NASA JOHNSON SPACE CENTER ORAL HISTORY PROJECT
ORAL HISTORY TRANSCRIPT

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INTERVIEWED BY MICHELLE KELLY
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KELLY: How did the LOR [Lunar Orbit Rendezvous] decision come about? I know Mr. [John C.] Houbolt wrote his paper and presented it to the various people within NASA, but how did they really take notice of the paper itself as a different approach?

SHEA: … [Dr. [Robert C.] Seamans gave a copy of Houbolt's letter to [D.] Brainerd Holmes. Holmes put the letter from Houbolt and Seamans] on my desk and said, "Figure it out." The tail end of this [letter] talks about LOR and [we] decided all we would do would be to study direct flight versus LOR and not anything else.

Houbolt played no part in this [study] at all. Houbolt was an apostle. Just read [the letter] those papers, you'll see how he was complaining about how the studies went, and they weren't fair, and all this sort of stuff, all this junk.

KELLY: Can you tell me a little bit about how you managed the different centers from headquarters, and just a little bit more about what you had just spoke earlier, about giving some of the different centers some of the opposing positions of which to study?

SHEA: I could tell them, "Will you guys please study this and please study that?" The centers did not work for us; they worked for Seamans [Robert C. Seamans, Jr.], but they did respond to a certain amount of direction.

KELLY: Did you come up with your own philosophy about how to do that, or was it just whatever you thought best?

SHEA: I just did it. When you run programs, you know how to run programs.

KELLY: Well, it very much seems to me, even from what other people have said with respect to your management style, I heard you basically wrote the book about managing large-scale technology and technological programs in the aerospace industry.

SHEA: Well, I don't know about that.

KELLY: A lot of people have said, not just one.

SHEA: See, you had to force it down to things that were either quantitative or sufficiently qualitative, and there were a number of qualitative things. For instance, in a direct flight mode, which was what Werner [von Braun] was interested in, the idea was that the whole command and service module was going to land on the moon. Well, when you really looked at that, that's what these meetings were, the big meetings: "Tell me how we're going to do this in detail." I've got the service module engine, with a bell underneath it. [Drawing] Okay, so here's the command module, the service module with the fuel and the fuel cells and all that sort of stuff, then an engine. Now, here's the lunar surface. It's got rocks, it's got dust, it's got junk all over the place. These are all going to be kicked up. Now, I can't land [the CSM [Command and Service Module] on the lunar surface], because I have to use [the Service Module] to take off on, so I have to somehow come up with a landing gear of some kind, not unlike what the lunar module actually finally had.

But now that had to be added to the service module, so the service module is no longer the simple thing that Houston was thinking it was; it was getting more complex. As a matter of fact, it probably needed—I couldn't have this engine built too close to the surface, or I might damage the engine when it was taking off, so it would have been better if this lower part of this thing was more like a solid piece. So it's no longer just a single service module. And that's when NASA, in its way of sharing the wealth among the centers, [Abe] Silverstein was running Lewis [Research Center], the propulsion center, and it was sort of semi-decided … that Silverstein would do this. So he had a vested interest now in the program.

So I called Silverstein in just like I did with Werner, went through the thing with him, showed him how complicated this really was and how much more it was going to cost. Silverstein was a rough old bastard, though. I finished the briefing, he said to me, "That is the most dishonest technical briefing I have ever heard." Tough. But the reason he said it was because it cut him out of a piece of work for his center. Those centers were so used to competing with each other for resources and trying to make themselves as big as they could be, they were parochial, is the appropriate word. The fact that this had to be added in, it came out of these two big meetings I had, one on how do we do Earth orbit rendezvous or direct flight, and how do we do the lunar orbit rendezvous. That was that.

KELLY: This was in 1962 once the decision was made?

SHEA: Yes.

KELLY: What happened after that decision? What did you go onto after? I believe it's my understanding you were still working at headquarters with Mr. [D. Brainerd] Holmes.

