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EDITED ORAL HISTORY TRANSCRIPT

INTERVIEWEE JOHN CONNOLLY
INTERVIEWED BY JENNIFER ROSS-NAZZAL
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ROSS-NAZZAL: Today is September 13, 2023. This interview with John Connolly is being conducted on Microsoft Teams in Houston, Texas, and Brenham, Texas, for the NASA Oral History Project. The interviewer is Jennifer Ross-Nazal. Thanks again for joining me this morning, I appreciate it, hope you're enjoying some cooler weather up where you are.

CONNOLLY: A little bit, thank you, Jennifer.

ROSS-NAZZAL: I wondered if you would talk about your interest in science, engineering, and math as a child.

CONNOLLY: That's really where it started for most of us who ended up at NASA. I was fortunate to have been born a child of the Apollo era. I was nine years old in 1969 when Neil [A. Armstrong] and Buzz [Aldrin] walked on the Moon, and that was the biggest thing ever to happen. As a nine-year-old who loved math and science and engineering and all those kinds of things, I was glued to the television watching the Apollo missions. I even remember all the way back to watching the Gemini missions. That was the first thing that really spurred me on towards wanting a career in math, science, and engineering.

The other thing was model rockets. I had cousins who were a little older than me who flew model rockets, and that was just the coolest toy ever. Back in the '60s, our parents encouraged us to play with toys where fire shot out one end and they leapt into the air at 200 miles an hour. That was perfectly acceptable and probably the greatest toy ever, and I still fly model rockets to this date. I attribute all of those things, growing up in the Apollo era, all of the space toys, and science-y toys like model rockets that were available then to really push me towards wanting to be an engineer. I'm still fascinated by all that stuff. I'm still fascinated by the Apollo missions, still fly model rockets. Now I'm departing NASA and heading out to Texas A&M [University, College Station] to continue teaching the next generation and hopefully stoking their fire, so they'll find the same interest and passion.

ROSS-NAZZAL: So you knew from a young age you wanted to be an engineer, was that your thought?

CONNOLLY: Yes! So beside all of the Apollo stuff that was going on at the time, I loved building things, I loved fixing things, and I loved taking things apart. Those are what the *Dilbert* folks would call having "the knack," so I guess I had the knack back then. I could take just about anything apart, make it better, and put it back together. If anything had to be fixed, I could fix it, and even today I love fixing stuff. I dislike hiring people to fix things for me, so I still have that engineering mentality where I love to know how things work. I love to pull them apart and see all the innards and then put them back together and see if I can get them working again or working better.

ROSS-NAZZAL: Were you following the Space Shuttle Program as it was being designed and developed at NASA? Did it hold the same interest for you?

CONNOLLY: Timewise, the Apollo program ended in 1972 when I was about 12 years old. Skylab was just a blip after that, and then the Shuttle Program started up in 1981. I was already in college by that point studying engineering. I didn't necessarily have my focus on NASA at that time. I liked mechanical engineering and mechanical systems most back then. In college, when the Shuttle Program started, sure everybody was watching it, and I had a giant poster of the Space Shuttle launching, one of the early launches, as a college student. Other people had posters of rock bands or whatever; I had a poster of the Shuttle. It caught my interest, but it wasn't exactly the same, say, as the Apollo missions. I understood that the Shuttle was a low Earth orbit vehicle and that it eventually would be tied to building Space Stations. Low Earth orbit held some fascination to me, but my sights were really set beyond that. I wanted to be part of getting people back to the Moon, and I wanted to be part of getting people to Mars, and so as I entered NASA in the 1980s that was really my focus.

Time is a funny thing. When I was a kid, I thought to myself, "Oh my gosh, I'm too young to be part of this Apollo program; it's all going to be over by the time I'm able to participate in it." I've now gone through my NASA career doing everything I can to try to get humans again beyond the low Earth orbit and back to the Moon on to Mars. Now, I'm ending my career, and I'm starting to think the opposite like, "Oh, my gosh, all this cool stuff is going to happen probably in the next 10 years and that'll be beyond my NASA career." I've had the fortune, I guess, of having my NASA career placed squarely in between the Apollo era and the Artemis era. Of course, I'm pleased to have done all the things that I did with NASA to try to connect those two, but I'm a little disappointed that we're not already back on the Moon and on our way to Mars.

