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EDITED ORAL HISTORY TRANSCRIPT 2

JOHN F. CONNOLLY
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is October 20th, 2023. This interview with John Connolly is being conducted in Houston, Texas, for the NASA Oral History Project. The interviewer is Jennifer Ross-Nazzal. Thanks again for joining me, really appreciate it.

CONNOLLY: It's a pleasure. I didn't expect this would take as long as it did, but this is fun.

ROSS-NAZZAL: Talk to me about how you became the Lunar Lander Pre-Project manager and what that project was.

CONNOLLY: After the announcement was made at NASA Headquarters [Washington, DC] in fall of 2005 that basically gave the shape to the Constellation Program, I returned to Houston from Headquarters and I was given the challenge of shepherding the Lunar Lander Project along. It was unofficial at this point because the official parts of Constellation that started off were the launch vehicle, the Orion capsule, and the ground systems at Kennedy [Space Center, KSC, Florida], the initial things you needed.

The program knew that eventually they would need a lunar lander. They would need lunar surface systems. So I started the Lunar Lander Pre-Project. I don't know if the term pre-project is an official term that NASA uses, but that's what I called it. There was a lot of interest in it. One of the first things I did was I put together an activity for every NASA Center to

participate in where Centers would put together design teams to design a lunar lander per the requirements as we understood them at the time. We called this the Lunar Lander Preparatory Study, LLPS. We had teams from every NASA Center who put groups of designers together, and we ran this for about six months in two cycles. The first cycle was just bring us all your cool ideas for lunar landers. We received between 50 and 100 concepts that ranged from things that looked like the Apollo lunar module to skycranes that looked like how we land rovers on Mars, and everything in between. A lot of creativity, a lot of great work by the people all across the NASA Centers.

We showed all these concepts to a review team that included current astronauts and flight controllers and ex-Apollo astronauts and ex-Apollo managers. We put our heads together, and we picked the best of all the concepts that we saw, and we assigned a particular lander concept to each of the Center design teams. The JSC [Johnson Space Center, Houston, Texas] team, for example, was given the task of designing a lander that makes use of the large hydrogen tanks as habitats once you land. You vent the tanks, you outfit them, and you use that giant volume for your habitat on the surface. There was that kind of assignment made to every one of the Centers.

Each Center team given another three months to work that design in more detail, and we had another review, again with a lot of NASA astronauts and Apollo era folks, and basically we made notes of what the best features were of each of these concepts. That was all captured in the Lunar Lander Preparatory Study. It ran from maybe end of 2005 through the beginning of 2006.

A lot of those concepts are captured in a book of lunar lander concepts since Apollo that was published in 2020. It was released as a NASA special publication, a nice hardcover book [After LM: NASA Lunar Concepts Beyond Apollo]. It's online in the NASA publications world; you can download it.

We did preserve all those lander concepts from the LLPS study, and we took the best parts, and we tried to use that as we put together what became the Altair Project.

The Lunar Lander Pre-Project lasted through 2006. At that point the Constellation Program had become real, so they had project managers who were chosen for the launch vehicles and the CRV [Crew Return Vehicle], the Orion capsule, and some of the other Constellation piece parts. They looked to me to sort of be the person to represent the formative lunar lander work. I did that, and it was a great time because that's when you're trading requirements, doing the high-level studies, really formulating the details of the architecture.

Then in early 2007 the Constellation Program decided that the lander needed to be an official project, and so they chose Lauri Hansen, who was with JSC's Engineering Directorate and Safety Directorate, to be the first project manager of the lunar lander, what became the Altair Project. It was called LSAM at first, Lunar Surface Access Module. Laurie asked me to help establish what the whole project would look like, who we would get to staff it, how we would organize it. I became the head of vehicle engineering for the Lander project, which was a great position for me, because I love doing the engineering. Lauri, I, and a few other folks, handpicked about 50 people from all around the Agency to be the initial staff and engineers of the Altair Project. We co-located everybody, starting in spring of 2007 and going through the summer. at one of the back buildings at JSC.

We wanted to give it kind of a "Skunk Works" head start. We could get everybody in one place and in every meeting. We started a series of design analysis cycles [DACs]. We love these at NASA, DACs, or RACs [requirement analysis cycles]. You hear them by many terms. We had lander design analysis cycles, LDACs.

We ran through the first three design analysis cycles while we were all co-resident at JSC. We had folks from every NASA Center. We needed propulsion people, we got those from Marshall [Space Flight Center, Huntsville, Alabama]. We needed GN&C [guidance, navigation, and control] folks, and we got those from JPL [Jet Propulsion Laboratory, Pasadena, California]. We picked up the experts from everywhere that they existed throughout the Agency. It was a really high-performing team, and it was a lot of fun being together with all those folks.

ROSS-NAZZAL: How did you decide who to include? Were they people that you had worked with on the study or how did that happen?

CONNOLLY: Yes, generally it was people who were known to us who were experts in that particular function that we were trying to fill. We enlisted quite a few participants from the Lunar Lander Preparatory Study, which we used it as a recruiting and interviewing tool, because we made notes of who the people were during that study who were really the high performers. A lot of the people who helped us with the Lunar Lander Preparatory Study ended up being part of that initial group of the Altair Project.

ROSS-NAZZAL: One other question for you. You said you were in charge of vehicle engineering, which I thought was interesting because last time we had talked and looking at your CV [curriculum vita] you had mainly worked on planning to go to Mars. Vehicle engineering is much more hands-on. It sounds like something very different from what you had been doing.