SHEA: Yes, but Holmes didn't last long at headquarters. I was writing the system specifications and trying to put order into what were the priorities in the program… Safety was …, the most important. Second was probably schedule because of the end of the decade. Third was—I'll give you another little something you can have.

KELLY: Thank you. What types of things do you think of as far as writing specifications for something that has never been done before?

SHEA: Well, it's relatively simple, as a matter of fact.

KELLY: Can you tell me a little bit about it?

SHEA: Well, obviously we had to be safe, and obviously we had to put a man on the moon and come back. So, safety had to be, we thought, or I thought, [balanced] against mission success, but they both had to be important. So the first specs I wrote said that safety had to be .999; in other words, one chance in a thousand of losing the astronauts. Mission success had to be about 90 percent. You could afford to do it if you got there one time out of ten.

I then tried to translate that into reliability requirements on all of the system elements, and then the actual studies that we ran broke the various modes down into maybe a hundred different steps: start this engine, stop this engine, stage, do this, do that, the other thing, assign a nominal probability to each of those [events] the way you calculate the probability of a whole bunch of things, and the [process] is to multiply it altogether, and then you come out with a number that tells you. As long as you have used the same numbers for the same step in each of the two missions you're comparing, then you can make a valid comparison. So the first numbers came out like 30 percent probability of mission success, which was optimistic, and about a little

less than one chance in a hundred of losing the astronauts. That's about all you can expect in terms of accuracy, those kind of studies.

KELLY: Were those just random numbers that you had picked, or was there a basis for them?

SHEA: Try and put it any higher, you can't ever prove it. There is an equation, in fact, when you read Logasen's paper, you'll see something about the Large Launch Vehicle Planning Committee, which was a joint DOD [Department of Defense]—Large Launch Vehicle Planning Committee, which had Nick [Nicholas E.] Golovin [as chairman]. He estimated that before he would be willing to put a man on top of a Saturn V, he would need something like 95 percent assurance of 90 percent reliability. In other words, one launch out of ten might fail, but he'd like to have 95 percent [assurance]. The equation for that is, if I tested N times to try and get the reliability assurance, is R to the Nth reliability I'm looking for, 90 percent to the Nth equals one minus .95. Work that equation out, and N equals forty-eight. So I have to launch forty-eight unmanned Saturn Vs, which I couldn't [afford]. I could only launch one about every three months at the most. The program would have been still going on.

So we finally concluded there was no way to assure statistical reliability. You had to really use engineering confidence and do a little wishing and lucking and hoping.

KELLY: And the Saturn V hadn't really been testing all that much before it was actually launched with men on top of it.

SHEA: Well, actually, we went away from what had been the more traditional kind of testing, which I would call incremental testing, to what was called all-up testing. Now, see if you can catch this on tape, because it is important.

KELLY: Okay.

SHEA: The way the Germans, in particular, like to test rockets, Saturn V is a three-stage rocket. Okay? So they would like to test several first-stage only, with just dummy second stages, then test first-stage and the dummy second stage, and then finally test the whole rocket. Okay? So you were just barely getting started. Now, this was the way we had started in the [Air Force] Ballistic Missile Program, too. We found every time we added an extra stage, by the time we got it integrated at the Cape, it was just as much trouble as starting a new launch vehicle.

Now, I should go back and make a point …, that [is] the program philosophy. That [is] very important for a program to have a philosophy. The program philosophy came out of three sources: the von Braun German team, the NACA aerodynamicists, and the few of us like George [E.] Mueller and myself, who had worked on the Air Force ballistic missile program. So it was the synthesis of those three philosophies. And we decided this incremental approach didn't make any sense at all, that what we would do would be to go to "all up." In other words, [on the first launch, all stages] would be a real stage… If [the first] one works, by God, you're now ready to [ignite and] test the second stage. You're ahead of the game already. [If second stage] one works, you can test the third stage and you're ahead of the game again. There's no need to do it incrementally. So that was really the origin of the "all up" philosophy.