ROSS-NAZZAL: I saw that you graduated in '82, so were you hoping to work for NASA? I didn't see you become a civil servant until about '88.

CONNOLLY: Yes. I graduated in '82 from Penn State [University Park] with an engineering degree, and I came straight down here to Houston and started working for a small engineering company that had some NASA contracts and did some cutting-edge engineering. Their first NASA project I was aware of was a study to re-man-rate Chamber A, which is a huge undertaking and which most engineering companies wouldn't want to touch because man-rating a vacuum chamber just screams of liability. The company I working for, at the time, loved taking on unique and hard engineering challenges. I had very excellent five years with them, and I got to know a lot of the NASA people in the process.

In '87, I interviewed with NASA because some positions came open, and they invited me to come on as a civil servant. That meant actually taking a pay cut, but it was probably the best thing I ever did career-wise. So in '87, I started at NASA and the whole exploration thing was just starting to bubble up again. There were some studies going on in JSC's Engineering Directorate and some by contractors looking at going back to the Moon, building lunar bases, things like that. That's when I got involved in exploration, and that was really my target for coming to NASA because I wanted to fulfill that childhood goal of getting us back to the Moon and on to Mars and beyond. Timewise, the Space Exploration Initiative [SEI] was announced in July of 1989, and I was asked to come out on to that project and participate in what was known as the 90-Day Study.

ROSS-NAZZAL: Would you talk about that study, and what were you looking at?

CONNOLLY: Sure. The 90-Day Study was initiated by then President George H. W. Bush, at a speech in front of the [Smithsonian] National Air and Space Museum [Washington, DC] in 1989 where he put forth this plan for NASA to return to the Moon, "this time to stay" and then to push onwards to Mars. That resonated with me and with a lot of people in NASA because that really got us back to our exploration roots that were cut off in 1972 when we last landed on the Moon. It also seemed like the natural extension of the Apollo Program. They gathered a bunch of us together in late 1989, and we did a Skunk Works kind of team, offsite near the Johnson Space Center, and we assembled something called the 90-Day Study.

The 90-Day Study was an end-to-end plan of how you could get back to the Moon and on to Mars, what pieces of hardware you'll need, what the mission sequence would look like, and ultimately what the budget would need to be for that. The budget part was never really published, but that was always an important thing for NASA management planning. The 90-Day Study was an interesting collection of people from NASA, from the Army Corps of Engineers, the U.S. Bureau of Mines, the Department of Energy, and the Department of Defense as well. It was really putting the entire technical, government workforce together to come up with this answer for how we would go back to the Moon and Mars.

Somewhat unsurprisingly, it ended up being a big, grandiose plan because we weren't given any specific budget guidelines. We were just told to put together a plan that got us to a permanent human presence on the Moon and then got us to Mars. There were new ideas like mining the Moon for resources that had not really been talked about before, so there was all types of big equipment that we are going to send there. There were big, new rockets that had to be built, there were lots and lots of other pieces of space hardware, space transportation, surface systems - all the pieces you would need to do a mission of that scale.

So the 90-Day Study was published, and technically, I think it was pretty sound. But then the budget was leaked, and the only number that people heard was $500 billion. That $500 billion was, by the way, a 25-year, or maybe longer, budget run-out for the entire program, so it's something on the order of the current NASA yearly budget for the next 25 years. When that number got out, the pure magnitude of it was almost a death knell to the program.

I think the Space Exploration Initiative also suffered from lack of political support. It was well conceived within the administration at the time, but I don't think it was socialized out to Congress very well. Because of that and especially when the big budget number leaked, whether it was right or wrong, that signaled an early death to the Space Exploration Initiative.