CONNOLLY: Right. Most of my career up to that point had been planning to get us back to the Moon and on to Mars. It was high-level architecture studies and high-level trade studies and parametric designs of vehicles. Now the Constellation Program was making that all real. I was given the opportunity with the Altair Project to take that step that all of us engineers want to take from doing conceptual design to doing real design, and I had a lot of knowledge of previous lander studies and previous exploration studies. This was a natural fit for me, and this is really where I wanted to be. I wanted to be in the real nuts-and-bolts engineering designing and building the lander that would go to the lunar surface. For a lot of engineers this is kind of the natural progression. You have to start with those high-level conceptual engineering, but then most of us want to be involved in the real hardware once that becomes available as an option.

For me personally, this was the first time that I had an opportunity to do this. I had been working at NASA now for almost 20 years, and working many things at the study level, at the conceptual level. Now that Constellation was a program and Altair was a project under it, this was my first chance in my career to actually make that step forward that I had always wanted to make to being part of a hardware project. That was a great year for me when Altair came into existence.

We had Lauri as project manager for a few years, and then Kathy Laurini took over a few years later. We organized ourselves a little differently than some projects do. We had a systems engineering type group that really did a lot of the requirements and the interface documents with the other parts of Constellation. Vehicle engineering really took a lot of that data, and we were heads down, actually designing the vehicle.

This was in some ways an old NASA way of doing things, where NASA itself designs the vehicle, but that ultimately wasn't our goal. Our goal was to come up with a design that was

a really good government reference design and then to bring the contractors in, to give them that design, and tell them, "Okay, here's what we have, now it's up to you. Tell us how you improve it; how you do something entirely different. Just go run with it."

So the idea was to have a good government reference design, but then to bring in the contractor community to build it, eventually. We weren't going to build it in-house. We just wanted a good reference design that met all the requirements to prove to ourselves and to the Constellation Program that we could build a lander for the requirements that had been on the books at the time.

We went through a series of design analysis cycles, four of them in total. They became longer and longer with time because the design gets more detailed as you go through each one.

We used a unique risk-based design methodology, and this was one that was suggested by the NASA NESC [NASA Engineering and Safety Center] a few years previous where you start a design with what they called it a minimally functional design. You take the requirements that are only the basic requirements: what this vehicle minimally must do. You design it single string, no redundancy, no extra protection for anything that could go wrong, the most basic vehicle. That becomes your starting point.

Then you analyze that vehicle for where it could break, what are the prime risks, where is it unreliable. Very methodically you start adding back safety and reliability. And we called it "buying back," by adding back redundant components or better design of a system or bigger margins. You start adding that back in a very purposeful way and document everything as to how it changes the vehicle performance, how it helps to lower risk or improve reliability, and ultimately how it affects cost, because a very simple unreliable vehicle will cost you a lot less than a more complex very reliable vehicle.

We used this risk-based design methodology through each of the LDAC cycles that we went through, and eventually we got through the fourth cycle and we were at the point where we were now satisfying the Constellation requirements. The two big ones were loss of crew and loss of mission. You had to have a vehicle that had enough reliability so that its loss of mission statistics were a certain number and enough safety so its loss of crew statistics was a certain number. We had a team of risk analysts that worked probabilistic risk assessment for us in real time as the designers were designing the vehicle.

It was very very insightful because we could tell you exactly why we added that backup com [communication] system, rather than just saying, "Oh, we have two strings for the com system," we could say, "No, we have two different com systems, and the reason we did it is because statistically it's a better choice to improve the reliability of the vehicle and the safety of the vehicle."

We had hundreds of these design choices that were documented in this risk-based design procedure. It's all documented pretty well in the Altair files, and we wrote quite a few conference papers about this design process, presented them at IAC [International Astronautical Congress] and a lot of the big conferences around the world. We were very happy with that process.

In about 2009 we started bringing industry on board, and we would give them the same set of requirements we were looking for and ask them, "Show us some concepts that you would come up with for the same set of lander requirements." They did that, and that was supposed to be the start of bringing industry on board.

At the time that Constellation was shut down and Altair was shut down at the end of 2009, we were working on a procurement called the Altair Conceptual Design Contract where

we would actually start integrating contractors and the Altair team together to mature the design to a point where we could actually then turn it over to the contractor community.

We never got to pull the trigger on that particular procurement because that was right when everything was shut down, but it would have been a very new and interesting way to do business at NASA where you have basically a common design team made up of contractor personnel from multiple companies working hand in hand with the NASA folks to figure out an optimum design. Then once you figure out the optimum design you lock it in place and then you bid it out to whoever wants to build it for the best price. That was Altair.

Constellation and Altair were a high point in my career personally. It was the furthest we had moved in a real way towards lunar/Mars exploration since I'd started at NASA. Everyone thought that we were building enough momentum that even if there were political changes it would sustain itself. Turns out that nothing is stronger than politics so the Constellation Program was chopped off at about the end of 2009, beginning of 2010. The Altair Program was shut down, so we sent everyone home. That became the end of that cycle. I think I've talked about how exploration goes in cycles, and it's like a roller coaster. What we experienced at the end of Constellation, after riding this roller coaster of momentum and optimism towards actually going back to the Moon—it crashed very quickly when the determination was made that it wouldn't be supported politically by the administration at that point.

ROSS-NAZZAL: Can you tell me about that day when you learned that the program had been canceled? What are your memories?