The second part of it was, it saves a lot of schedule time, because every launch we took out was saving three months, and the rest of the schedule was slipping anyhow, and we could still hold in the first manned flight date, because we could sort of adjust the schedule. So "all up" was the decision that enabled Apollo to get to the moon on time.

The first schedules had about ten [incremental vehicle tests] in them. We finally cut it down to two. The philosophy we used—this was Mueller and myself mostly—"We'll shoot one all up, put a lot of heavy telemetry on. If everything works, we're ahead of the game. We're going to shoot a second one to make sure the first one was not a random success." You talk

about random failures. You've got to have random successes. "So you shoot a second one, and again, if everything works all right, then we will put men or a spacecraft aboard a third." That's the whole genesis of the so-called "all up" philosophy, which you may or may not have heard about.

KELLY: I have, as a matter of fact. Who came up with that idea? How did that idea evolve?

SHEA: Well, it first happened when Holmes was still there and the schedule has slipped. We had, I think, ten launches scheduled. I went to Brainerd, "Look, we're not statistically significant anyhow. Why don't we take out three or four launches? You'll gain back a year, and you'll be back on schedule." So [he] agreed to that.

Then when Mueller came in, he understood this better, so he and I worked this out together. I can't say it was his idea, I can't say it was my idea. It was just the two of us. Selling it to Werner was not easy, but we sold it to Werner.

KELLY: How did that come about?

SHEA: We just told him that's the way it's going to be, finally. By that time we were in stronger control of the program, because we finally had [agreement on] a clear mode to go, and the program was on its way. It was gaining momentum, and it's a little easier to get people to go along with you when you're gaining momentum.

KELLY: When was this decided that you would go ahead with the "all up" testing as opposed to the incremental testing?

SHEA: That would have been shortly after Mueller came in, probably within six months of Mueller coming in. You'll have those dates someplace.

KELLY: Sure. It seems like NASA's still using this philosophy.

SHEA: Yes, of course. So's the Air Force. That's what makes sense.

KELLY: It saves money and saves resources.

SHEA: And the important thing is, if [the stages at testing] this works, I will take advantage of its working by finding out whether this one works, and again, I'll find out if … in one launch I can evaluate my whole stack, instead of requiring three or four or five launches to have a chance of evaluating the whole stack.

KELLY: While you worked on both the Titan I and Titan II programs, did you have similar philosophies, or were you not necessarily involved in the entire program [unclear]?

SHEA: I was involved in the entire programs.

KELLY: Can you tell me a little bit about how that worked with actually designing the Titan, and developing it and testing it?

SHEA: No, I was the system engineer on the guidance system for Titan. That was a radio system, involved a radar that was derived from the Nike Hercules. I was the one that had to figure out how to take our equipment and integrate it into the missile. So I was the main interface between Bell Labs in New Jersey and the Air Force and TRW and the air-frame people

on the West Coast. I could not have had a better learning experience. I learned how engines worked, how power systems worked. I went through everything that you had to do to get systems integrated together into a missile. Then when … I ran the [Titan II] Guidance Program, that gave me the management experience of actually running the whole program.

KELLY: When you were involved with the Titan Project, did you have any idea that it would be sending men into space at the time that you were actually integrating the programs, the systems?

SHEA: No, it was strictly a ballistic missile at that point in time.

KELLY: Were you involved at all, or did you even hear about the decision to use it within the manned space flight program? The Titan II, I believe, then it was.

SHEA: That came later on. That's much too small a vehicle. That only puts 40,000 pounds [in orbit], much too small a vehicle. I did not get involved in that.

KELLY: So you just jumped right on into Apollo then.

SHEA: Yes, essentially I went from Titan to Apollo, yes.

KELLY: Were you involved at all in the selection of the contractor to build either the Saturn V—I know that there were several various contractors.

SHEA: No.

KELLY: Or the command module itself?

SHEA: No. That was done by the centers.

KELLY: It was done by the individual centers themselves?

SHEA: Yes.

KELLY: Were you at that time working with them at all while you were at headquarters, or you just oversaw what the centers did?