We worked on the SEI through 1990 and 1991, and by 1992, the Space Exploration Initiative was essentially nonexistent anymore. It was really reduced to a small number of people who were still working exploration studies. At that point, I was fortunate to be one of those people who was asked to keep the exploration flame alive. Generally, there's always been, a group of people in NASA who, regardless of what is going on politically or elsewhere in the world, always have their eyes to the future. That's pretty much been my career at NASA, always looking to the future and having that plan ready to go when all the tumblers fall in place. It turned out in 1989 through 1992 that it wasn't time. At the time, NASA was debating the Space Station, and so the Space Station really received the majority of funding; it received the "go" whereas the return to the Moon program did not. That was the Space Exploration Initiative.

My particular job was working lunar and Mars surface systems. I have an interest in lunar landers and an interest in all of the things that it takes once you land on the Moon or Mars to set up a permanent base or to conduct a mission. I was the planet surface systems guy back during the Space Exploration Initiative, so if you read the 90-Day Study and you go to planetary surface stuff, that's the stuff that my small team put together. That became the place I was most associated with as my career went along. It was lunar landers, lunar surface systems, and general space mission design.

Space mission design is all about how all those pieces come together. You have to know something about the rockets, how you get from point A to point B in space, how you land, what are the systems required once you land, how do you operate them, how all those pieces come together. It's a branch of systems engineering, a specialized branch that I would call "space mission design." I liked space mission design and knowing how all the pieces fit together, because that's a very engineering thing. I especially liked lunar landers and the lunar surface systems.

ROSS-NAZZAL: What lessons learned did you take away from that 90-Day Study because looking over your CV [curriculum vita], this was something that you were working on quite a bit over the course of your career. Was there anything that you took away from it, maybe budget for instance or making sure you've got policymakers on your side?

CONNOLLY: Yes, so there were a number of lessons learned from the 90-Day Study, and interestingly, I just wrote a chapter of a book for the AIAA [American Institute of Aeronautics and Astronautics] that goes through how the Apollo Program was managed, how the Space Exploration Initiative was managed, how the Constellation Program was managed, and what we learned from those and what went wrong, especially in the SEI and in Constellation. I have to point you to that book where I've actually gone into this in some depth, but generally, the Space Exploration Initiative lessons learned were that you probably do need to start with the budget cap. You can't just start with an idea that we want to do everything in space and, "Hey, let's see how much that costs and see if we can get the money for it." It's good to put some kind of constraints on it, and the constraints are usually time or money.

Back in the Apollo days, the constraint was time; we had to get it done by the end of the 1960s. In modern NASA, everything is constrained by budget, and schedule can be stretched out if needed. We weren't really given any constraints; we were just given a big picture that we are shooting for. I wasn't personally working the politics at the time, but it became clear as we went on that we didn't check off all of the boxes politically. We put out this study, and it seemed to come as a surprise to the people who write the checks, and that's never a good thing. You want to make sure you include the policymakers in the process. They're probably not good rocket designers, but they know they're part of that equation very well. Unless you get the politics and the money and the technical stuff all correct, again, you don't really have a chance of flying.

That's systems engineering on the very highest level, it includes all those things that engineers typically hate thinking about. Engineers like having a good, tight engineering system or a good, tight mission design. Where the money comes from or whether you've checked off how many political organizations are happy with this and would support it, engineers care less about that than they do about the engineering. But in reality, you have to engineer a system that takes all that into account. I think it was that the highest level of systems engineering that we didn't do a good job of with the SEI.

ROSS-NAZZAL: I was looking over your CV, and you were working on Human Exploration and Development of Space, which I thought was interesting. I wondered if you would talk about what its purpose was and what some of the goals were of that effort.

CONNOLLY: Human Exploration and Development of space, HEDS, was one of the many acronyms that the Human Exploration Program at NASA Headquarters [Washington, DC] had over the years. I don't recall the dates exactly for that; you can look that up. Starting with the Space Exploration Initiative, there was the Office of Exploration that was created at NASA Headquarters, and Mike [Michael D.] Griffin at the time was the associate administrator. When that went away, that might've been about when we transitioned to HEDS, and there was a strange period in there in about the early 1990s, maybe '93 through '97 where the word exploration actually became an unacceptable term in NASA. Because exploration was about human exploration, it was associated with very high-dollar programs, and it wasn't well received politically.