CONNOLLY: Yes. It happened in stages. I heard the rumblings earlier, so you get these trial balloons that are floated and the NASA folks get a chance to kind of respond to those. Probably for a month or two before they closed down Constellation, we had heard that the administration was planning on doing this. Of course what NASA does is we try to meet with them and try to understand why they want to do that, whether that's really what they want to do. Or do they want us to reformulate the program, lengthen the schedule, bend the cost curves a little bit. But ultimately it seemed that the political motivation was to shut it down and to basically take any emphasis off Moon and Mars exploration at that point.

Yes, those are harsh things, and that had happened to me once before when the Space Exploration Initiative [SEI] was shut down, so this was my second roller coaster crash in my career. At that point you start wondering is there any way we can actually get exploration working given the political system that we exist in or is it going to be a thing where every four or eight years as administrations and politics change everybody will want to put their new stamp on it or not want to continue the other guy's programs.

It was very disappointing because at the same time we were doing that, the Shuttle Program was also coming to an end. There was a great deal of concern especially at Johnson Space Center about all these people who were rolling off the Shuttle Program and all these people who were rolling off the Constellation Program.

In the middle of that somewhere I had my fiftieth birthday party at the Outpost. Right before we shut down Altair, my wife planned a great birthday party at the Outpost with the Altair team and all my NASA friends, and I think that was one of the last big events that happened at the Outpost before it burned down a month or two later. Glad I got that in.

At the end of Constellation we had quite a bit of hardware built. We had the Ares I-X Test Vehicle on the launchpad, which we were allowed to launch. A lot of money spent, but the expenditure of funds and the real hardware couldn't compete with politically motivated decisions.

After the cancellation of Constellation, NASA went into its usual replanning mode to figure out what to do next, and we were told to work on things like an asteroid retrieval mission, which was interesting academically, but I don't think anyone at NASA really believed that was a mission we would ever really do. But we worked on that. We looked at lunar orbital missions where you can go to the Moon with astronauts in orbit around the Moon but you couldn't send them to the surface. There were teams like the Human Architecture Team and others put into place after 2010 to look at those missions.

There were a few years that were recovering from Constellation and with different people leading different teams to try to figure out what to do next. A lot of us did many different things during that time, but it was basically trying to figure out what to do with the people who were rolling off Constellation and was there a way to make use of some of the Constellation assets. Ultimately the decision was that yes, we would save the big launch vehicle program. It changed from being called Ares to being called SLS [Space Launch System]. But essentially the same type of program, a large launch vehicle based on Shuttle era hardware.

There was the Orion capsule, the CRV from Constellation, that continued on because it was seen that that was a valuable element that we would need one way or another going into the future. The ground systems work at Kennedy continued. What got cut off was anything that had to do with going to the Moon such as lunar landers, so the Altair Program was shut down. Lunar surface systems, which was a pre-project at that time, was shut down as well. Anything that was

focused on going to the surface of the Moon went away. But again thanks to some savvy negotiations politically and by the NASA folks at Headquarters, a few key components of Constellation lived on. That's good, because we would not have SLS or Orion today if it didn't.

Fast-forward to about 2013. I got to admit that 2011, 2012 were a bit of a blur, working with different teams that were trying to figure out what the next human architecture should be that didn't touch the Moon, but looked at the Moon maybe while orbiting it or operated rovers from an orbiting spacecraft.

I don't know if anyone was particularly enthused by any of those studies or working on any of those teams. But in 2013 a good friend of mine who was the chief exploration scientist at NASA Headquarters, a gentleman named Mike [Michael J.] Wargo, suddenly and unexpectedly passed away, and he was one of these folks who is kind of a force of nature. He had a lot of balls in the air as we say. Right as he passed away, I got a call from Headquarters asking me if I could step into that position.

Of course I would do that for Mike and for the Agency. I'm an engineer, but I speak science pretty well. To be the chief exploration scientist you had to understand the engineering and what goes on in the exploration directorates, but you also had to understand the Science Directorate and what they did and the Technology Directorate and what they did. It was really the integration of those three big groups at Headquarters. At the end of 2013 I was back at Headquarters. I was commuting up there every week, so I'd get on a plane Monday morning, usually with the Texas congressional delegation, fly up to Headquarters, work there all week, come back on Friday, usually with the Texas congressional delegation. I got to know a lot of those guys, which was interesting.

ROSS-NAZZAL: Was that beneficial do you think in having conversations about NASA and science, engineering, all those topics?

CONNOLLY: Absolutely. When you get to talk to politicians in a personal way, you see them as real people who have real ideas about what they think is good and bad. It's usually not the persona you see on TV. You get to know them more personally for what they believe. Yes, for me that was very educational to know some of these guys and actually see them as people rather than as politicians. That was really helpful.

I don't want to be the guy sitting on an airplane next to a senator who's trying to make NASA policy. I'll answer questions if they had them, but I wasn't going to try to do the elevator pitch to them on a certain mission or something like that.

So 2013 and into 2014 I'm working at NASA Headquarters as the exploration chief scientist. It was a good job. It was a good fit for me because as I said I like to exist at that intersection of engineering and science and technology. I did that for the better part of a year. I knew that the Exploration Directorate was looking for a permanent replacement who probably came out of the science world, so I was helping with that as well, and we did some other good things while I was up there. I was doing more than just filling a seat. We actually kept everything moving forward that Mike Wargo had started.