SHEA: Just oversaw. We did not get involved in the source selection, if that's what you're asking.

KELLY: Okay. That makes sense. Was there anything else that you'd like to talk about with respect to your time at headquarters? Because I'd certainly like to talk to you about your time at the Manned Spacecraft Center, but I don't know if there might be anything in addition you'd like to add.

SHEA: Well, I would almost say—let's save the time at the Manned Spacecraft Center [for later], because that involves a different role. That involves the actual role of managing the program.

KELLY: Right.

SHEA: It's a long story. I found a mess when I went to Houston, and even a bigger mess equivalently than the system engineering mess that I found at headquarters.

KELLY: How did you get involved in fixing these problems, or in determining what these problems were?

SHEA: You want an example?

KELLY: Sure.

SHEA: I'll give you a simple example. Do you know what a specification tree is?

KELLY: Yes.

SHEA: All right. So when you lay your program out, you have your top spec, and then you come down from the top spec, and you go to each of the boxes, and you say what the requirement in the box has to be, you say what the cost should be, we estimate what the cost could be, and then you hopefully set a schedule for it. Well, I'd been at Houston running the program for, oh, more than six months, been there probably a year.

The one thing I did when I went to Houston that was different than the way they had been managing. The guy who was the program manager first was a guy named Charlie [Charles W.] Frick, who was a terrible program manager. He kept the program office isolated from the rest of the center. But the rest of the center had, say, a thousand people, and he had a hundred. I knew that the thousand people they all worked for [Maxime A.] Faget, and they had access to contractors. They could go and look and see what the contractor was doing, comment on it. In principle, they shouldn't give direction and say, "Do it this way," but they did anyhow. So it was very hard to keep any kind of contract control on. And they had no other responsibility. So I took all of the systems specs and turned them into—do you know what a work package is?

KELLY: No, sir, I don't.

SHEA: Well, take the systems spec that you've gotten from the spec tree, and the cost estimate, how many man-months per month you're going to have to spend on it, and how much material, what sort of schedule or milestones you're looking for. We made those into individual contract packages which we then gave to the individuals in Faget's organization as their responsibility. So they had to report to me, not just on technical progress, but on cost progress and schedule progress. I set up a scheme of having [them] write me a memo once a week to tell me where their organization was, and I would annotate the memo, send it back, and we'd annotate it back and forth, or work the problems out.

So the one example I would give you is, we finally got equipment enough to test the heat shield material. The heat shield, if it stays in one attitude and the sun is beating on it from this side, the temperature goes to about plus-250 degrees Fahrenheit. The other side, which is now looking at outer space, which is cold, so it's radiating in outer space, and it goes to about minus-200 degrees Fahrenheit.

So we finally got the ability to put the heat shield material in an electric shock tube, heat it up to 250 degrees, and then cool it down to see what would happen. The surface of the material started to crack and craze, and the heat shield guys came to me and said, "Oh, we've got to start a whole new heat shield program. Estimate $60 million; we can't tell you the time."

So I scratched my head and I said, "How long does it take for the temperature to change from, let's say, ambient temperature to this minus-200 or plus-200?" It's called a time constant.

"Oh, about thirteen hours."

I said, "[Why] the hell does the spacecraft have to stay in any given attitude for thirteen hours?" It's a three-day trip to the moon, and three if you're back, but I can certainly change the attitude. You know, the idea of just slowly rotating the spacecraft one revolution per minute.

Well, the medical people said, "Oh, the astronauts [might] get dizzy…"

The attitude control people said, "Well, we're not sure whether the attitude and control [system can keep it stable]."

Well, I knew enough about control systems, and I knew they could do that. So I sent them back to the drawing board, and we put the rotisserie mode in, so we slowly rotated going up to the moon, and slowly rotated to come back again. The temperatures never varied more than about 40 degrees plus or minus on the heat shield. That's what a program manager can do, ask the fundamental question, "Why is the requirement what the requirement is? Does it make any sense, and how can you change it, or can you change it safely without any problem?"