There was actually one NASA strategic plan where the word exploration was scrubbed from the strategic plan entirely. That word did not appear, and it's hard to believe that would happen, but that showed you how they wanted to change the emphasis away from these perceived high-dollar human exploration plans towards the International Space Station, which was in its early beginnings at that time.

We had the Office of Exploration, we had the HEDS Office, there's other iterations of what that office was called up until today. Luckily, we've been fortunate that there's generally always been an "Exploration" Office at NASA Headquarters with the people who are thinking beyond low Earth orbit] It's generally separate from the programs that are currently ongoing like a Station or a Shuttle at the time, and it's the folks who are looking at the next step. I've been generally associated with those offices throughout my NASA career.

There was one other thing that happened during the Space Exploration Initiative. Many of us who work at NASA have a lot of events in our lives to thank NASA for. In 1990, I was asked to jury some research work that was being done at the University of Wisconsin [Madison]. They received a small grant from NASA to do some space architecture work, which was a new thing back then, and we were introducing architects into the space world because architects are very good systems thinkers. They know how to put lots of pieces together, and they're very aware of the human in the middle of that system. I went up to the University of Wisconsin and took a look at their work, which was very good, and I got to know one of the teaching associates, a woman named Jan Huebner. Eventually, she came to work for NASA as a graduate intern and then a NASA employee, and then she became my wife, so some of us owe even more to NASA than just a career.

ROSS-NAZZAL: That is great. I've heard a lot of stories from people about having met their spouse at NASA, so that's wonderful. Did she continue working on space architecture when she came down here?

CONNOLLY: She did. Jan has a couple of degrees in space architecture and a human factors degree as well, so she ended up working in the space human factors division at the at Johnson Space Center as a space architect. Yes, she has things that she's designed that are flying on the Space Station today, so she's had a very wonderful career, and she's very, very happy with that.

ROSS-NAZZAL: That's wonderful. I was particularly surprised when I was looking at your CV because you were doing a lot of robotics work initially on Mars missions, not necessarily related, in my thinking, to work that someone would do at Johnson Space Center. I wondered if you would talk about being the JSC representative working on these missions and how you got selected, why, and what you learned from those jobs.

CONNOLLY: BY the early '90s, the Space Exploration Initiative had come to an end, and there was a low peak for a number of years where a small group of us were set aside by the Center Director, George [W.S.] Abbey at the time, and told to run silent, run deep, but keep the exploration flame alive. While exploration became kind of a dirty word in some parts of NASA, we kept working on better optimized designs to come up with new and better ways to get people back to the Moon and on to Mars. That went from '93-ish until about '97, and then about 1997, is when Dave [David S.] McKay and a number of his colleagues published their paper about finding potential life on Mars. You may have remembered that. That came out of the ARES group at Johnson Space Center, and all of a sudden, possible life on Mars elevated exploration back on to the front burner.

So starting in about 1997, Doug [Douglas R.] Cooke also came back as the head of the Exploration Office at JSC. He wanted a joint working group with the Jet Propulsion Laboratory [Pasadena, California] where we can get the human exploration folks and the robotic exploration folks to work together. This was called the HRET, Human-Robotic Exploration Team. Starting in 1997 and going for about five years, we had regular interface meetings with the Jet Propulsion Lab folks to trade mission design information and other information about Mars missions and human exploration, so there's a lot of good cross-pollination there between the robotic community and the human spaceflight community.

As part of that, I was asked to spend some time at the Jet Propulsion Laboratory advocating for human exploration payloads that could be placed on Mars robotic missions. That had not really been a part of Mars robotic missions in the past, so our first chance was a 1997 or 1999 mission, which was part of the JPL sequence of every 26 months landing a mission on Mars. We were going to put some simple radiation sensors on the vehicle to measure what the radiation level was at the Martian surface to see how damaging that could be to humans. I became the human exploration guy within the JPL Mars Exploration team. Incidentally, JPL uses the term "Mars Exploration Program" to mean just the robotic programs.