Near the end of 2014, in the fall, we were getting close to filling that position with a scientist, and it would eventually be filled by Ben [J.] Bussey, who was a scientist out of APL [Applied Physics Laboratory, Baltimore, Maryland]. Right about that time I received a call from Gary Martin, who worked at NASA Ames [Research Center, Moffett Field, California]. He was seconded to International Space University [ISU] at the time as the director of their Space

Studies Program [SSP]. NASA had always detailed the director of that program to ISU as part of our in-kind contributions to ISU. NASA didn't give ISU any direct funding, instead we gave them an in-kind contribution of people and expertise to teach and to keep that institution running. ESA [European Space Agency] does the same thing other space agencies do the same thing as well. That's part of how ISU exists.

Gary was just finishing up his term as the director of the Space Studies Program, and he asked me if I would be interested in a detail to take over for him. I had a long history with International Space University. I had been teaching there since 1993; at that point it had been 30 years or so, I'd been a lecturer and a department chair and other positions at ISU. This would be that next notch up the ladder where I'd actually be running the whole program. I was intrigued by the offer, and I started asking around to International Relations Office and my management whether it would be possible for me to take this detail. It basically becomes an IPA, interagency personnel agreement, for one to two years as the director of the Space Studies Program. I received all the permissions, everybody was excited about it, and I began as the director of the ISU Space Studies Program in the summer of 2014 in Montreal.

The Space Studies Program, for folks who don't know, is a program that moves around the world every summer. Because of this changing host site location, it is chock-full of logistics challenges. We're basically moving a two-month university program around the world every summer. You have to get the teaching staff there as well as the regular staff, and you have to figure out where the classrooms are going to be and where the students are going to stay and where they're going to eat.

I started in Montreal; we were there for three months or so during the summer conducting the Space Studies Program, and after that I became the full-time director where I was now

choosing the host sites for future programs as well as planning the entire content of those programs. In 2015 we were at Ohio University [Athens] here in the States. That was relatively easy because it was here in the U.S., and the logistics are very familiar to us. But then in 2016 I had to plan and execute the ISU program in Haifa, Israel. That turned out to be very challenging. It was the first time in our ISU history that whenever we took a bus from Haifa down to Tel Aviv or elsewhere in Israel, we had to have an armed escort on our bus. I had to arrange for the safety of the 150 students and the 200 or so faculty and staff members that we had there. It was a great challenge if you like personnel challenges. It was a great experience. Different than anything I'd done at NASA before, because it was all about people management, planning, negotiations, not as much building spacecraft.

A quick word about ISU. ISU is not a normal university. It's a nonprofit specialty university that emphasizes educating the future leaders in the space sector. The students are handpicked. There's about 100, 120 every year, maybe. Some of them are sent by agencies like NASA or ESA or JAXA [Japan Aerospace Exploration Agency]. It's typically the people that those agencies think are the up-and-comers. Those are the students we get. We call them participants because many of them are young professionals, not really students. The space agencies around the world also send us staff and teachers. All our lecturers basically come from the space agencies around the world. That makes it a very unique university in that it's very focused on space and it's very focused on space in its biggest whole form. Everybody gets an equal education about space science, space engineering, space policy and law, space business, space life sciences, space applications, even space humanities. It's a very broad umbrella type of education so you can see the big picture of all the pieces that make the space sector work. That's

really the key to ISU and why it's been popular now for 40 years or so, because people want this high-level broad perspective of the space world. I got to lead that for three years.

ROSS-NAZZAL: Do participants end up with a certificate or some sort of degree?

CONNOLLY: ISU has a number of programs. The program I led is the eight- or nine-week summer program which also has a five-week component in January down in the southern hemisphere. The northern hemisphere and the southern hemisphere programs were my programs to lead. There's also a—I wouldn't say standard, nothing at ISU is standard—more of a traditional master's program that is resident in Strasbourg, France. If you want an accredited master's degree in space studies you can go there and you basically get the whole umbrella treatment, only stretched out over two years.

ROSS-NAZZAL: What do you think are the benefits for NASA for an employee to be embedded in that university?

CONNOLLY: NASA has I'd say between 150 and 200 ISU alumni in our ranks, and a lot of those people are the people you see coming up to positions of greater and greater responsibility. We have program managers and flight controllers and astronauts and a lot of folks who've gone through this program. In some ways it's a common experience that bonds the people who go through it because it is much more than academics. It's very intense for the eight weeks that you're there. It's one of these life-changing experiences for many folks. The folks who go through this are very tight. *Forbes* magazine even wrote an article about ISU where they

referred to ISU as the "space mafia." That is because the folks who go through ISU always are part of a family and they always ping each other on things that are going on or they use each other for common projects because they know what they'll get. That's one of the things that makes it very unique and very interesting. We're just getting ready, by the way, to host the 2024 version of that here in Houston. I'm leading the local organizing committee to bring it to Houston and host it at Rice University with JSC as the cohost.

What else about ISU? It's very small; it's a nonprofit that does great things with very very small budgets. It relies on the goodwill of agencies like NASA and the other space agencies of the world to provide both staff and lecturers and teaching positions and management. That's what everybody gives.

What they get in return is young professionals—let's call them that rather than students—who now have this understanding of the space sector that goes beyond the stovepipes that we normally see many people in. The three I's of ISU are: international, interdisciplinary, and intercultural. You're in a class that comes from 30 or 40 different countries, and it's very international, lots of different cultures. We make sure that everybody shares their culture; we have culture nights. I'd say that ISU started out heavily leaning towards engineering, and now I would say 25 percent of the people we get are engineers, and there's now just as many lawyers, artists, teachers, scientists, people from all walks of life who have that intense interest in the space world. It's very cool. We have a number of astronauts at NASA who went through the program as well.