Same thing happened on the docking mechanism. The structure people came to me who designed the docking mechanism, "Oh, we can't make it strong enough for the LM to push the command module."

I said, "Oh, come on, you know you can do that. It's easy enough to do."

Well, it's more [an attitude] control system problem which they could solve. So I insisted that as part of the redundancy, because the only two non-redundant elements aboard the spacecraft are the engines on the lunar module and the engines on the service module. So I insisted that the [lunar] module be able to control and push, that the interface be strong enough that they be able to push the command module. If it hadn't been for that decision, the movie *Apollo 13* would have been a tragedy instead of fun. But you've got to ask the right question and you've got to understand the system. That's all.

KELLY: That's interesting. You had mentioned that the only two systems that weren't redundant were the engines on both the command module, or service module, and on the LM. Were you involved in making that decision?

SHEA: There was no other way to do it. You couldn't put two engines on. We made all the valving and piping and everything else … redundant. The only thing that wasn't redundant was the engine bell itself. That was something we decided we could live with, so we did.

KELLY: What other types of things did you work in with respect to getting the command module along the lines and getting it moving forward to the point where they could actually use it as a spacecraft?

SHEA: Well, you could always use it as a spacecraft. It was designed as a spacecraft. It came out of a study that had been done by the space task group long before Apollo started. It was designed to be a three-man spacecraft, and it was an adequate three-man spacecraft.

KELLY: How did it go from the drawing board onto the actual assembly line and actually producing them? Can you tell me a little bit about some of the decisions that were made? For instance, I'll just think of an example. Some of the systems with regard to the environmental control system, or the reaction control system.

SHEA: Those were easy systems to spec. The thing I found when I got to Houston was that there were a number of test spacecraft, and North American was making every goddamned one of them different by a little bit as the design was evolving. I said, "That's too expensive. We're going to stop that. We're going to have one block, one design, until we get the lunar module designed, and then we'll have a combined design for the lunar module and for the command module. That'll be called block two." And that was what finally flew.

KELLY: Why didn't the block one command module ever fly?

SHEA: Because it burned up.

KELLY: That was the only one that was designed, then?

SHEA: There was one more.

KELLY: Can you tell me a little bit about working with North American? I had heard from several other people that I've interviewed that they had been working with McDonnell for so long during the Mercury and Gemini Programs that the really felt comfortable with them, but it was just a very different atmosphere working with North American.

SHEA: North American was a very difficult company to work with. The night they won the contract for the [unclear] service module, they had a party. They gave out hats, [unclear] hats. Do you know what was on the hat?

KELLY: What's that?

SHEA: Here's what the hat looked like. [Drawing: NA$A]

KELLY: Oh, no.

SHEA: Yes, ma'am. That's right. Honest to God, that's how—

KELLY: Just for the tape I'm going to say that it says NASA with a dollar sign as the S (NA$A).

SHEA: Dollar sign in the middle. And they acted that way most of the time.

KELLY: Oh, really? Had you ever worked with any of the people at North American before?

SHEA: No.

KELLY: So it was a totally new ball game for you, then.

SHEA: Yes.

KELLY: Can you tell me a little bit about your first introduction with North American and the relationship between NASA and North American?

SHEA: Well, I wrote a memo to George, one of which I will give you next time.

KELLY: Okay.

SHEA: We cited some eleven or twelve conditions under which I would go down to Houston and take over the spacecraft program job. It involved changing out people; it involved a few changes in system philosophy. We can talk about that next time.

KELLY: Okay. I'm very interested to find out how you got to Houston and why they asked you to go.

SHEA: Because after Frick quit, Bob [Robert O.] Piland, who had been his deputy, became program manager. Piland didn't want to be program manager. Mueller came in. Piland quit after Mueller came in. I sort of hinted to Mueller that I would be willing to go down to Houston

and run the program if he wanted me to. Then I wrote him a memo which essentially contained the conditions. [unclear].