Bringing human exploration into the robotic Mars program was a little bit of a strained relationship because every kilogram you send to Mars is precious, and the scientific community was very protective of wanting to do as much non-human-exploration-related science as they could on every mission. They saw even a small radiation detector as perhaps taking away a little bit from that mission's science capabilities. I had to do the best I could to explain how there's a relationship between the two, and a radiation detector for humans also produces all kind of good data that that is scientific data as well. A lot of times we found that the scientific community and the human exploration community were talking about the same thing but using different terms. The human exploration community might want to know what the angle of repose of soil is on the Moon or Mars because when you push it into a pile, that's the angle you get. The scientific community wanted to know what the internal friction angle was of soil on the planets. It turns out those two are the same thing, we just use different words to describe them. My job was to speak science and engineering together and bring those communities together, and that actually helped me later on my NASA career because I do speak science pretty well as well as representing the human exploration folks.

In the end we were able to put on human exploration radiation detector on what became the Mars Odyssey spacecraft that was launched in 2001. We were also able to put a surface radiation detector on the Mars Phoenix Lander, which was launched a few years after that. The idea was to keep notching that up to an ISRU experiment, in-situ resource utilization. ISRU is all about how to use the materials you find where you land to help bootstrap your existence there; how to live off the land, if you will. So we had initially advocated for a small ISRU experiment where we would take the Mars atmosphere and crack the oxygen out of the carbon dioxide atmosphere and use the oxygen for other purposes.

It turns out we finally were able to fly an ISRU experiment to Mars. There is an experiment operating on Mars right now, MOXIE [Mars Oxygen In-Situ Resource Utilization], but that's taken from about the year 2000 till now. That's over 20 years to get that experiment manifested and on to Mars. So we did make small progress towards bringing the human exploration and the robotic exploration programs together, and I did get to spend quite a bit of time out of JPL and make some great friends out there.

But ultimately, the robotic program really responds mostly to science. The Decadal Survey that is done every 10 years defines what science NASA should be working on and very explicitly delineates the scientific priorities for Mars robotic missions—it does not include any human exploration content; it is pure science. The Decadal Study is the bible that the Science Mission Directorate folks use to formulate their missions. So we were coming in kind of a little bit orthogonal to the Decadal Study with our requirements and that caused a little uneasiness between the human exploration community and the robotic community, and we were able to resolve that in small part over time.

ROSS-NAZZAL: How did you come up with ideas for experiments? Were you working with people in Space and Life Sciences or working with university partners?

CONNOLLY: Yes, when I went out to JPL, we had had a number of studies we had done since the late '80s on what precursor measurements need to be done both on the Moon and Mars to get ready for human exploration. We had a pretty well documented catalog of the unknown properties of the soil or of the atmosphere or the radiation environment or the resources that were available. We had a list of all these unknowns, and we were able to introduce that to the science community as part of a working group called MEPAG, the Mars Exploration Program Analysis Group.

The MEPAG folks had a document where they would take the Decadal Study priorities and line it out in a way that connected science themes to specific measurements and experimental payloads. These were mostly the ones that pertained to geology, and to find out if there was water and life. MEPAG created a whole section for human exploration "precursors" that became the measurements and technology demonstrations you need to do to get ready to send people there. The MEPAG document is the document that drives the Mars robotic program, and human exploration content has now been part of it for two and a half decades. We were able to take our robotic precursor needs that the human exploration community had been working on separately and add them in this document, and they appear in more or less priority order. These are the measurements we want to make of the environment so that we could safely send people to Mars or know how to design systems that can work in those environments.

ROSS-NAZZAL: You mentioned that the scientists weren't always thrilled—they wanted their scientific experiments on board. Were you able to get policymakers on board to say that we need this, say Dan [Daniel S.] Goldin who was pushing for faster, better, cheaper missions? Or were there some other people who were recognizing that we would need this information and it was best to get it sooner than later?