What the agencies get for contributing folks like me is they get students returning back to the agencies with this broad perspective of the space world, a huge set of connections, and some people think that's maybe the most important thing, because you're connected to literally

everybody else internationally in the space world. It's things that are hard to put a value to, but we know just from working in the international space world how valuable it is to have connections and to know people at every space agency in the world.

From '14 through '16 I was the director in Canada, the U.S., Israel, and Australia. There's quite a bit of travel that goes along with ISU. I enjoy travel, so I didn't even mind the 17-hour plane flight down to Australia. Although that is kind of rough at times. The job is not easy. It's long long hours, 100 to 250 emails a day, but you get that satisfaction of working with these very very bright handpicked people from all around the world who you can just see it in them that they're going to be something great. They're the future space leaders. I found that position very satisfying. Even though I was never a student there myself, I started being a lecturer in '93. I think that ISU has changed my life as well, because I've gotten this greater perspective of everybody who's out there. I can also claim that I have friends from 50 different countries.

Fast-forward a little bit. I'm still on the ISU faculty. I still go to ISU sessions, but now I'm not there managing it. I'm just there as a lecturer or leading workshops. Maybe for a week or two a year I get my dose of ISU for teaching and interacting with the students and getting back into that ISU bubble again, which is very satisfying.

In fall of 2016 I handed over the reins of the ISU position to another JSC engineer/manager who was seconded to ISU, and I returned to JSC and was offered the position of leading the Agency's human Mars mission planning team. A good friend of mine who had been leading that for years was retiring so the timing worked out really well; it was a great position to step back into. When Bret [G.] Drake left the Agency, I took over the human Mars program. The human Mars program at NASA has been something we've had for a long time,

and it's always been a planning activity. We've been talking about sending people to Mars since the '60s, but we haven't really gone much past the planning process.

But we like to always have a planning team who's looking at that, looking how new technologies can be incorporated into mission designs, trying to come up with a different range of different ways to do it at different levels of cost and risk and schedule. We continue to do that. We have a series of what are called design reference missions or design reference architectures. The design reference architecture was basically our best current thinking of how we would go to Mars if we were told, "Hey, today, we're doing it; we're going to start a Mars program. Here's the money for it. How are you going to do it?" We always have the design reference architecture handy as our best guess.

When I took over this group, I wanted to revisit the design reference architecture that was currently on the books because the last one that had been published was, I don't know, more than 10 years old. I put together an architecture group. I started with something I call an expert group, which is a small group of people who I know and trust and we can bounce things off each other, they're basically the smartest people in the room.

Our little expert group would meet a couple times a week, and we'd start drawing up a better Mars architecture than what we had last time. Then we had a team who we could assign to work the details of all that. That was basically my return from ISU in 2016 and into 2017 and '18 we kept working this. By the time we got to the point where I was asked to come back to the lunar side of the house, we had published an internal document called the "Mars Basis of Comparison" architecture. We didn't call it a design reference architecture because this was meant to be the one you compared everything else against. If you got a better idea, great, but if you don't, this is our best thinking.

By the end of 2019 we had the new Mars architecture. I turned the Mars team over to a colleague, Michelle [E.] Rucker, at the time, who was the biggest fan of getting us to Mars that NASA has ever had. She still continues to be the best advocate of human Mars. Then in about 2019 there was a shift of emphasis towards the Moon and I was asked to step back to lead the lunar surface systems work for I what you would eventually be called the Artemis group at that time. So I turned the Mars program leadership over to Michelle, and I started working Moon again.

Artemis at that time started out as many NASA programs do as a transportation architecture. Engineers like to start with transportation architectures.

ROSS-NAZZAL: Can you explain what that means if somebody were to pick this up? What does transportation architecture mean?

CONNOLLY: Transportation architecture is basically how you get from point A to point B and back. At the time it was how do you use the items we preserved from Constellation, Orion, SLS, Exploration Ground Systems, to do a human lunar mission. The architecture studies all used those piece parts because that was ground ruled in. We had been investing in those for many years.

Basically the architecture was a description of how you got from Earth orbit to lunar orbit and then from lunar orbit back to the Earth. It didn't say really much about what you did once you got to the Moon or how you got down to the surface of the Moon. It really didn't talk about landers or rovers or EVA [extravehicular activity] suits or science or site selection or surface habitats or any of those other parts, it was just the transportation piece.

That's maybe the necessary start because without the transportation part none of those other things get where they need to go. But it also continues this idea that launch vehicles and in-space transportation drive the architecture. That is one way of thinking about it. Another way of thinking about it is that you define the things you want to do on the Moon when you get there and size those, and then use that sizing to derive the transportation that you need to get those things there.

That's why we needed surface systems, because all those other things were undefined. That's where I came in, and I started a lunar surface systems group to start working out the details of what you need on the lunar surface. We started defining all the piece parts: habitats, rovers, ISRU. You're familiar with ISRU, in situ resource utilization. It's how you use the resources on the Moon to your benefit. If you can find water, you can use the water contained in lunar minerals to crack out the hydrates. All those were part of the lunar surface systems world: space suits, site selection, things like that. Basically everything once you approach the surface of the Moon and land, it's everything you do once you get there, and how you're supported.

As part of the lunar surface systems work, we were coordinating with other parts of NASA who were working the launch vehicles and Orion. There really wasn't a cohesive program yet at that point. That all changed in 2019 I believe, in March of 2019, when the Vice President, Mr. [Michael R.] Pence, made an announcement that we were going to go back to the Moon in 2024. Many of us were at an internal NASA workshop down at KSC at the time and we all looked at each other. We said, "Wow, that's quite a challenge, we better get to work on that."