KELLY: Thank you. This is your memo to Dr. Mueller.

SHEA: You might want to write on top of that, "Conditions for going to Houston."

KELLY: Okay. I'll jot this down here. Did you then go to MSC shortly after that and then Spacecraft Center after you discussed this?

SHEA: Yes. Almost immediately.

KELLY: Oh, really? What was that like uprooting your family and going to Houston?

SHEA: They were used to being uprooted, poor kids.

KELLY: What was the Manned Spacecraft Center like when you first arrived there? Essentially it was really a new center altogether.

SHEA: It wasn't on the base yet. I went down and I just immersed myself into the organization, not as a headquarters guy, but as one of their guys. I was really Mueller's guy in Houston, but I acted as if Mueller was headquarters just like anybody else, and became part of the center. I assigned studies to various parts of the organization that I thought would cause them to change their mind about the things that were wrong, that were wrong, in my mind.

KELLY: Can you tell me about some of the people that you worked with when you were out there?

SHEA: Tom [J. Thomas] Markley, the guy who just called, he became my deputy. He was a very strong guy, a very strong guy. Faget was there, of course.

I didn't tell you the story about when I went around to start the studies on LOR direct flight. I went to von Braun. I had no organization in Washington. I had maybe two people. I said I needed some people, and he gave me one guy, named Arthur Rudolph, an old guy who used to run the factory at Peenemunde. I went to Gilruth, he turned me over to Faget. Faget said to me, in Faget's gracious way, "You're not getting anybody from me. I have a thousand people, you have hardly anybody. We're ahead of you, we'll always stay ahead of you. We don't need you, you get nothing."

Then I went out to JPL [Jet Propulsion Laboratory] and talked to Bill [William H.] Pickering, who's a moralist, you know, and Pickering said, "Of course you have a problem." And Pickering assigned thirteen of his better people to Washington, detailed to Washington for six months, and they were the ones that actually did the back work on writing the reports and so on. Not Manned Space Flight people, but JPL people.

KELLY: It seems like he really helped you out.

SHEA: Oh, he did, yes.

KELLY: What then did those people go on to do?

SHEA: Well, they went back. One was Ed Recatin, who became president of Aerospace Corporation. [Later,] he was director of DARPA, the Defense [Advanced] Research Projects Agency. They were good guys.

KELLY: That's terrific. Any other people of note that you might want to mention, people you worked with at the Manned Spacecraft Center?

SHEA: Well, a guy named Rolph [W.] Lanzkron, L-A-N-Z-K-R-O-N. That's all part of the story of what went on down there. If you choose to come back again, we'll get into that.

KELLY: I would love to do that if you would be willing to do that.

SHEA: I don't know if this is useful for you or not.

KELLY: Oh, absolutely. This is marvelous.

KELLY: As a matter of fact, as I mentioned, what we're trying to do is just trying to get a very broad overview of what happened with Mercury through Apollo Programs, and this fits right into the very beginning of Apollo.

SHEA: This is a very negative view, but it's a very true view.

KELLY: That's what we're looking for. We're looking for history and documenting history, and these are the actual documents.

SHEA: Some of them are the actual documents.

KELLY: That is going to be really terrific research. Is there anything you would like to talk about today?

SHEA: I think we've pretty well covered … the system engineering part of it. I'm still writing more stuff. I have a secretary that's typing for me. Maybe when you come back again, I'll have a few more things for you.

KELLY: That sounds terrific. What I'd like to propose, if this is okay for you, I'd like to read through this research, and listen to this tape a little bit more, and go through it a little bit more in depth, and do some more research on my own—

SHEA: And come back again.

KELLY: —and come back with more detailed questions.

SHEA: Certainly. I'm retired. There's not restriction on my time. If it's useful for you.

KELLY: Absolutely.

SHEA: The only thing I would say is I consider some of the material proprietary.

KELLY: I understand. Certainly.

SHEA: The stories are, like that story there, perfectly permissible to talk about.

[End of interview]