CONNOLLY: There's an interesting dichotomy at NASA; there is the science community and there's the human exploration community. The Science Directorate owns Mars robotic missions; human exploration at NASA, of course, owns all the human missions. If you want to put some human exploration payload on a science mission, you have to cross directorates, and the directorates at NASA—and this had changed a little bit over time—they operate, more or less, autonomously of each other. And, yes, you do have the NASA administrator who can give them direction, but generally when we get our budget from Congress, there is a line item for science missions and there's a line item for human exploration missions. There's generally no money in the Science Mission Directorate for human exploration stuff, so money has to cross from one to the other. Just by virtue of the fact of how NASA is organized and how we get our budget from Congress and the kind of direction we get from Congress that comes with those budgets, it's not always easy to cross over from one program to another.

There are ways to do it, but there's also ways to use that as a way to keep people from crossing over. So, yes, in the early days of trying to do this, the question that would always come up, "If you want to fly that kind of instrument on a Mars mission, where's the money to do it?" We need you to build the instrument, and we need you to pay the Mars program so many millions of dollars to accommodate it on their missions, and that became the term that people learned to hate, accommodations cost. Because it was as though you were taking an unwanted payload and yes, okay, we'll accommodate you at a cost, but you're not really welcome here. Luckily, that's moderated over time, but in the early days that was the subject of a lot of discussions.

ROSS-NAZZAL: I can imagine that is challenging. One of the things that was interesting is you were on the Mars program systems engineering team, trying to figure out how we were going to bring samples back and mitigating that risk. Again, being a human spaceflight expert, that was something that really stood out to me. Would you explain why that was important and why you were included?

CONNOLLY: Sure, so the Mars program systems engineering team was formed of engineers who were very clear thinkers and who could see the "big picture." It included some notable folks like Gentry Lee at the Jet Propulsion Laboratory and Charles [W.] Wetsel and a few other folks, and I was human exploration representative on that team. The team basically worked systems engineering issues that affected the robotic Mars exploration programs, so I was very, very happy to help out with that.

One of the topics that came up was—and this is still a current topic—is Mars sample return. Mars sample return has always been the Holy Grail of the Mars robotic science community—getting a pristine sample of Mars back into the laboratories here on Earth where we can use the best instrumentation available to find out what Mars is really all about and maybe find if the conditions for life ever actually existed.

I listened for a while as the JPL folks had been talking about this Mars sample-return mission that involved multiple launches, multiple spacecrafts, and multiple handoffs of the sample as you went from the surface of Mars back to Earth. I did a little research on it, and I found mission designs for Mars sample return that went back to the ’60s—mainly done by the JPL folks, but by other NASA folks as well—that involved multiple launches, multiple spacecrafts, and multiple handoffs of the sample between the surface of Mars and Earth. Being a good systems engineer, I started thinking, “why are we only looking at this one way of doing Mars sample return?” Surely, there must be others. Being good systems engineer, I first drew up what we call a trade tree. It’s a branching tree that shows the first big mission design decisions as a branching tree, and then for every other decision you make after that, you get more and more branches, and you eventually get the spreading tree effect. I did a thought study of what are the primary decisions you have to make for a Mars sample-return study—the ones that most affect the cost and risk. Risk is probability of mission success, the success of getting a Mars sample back.

I came up with seven questions: one had to do with the number of launch vehicles it took to launch the mission, the number of independent spacecraft you had to build because both of those are very costly and introduce risk if there’s more than one. The other questions included the number of sample handoffs, how you acquired the samples on the surface, things like this. I dug into the history of Mars sample return, and I basically found out that for the last 30-plus years, the Mars sample-return community had been looking at one specific branch of this trade tree over and over and over again, and there were dozens of other branches unexplored. I figured it was my duty as a member of this systems engineering group to show other options.

I did a little mission design work on a few other options. I took every decision that had been made in this one path on the trade tree that had been explored over and over again, and I randomly made the opposite choice at each intersection just to see what it would look like. The mission design came out to be a really, really good Mars sample-return mission. I did a little more design work on that, did some cost estimating, did some risk analysis on it, and it turned out, it had only a fraction of the risk of the mission that had been looked at many times. It was a little different scientifically. It didn't have rovers going and grabbing samples and putting them in pristine tubes; it was more of a simple grab-and-go sample-return mission, just robotic arms that scoop up some rocks and soil and put them in a capsule and return them home, a very simple sequence of return that uses very highly efficient spacecraft and electric propulsion.

