into deep space, so we went back to that. It was one of those on paper that looks great, got a clean, green prop [propellant], let's do it. Then at the same time, hey, you got to build

something real, and you've only got so much room, and you got these other requirements that we wanted in that service module, and the volume didn't work.

ROSS-NAZZAL: Would you talk about the shift from the aluminum to the aluminum-lithium alloy? That was something else that reduced the mass and changed things.

GEYER: Actually I was a little confused by that.

ROSS-NAZZAL: Sorry.

GEYER: No, not by what you said. But we actually changed a couple times.

ROSS-NAZZAL: Talk about that.

GEYER: Most of the pressure vessel is actually aluminum, but there were sections of it that were aluminum-lithium. We actually had a problem where we had welds. When we cracked the pressure vessel during the proof pressure tests on EFT [Exploration Flight Test]-1 one of the things that we didn't model very well—we had different types of this aluminum alloy. They have slightly different properties. They were also welded together, so we didn't properly account for some of the weld shrinkage. We didn't properly account for I think it was strain capability of this particular alloy. It was a little weaker in one direction. Since we're using different pieces in different areas, it actually caused us to not calculate correctly, and then it cracked during the proof pressure test. It was easy to fix, but it was a surprise.

ROSS-NAZZAL: I think this might be a good time if you want to stick your head out and just see if your folks are here.

GEYER: Yes, let me see if they're all out there.

ROSS-NAZZAL: You want to take the mike off just in case?

[End of interview]