At that time lunar lander work was being managed out of NASA Headquarters, primarily by folks who were detailed there from Marshall. Later that year in August of 2019 the Lunar

Lander Program was officially given to the Marshall Space Flight Center. At the same time it was announced that JSC would lead the lunar Gateway work, which became the Lunar Gateway Program. That was a sea state change from Constellation, where JSC had led the lunar lander work and it disappointed a group of us who had been working landers 10 years prior because now all of a sudden the centroid of that work had shifted.

Nonetheless, in 2019 I was asked to join the HLS [Human Landing System] team because that had been my specialty during Constellation, and I guess folks recognized me as a lunar lander subject matter expert. I turned the lunar surface systems work over to another colleague, seems to be a common theme in my career. I get a job for a certain amount of time, I'm called to do something else, so I turn that job over to someone else. I turned the surface systems work over to Jeff [Jeffrey] George, a colleague, who worked it for quite a while after that. I returned to the lunar lander world where a good bit of my previous experience was.

One of the first things I did as I looked around the lunar lander landscape that the Marshall folks were creating is I realized there was a need for people to be educated about the work that had been performed previously on lunar lander designs. The Lunar Lander Preparatory Study and the Altair Project had been keeping excellent files; I had notes of all the lunar lander designs we had done over time. I had about 115 lander designs at the time. One of the first things I did was I restarted this project that I had started up many times but never finished of creating a catalog of lunar lander concepts.

I finally got some help with some of the folks from my office to finish that, basically created a catalog of all the lunar lander concepts that had been created by NASA or its contractors in the years since Apollo. I took all these piles of notes and reports and arranged them temporally into a book outline. Two colleagues of mine, Alida Andrews and Kevin Watts,

helped me pull it together and in early 2020 the book was published by NASA Headquarters. It was called *After LM*: *NASA Lunar Lander Concepts beyond Apollo*. It turned out to be a popular book. There were hard copies sent out to all the libraries around the country, and the majority of people who have seen this book have downloaded it from the NTRS [NASA technical reports] server. I think there have been many thousand downloads. Surprised me how much it's been downloaded. I'm very proud of the book.

ROSS-NAZZAL: Congratulations!

CONNOLLY: I'm already collecting lunar lander concepts for volume two or second edition, I guess, because we cut that book off at the end of Constellation. Since Constellation we've had lunar lander concepts that have been worked at Headquarters as the Artemis Program came into being, and then of course everything that's been going on with the Human Landing System Program since, including the actual lunar lander concepts that are being built into actual vehicles by SpaceX and and Blue Origin. Hopefully the books helped people understand why we made the decisions we did with some of these conceptual studies, and it has a lot of engineering detail in it on subsystems and why things were chosen.

Let me backtrack a little bit because I have been part of a number of books. The lunar lander book was the first one I compiled in its entirety, editing all these concepts that other people had done. But I had been one of the major authors on a book called *Human Spaceflight*: *Mission Analysis and Design*. That ended up being the textbook that a lot of people still use for teaching human spacecraft mission planning and spacecraft design in universities.

I also wrote a good part of one called *Planning and Execution of Human Missions to the Moon and Mars* that was just published by AIAA [American Institute of Aeronautics and Astronautics] last year. I wrote the management chapter, how you manage a large Moon/Mars program. Turns out that the management structure I proposed in the book is approximately the management structure that NASA has chosen for the Moon to Mars Program currently. So I'm pleased I got that pretty close.

Then I contributed to another book called *Farthest Shore*. There have been a number of books where people have asked me to contribute chapters or multiple chapters based on my expertise on Moon/Mars, lunar landers, and this breadth of human Moon to Mars mission planning I've done over the years.

We're getting near the end here, I think. Let's see, 2019 I'm working on HLS, and then COVID comes around. One of the things I had done for HLS was I helped a bit on the procurement activities to select the contractors who would build the first human lunar landers. NASA chose three commercial companies in spring of 2020 to perform initial design work on human lunar landers: Dynetics, Blue Origin, and SpaceX. Those three teams were asked to do conceptual design work, and during that time SpaceX requested me to be a technical collaborator with them. Part of these contracts allowed NASA people to basically be embedded within each of these teams as collaborators, at no cost to the contractor teams. There were a certain number of FTEs [full-time equivalents] that every team could ask for. So I was embedded within the SpaceX team from very early on, and that continued to where my NASA career is actually going to end. For the past three and a half years I've been embedded as a collaborator within that team, and that's pretty much been my full-time job.

ROSS-NAZZAL: What do you do as a collaborator? Are you working on hardware or design? What are you working on?

CONNOLLY: This is how things come full circle back to where you want to be. HLS collaborations are a new and different animal for NASA. NASA personnel are basically on loan to one of the HLS contractors and embedded within their team. The idea is to help the contractors succeed. We're taking NASA expertise, where maybe a company does not have that specific expertise, and we're doing work with them as part of their team to help their design succeed and for them to build a successful vehicle.

It's interesting because when you're embedded in a team, you're actually not wearing a NASA hat anymore. You're wearing the hat of that contractor. You have to comply with all those contractors' IP [intellectual property] policies, and—in many cases—you can't discuss what you're doing back to NASA. If I were to do work for a contractor, I would do my best and hand them the work, and it would be up to them whether they actually told NASA about any of that. Of course we have to give NASA a general status that we were doing good stuff. But we weren't really giving briefings back to NASA about specifics of what we were working on. That's a very different way of working than in the past. I think it's very good because it's a way of NASA sharing our expertise with these companies who request it. Doing this collaboration work has in a way substituted for maybe not having the lunar lander program here at JSC and not working in the management of that.