I introduced that to the systems engineering group, and it wasn't well received because it did not match the well-worn paradigm of how a Mars sample-return mission should be conducted. I ended up writing a paper about this just to document it, and I've had requests, over the years, from different JPL folks to send them that paper and to brief them on these other ideas I've had. It turns out that JPL is in the process of a planning a Mars sample-return mission right now that involves multiple launches, multiple spacecrafts, and multiple handoffs of the sample on its way from the surface of Mars to Earth. They're basically following the same path that they had looked at for the past 50 years, which is very costly and high risk. I like to think that at least I contributed to maybe opening the minds of some of those folks, but I did not succeed in changing how a Mars sample-return mission was done.

ROSS-NAZZAL: That's very interesting that they're still continuing down that path 50 years later. One of the other things that I saw was you were part of the Mars Exploration Program Project Analysis group, and you said that you authored a section in one of their reports.

CONNOLLY: Yes, the MEPAG document is actually online, and maintained by JPL. You could find the MEPAG document just by Googling MEPAG and JPL or MEPAG document.

ROSS-NAZZAL: Okay.

CONNOLLY: I'll talk about that for a for little bit because I introduced that a little earlier. The Mars Exploration Program Analysis Group is primarily a group of scientists that get together to advocate what the next mission to Mars should be, to help the JPL folks programmatically put together what are the requirements for the next Mars mission or missions. Again, I was part of that as representing human exploration. If you look at the MEPAG document online, you'll see that it very nicely goes through the scientific priorities of the most recent Decadal Study, and sometimes it involves some shuffling by the MEPAG group on things that they think are the highest priority because they are the current scientific leaders generally in the Mars community, and then it includes a section on human exploration, payloads, and measurements as well. I was the person who initially authored that that human exploration section of the MEPAG document and very happy to see that others who have followed me have kept it going. It still exists as part of the MEPAG document and that the Mars scientific community recognizes that having Mars robotic missions serve as a precursor to human exploration that it is not only a viable thing to do but is an important part of linking the Mars robotic program to the human exploration program.

There are unfortunately scientists who think when we conduct the very first human mission to Mars, that the Mars robotic program will evaporate and go away, and their livelihoods will evaporate at the same time. I don't think anything could be further from the truth. We know that robots are very good at doing some things that humans can't; we can send them the places we would never send humans. For example, we're sending a rover into a permanently shadowed region of the Moon. We would never send a human down into a permanently shadowed crater, so the VIPER [Volatiles Investigating Polar Exploration] rover that is currently being constructed at JSC [Johnson Space Center, Houston] is an integral part of exploring the Moon. It's integrally linked to the things we want to know about the Moon and lunar resources, but that we would not combine with the human missions.

I think that the folks who think that a human mission to Mars will be the end of the Mars robotic program aren't thinking broadly enough about it. I think you do need to have the big systems view of things to see how robotic missions and human missions work together. I think that the first human mission to Mars will be a treasure trove of science far in excess of the sum of all science done by robotic missions to date. I think that's what we found out with Apollo. We sent the Rangers and the Surveyors, and they found out some interesting things about the Moon. The first samples brought back by the Apollo astronauts, that was the motherload of science. We found out more from those samples than we had ever found out about the Moon before.

ROSS-NAZZAL: I wanted to shift gears to talk about the [Space Shuttle] *Columbia* accident [STS-107]. I wondered if you would talk about where you were when the Space Shuttle *Columbia* was lost.

CONNOLLY: THE *Columbia* accident was 2003. At that time I was detailed to the Astronaut Office, and I was working with Scott [J. "Doc"] Horowitz in his exploration group, and our group included John [M.] Grunsfeld, the Kelly twins [Mark E. and Scott J. Kelly], Marsha [S.] Ivins, Mike [Michael T.] Good, Stan [Stanley G.] Love, and a few others; it was really a great group of people to work with. Being part of the Astronaut Office is a special thing. I got to attend the Monday morning meetings with the astronauts. I was one of the few non-astronauts working in the office at the time. I got to fly sims and go to the Cape [Canaveral, Florida] with crews and do just about everything that folks in the Astronaut Office did except fly in space.