In fact it's allowed me to be an engineer for the last three and a half years. I'd say if Altair had continued on, I'd be somewhere in the management. I was the deputy project manager at the end of Altair. If that had continued on probably would have continued up into the

upper management of that. With collaboration tasks I'm allowed to actually dive into the nuts-and-bolts engineering, and yes, I still do some high-level study work for them, but a lot of it is real hard-core engineering which I really really enjoy.

It's a much different way of doing business. The lander is not designed by NASA. We simply write requirements on its functionality and operations. The contractor builds and operates it, but they use NASA expertise along the way to help with that design. NASA is buying a lunar lander service. We're not actually buying the vehicle. We're buying the transportation service. Think of it as an elevator that goes from lunar orbit down to the surface and back. You're buying an elevator ride. Of course it has to comply with all of our safety requirements. But it's the new way that NASA is doing business.

This started with commercial cargo to ISS [International Space Station], Commercial Crew to ISS, Commercial Lunar Payload Services, where we're buying services to land small science payloads on the Moon. The new EVA suit contract, the contract we'll have soon for a lunar rover. This is the new way of NASA doing business. Rather than NASA doing the design work, we're in a transition where we offer our expertise and we have the high-level architecture. We write the high-level requirements, but then we let the expertise of the contractor community, which has been rising rapidly over the years, and let them use their creativity and their expertise to actually execute the hardware program. I think that's the NASA model that we'll see for the foreseeable future. The old government-owned model where NASA did everything is the old NASA way of doing business, and the purchasing services from commercial vendors is the new way of doing business.

That's not a bad thing. The economics work out very well. I won't say we're saving a ton of money. Let's just say that economically I think we get a very good value for this because we're cost sharing with the commercial vendors.

That's where I am. I'll be in a meeting later today about that very thing.

ROSS-NAZZAL: Do you spend time out in California [at SpaceX] or maybe on the floor? I don't know how much you can talk about what you do because I know a lot of that is proprietary.

CONNOLLY: Yes. Part of that is working out in Hawthorne and working down in Boca Chica where they're actually building the vehicles. Earlier this year I was able to actually watch the first launch in person of their Starship/Super Heavy rocket, the largest rocket ever launched by humans. It was quite a sight. It wasn't 100 percent successful, but it was a first flight and they're gearing up for their next test flight sometime soon. One of the good things about being embedded in a team like that is you get to participate and see a lot of that stuff going on. It's a very fast-paced team with some very good people.

The contractors I've been working with do business different than NASA, but not worse. It's just different. There are other ways to do systems engineering and to do design work and to do testing, and they're no better or worse than what NASA has done in the past, they're just different. I think what we're seeing is the contractor community in some ways eclipsing where NASA has been for most of its existence and moving out ahead of us. I don't think that's a bad thing. I think we'll be able to do lots more with the resources that we have if you have a very educated and capable contractor community.

ROSS-NAZZAL: Can you explain what you mean in terms of doing systems engineering differently? How does that work?

CONNOLLY: No, I can't really get into details of that; that's part of the IP thing.

ROSS-NAZZAL: No problem. You did some work on the Google Lunar XPRIZE. We didn't talk about that. I wondered what your role was in that and how you got involved.

CONNOLLY: I'm friends with a gentleman named Peter [H.] Diamandis. He is actually one of the founders of International Space University, and Peter is the head of the XPRIZE Foundation. I got a call from him one day saying, "John, could you be in California tomorrow? We're having a meeting of some folks; we want to put another prize together. I can't tell you who the sponsoring organization is, but it's all aimed at landing on the Moon and that's kind of your thing, so can you get out here?"

I flew out to California. I met with him and a bunch of other prominent folks and the Google folks were there as well, and we were told that they wanted to sponsor an XPRIZE that would basically jump-start small commercial lunar landers. In one day we all sat down together, we wrote the requirements of the Google Lunar XPRIZE. That took about one day. After that it was announced and there were teams from all around the world who registered for it and started designing lunar vehicles, and in some cases started building small lunar landers. I was pleased to be part of that from the very beginning. Ultimately the Google Lunar XPRIZE was never awarded because the timeframe for the prize money ran out before anybody had a chance to launch. But what it did was it created in many ways the subset of small lunar lander companies

we have today who are building landers to go to the Moon for different countries, who are building landers for NASA for our CLPS [Commercial Lunar Payload Services] Program. I think it started a cottage industry of small lunar lander contractors. It did have some legacy.

ROSS-NAZZAL: Just going back to the lunar lander preplanning phase, you had said something in your resume that I thought was interesting, that you based it off of a JPL model for creating a lunar module. I wondered if you would compare that to a JSC model. I wasn't sure what that was referring to.

CONNOLLY: JPL has a few unique organizations where they can quickly cycle through new designs and new concepts. The most popular of these organizations is called Team X. Team X is a conceptual design organization. It's a concurrent design team basically. They're able to get experts together in one place and quickly cycle through design work. It's a pretty standard tool now where people use concurrent design teams. At the time though that was new and different. We kind of used the JPL model of concurrent designs and Team X as a way to quickly cycle through some of the early designs of the lunar lander. Yes, I'd been working with JPL on robotic Mars landers in the late '90s, and so I'd seen how they did this. I was in a number of the Team X sessions. I kind of took some notes on how quickly they could cycle through design work. That's what we incorporated into some of the early work that we did with Altair.

ROSS-NAZZAL: Looking back over your career what do you think was the greatest challenge that you faced?

CONNOLLY: The greatest challenge. Careerwise I've been blessed with so many opportunities that have come my way. Just wearing a NASA badge affords you so many opportunities that normal folks can't even dream of.

The biggest challenges have actually been with executing programs, and those are challenges that are a little bit out of our control, because it has to do with the cyclical nature of politics. One of the biggest challenges is when you start something like the Space Exploration Initiative or Constellation Program and then you get an administration change that has different priorities and the program gets shut down. It becomes a challenge to sustain the enthusiasm and the desire to keep doing that.

As I approach the end of my NASA career, my biggest challenge has actually been time. When I was a nine-year-old I was one of the kids of Apollo era who watched the Apollo missions on TV, and I fretted that I was too young to be part of that Apollo work. When I arrived at NASA in my twenties, I thought I had hit the jackpot. The Moon was back in focus and on to Mars. But now after almost 37 years with NASA, returning to the Moon is still some number of years in the future and now beyond my career.

So I've ended up being in this sandwich generation between Apollo and the next era of exploration. I didn't see that coming when I started at NASA. I thought we'd be back on the Moon in a couple years and then on to Mars, and that would be the highlight of my career. It turns out that myself and many others are part of the generation that bridge between Apollo and the next exploration programs.

I'd say time running out ended up being the biggest challenge. I don't have any regrets about that. There's nothing you can really do about time. But with 14-year roller coasters between the peaks of exploration programs, you only get so many of those as part of one's career

and one's life. So I'm a little disappointed about how things have worked out timewise, but I realize I can't do anything about that. Time is a damn thing.

But as I said at the start, I've enjoyed every minute I've worked at NASA. I got to do things that are crazy amazing. I've met so many astronauts. I started at NASA by receiving an award the first or second year I was there from Alan [B.] Shepard. I've met Neil [A.] Armstrong and Buzz Aldrin and most of the guys who walked on the Moon. I've worked in the Astronaut Office with the [Mark E. and Scott J.] Kelly twins and Doc [Scott J.] Horowitz and John [M.] Grunsfeld and others. I've become friends with folks like Fred Haise and more recent astronauts like Jessica [U.] Meir and Don [Donald R.] Pettit. Like many NASA folks, I've applied to be an astronaut, which is why many people come to NASA by the way. It's only an old hockey injury that really kept me away from advancing further on that.

I've had amazing opportunities and working at NASA is pretty special. I've flown the KC-135 many times. I have hours of zero G [gravity]. I've held Moon rocks in my hand in the Moon rock lab. I've actually toured the world with Mars and Moon rocks. I've represented NASA all round the world and had amazing opportunities to travel. What I got from NASA was this amazing career, this opportunity to work with folks who are some of the smartest folks on the planet, a chance to be part of the next step of human evolution that will eventually happen, even if it won't happen during my career. I even found my wife at NASA. It's been an extraordinary place to work, an extraordinary part of my life.

ROSS-NAZZAL: If you had to point to one thing, what do you think was your greatest accomplishment?

CONNOLLY: This may sound a little weird. I'll try to find the right word for it. Continuity. Because exploration programs go on this roller coaster cycle, having continuity and corporate memory between those peaks is important. Those aren't always the most fun times to work, but it's important to have folks who span the peaks of exploration. I've spanned a couple of those, and I've been the guy who's kept the exploration archives. A small group of us were the folks who were told during the dark days after SEI to keep the flame alive. We did so, happily. I think maybe my greatest contribution was to keep exploration present and to keep that continuity of work going on even when exploration was an unacceptable term at NASA. There was actually one year where if you look at the NASA Strategic Plan, they edited out the word "exploration" from a NASA Strategic Plan because it was politically unpopular at that time. It's almost unthinkable, how could you even talk about what NASA does without saying the word exploration? Yet they did. Some of us had to keep that exploration flame alive, and hopefully that has helped us get to where we are today.

ROSS-NAZZAL: What year was that, do you recall?

CONNOLLY: That was at the end of SEI so that would have been 1993 thru 1996. It was between the end of SEI and the publication of the life on Mars paper by [David S.] McKay which then reinvigorated the interest in exploration.

ROSS-NAZZAL: I wonder if you have any other thoughts that you wanted to share. I think we touched on all parts of your career but wasn't sure if there was anything else you wanted to add.

CONNOLLY: No, I think that whole discussion we had about how my career has been bookended by Apollo on one end as a kid and what's going to happen in the future of human exploration was kind of my parting comment—and about how amazing it's been and what it's given me back over the years. If there's anything else I'll call you up.

Maybe the last thing I'll say is about how circles sometimes close and how satisfying that is. As I said, I was a kid growing up in the Apollo era. I loved everything about space exploration. My family heaped space toys and model rockets on me. My enthusiasm has been Moon-high for 50 years. But as a kid watching Apollo 11 from a coal town in Pennsylvania, and some decades later actually getting to work with Neil and Buzz and Mike [Michael Collins] and actually knowing those guys personally after what they meant to you back in the late '60s, early '70s, the way those worlds have kind of come together is very very satisfying.

ROSS-NAZZAL: I imagine.

CONNOLLY: I'm very blessed with some of the things that have happened to me as part of wearing a NASA badge.

ROSS-NAZZAL: It's a great place to work, that's for sure. I will let you go.

CONNOLLY: All right. Thanks, Jennifer, it's been a pleasure.

ROSS-NAZZAL: Thank you very much, have a great weekend.

CONNOLLY: Okay, you too.

ROSS-NAZZAL: All right, bye-bye.

CONNOLLY: Bye.

[End of interview]