At that time, unfortunately, we had the *Columbia* accident. The response by NASA is interesting and maybe somewhat predictable. The accident happened on a Saturday morning, and by Saturday at noon, I would guess, most NASA people had made their way to work; they had responded by coming in to JSC. I think that very first day, I was put on a phone line for people who were calling in identifying pieces of debris that have fallen in their backyard or nearby or things they couldn't identify and so I was immediately wrapped up in the *Columbia* recovery in that way. It wasn't long after that that we had set up the field offices up in north Texas all the way across to the Louisiana border to actually organize and recover the pieces of *Columbia*.

I got assigned to one of those groups and spent a good amount of time up in parts of north Texas I have never thought I'd ever see with a group of Forest Service folks. We combed many, many thousands of acres along the flightpath that *Columbia* came down on, and everywhere we looked, we found pieces of the Shuttle. It was as though it had snowed pieces of the Shuttle all over that part of Texas. We'd come back at the end of the day with lots of tiles or pieces of metal or things we couldn't identify. That was a really unique experience. It was something we had to do. It's not part of the job you sign up for when you come for NASA, but it's a necessary part of the job when things happen. The whole idea back then was to bring *Columbia* home and find out why the Shuttle had disintegrated on entry.

So during the *Columbia* recovery, I got to know some of the finest people I've ever met. The Forest Service workers are just amazing. We see them fighting fires dressed in their yellow shirts, but you never get to know them. It turns out that almost all of them, to the person, are very well read. They always have books with them because that's really all there is to do when they're camping out in the forest, and they play cribbage. Reading books and playing cribbage and just talking with some of the most interesting people that I've been around was a part of that experience.

Ultimately, we were able to recover enough of *Columbia* to figure out what happened, and again since I was in the Astronaut Office, I got to go in the hangar where they were assembling all piece parts and parts of the crew cabin and kind of coming to grips with that what had happened. We found the MADS [Modular Auxiliary Data System] recorder eventually, which was like the black box of the of the Shuttle that *Columbia* had on board and the data that really supported what happened to the left wing as *Columbia* came apart. So, yes, the *Columbia* recovery was—again, not one of those things we sign up for, but it's one of those things you have to do, and I'm proud to be part of it.

I was called to testify to the *Columbia* Accident Investigation Board [CAIB], and this is an interesting connection back to that Mars sample-return discussion. In the Mars sample-return study that I had done as kind of an alternate to the way JPL was doing Mars sample return, I suggested bringing the Mars sample home by putting it in orbit around Earth and having the Shuttle go up and get it, put it in a big cask in the back of the Shuttle, and bring it home because at the time, the Shuttle entry was 100 percent successful. It was perfect on entry, so I figured that was the safest and most reliable way to bring it home, and that's what we were trying to do, we were trying to maximize mission success.

So we built a whole simulation to do that, and I wrote a paper about bringing Mars samples home in the Shuttle, and the CAIB got hold of the paper because they saw that I had put reliability numbers to the Shuttle coming back to Earth. I had to estimate what the probability of a safe entry of a Shuttle coming back to Earth was, and it's never perfect, it's always less than one. But through some analysis that that we did, I estimated that the most probable means of failure of a Shuttle during entry would be aerodynamic breakup due to failure of some part of the thermal protection system. That turns out to be what happened during *Columbia*, so they wanted to talk to me about that.

So after returning to the Astronaut Office, the CAIB report came out, and I was part of the team from CB [mail code for the Astronaut Office] that wrote the Astronaut Office response to the *Columbia* accident investigation report as well.

ROSS-NAZZAL: Can you talk about that, what sort of things were the astronauts supportive of, what were they critical of from the report?

CONNOLLY: It was a very detailed report. We tried to answer it item by item. For the most part, the Astronaut Office agreed with the vast majority of the comments made in the CAIB report.

ROSS-NAZZAL: How long were you out in East Texas working on the recovery of *Columbia*?

CONNOLLY: About a month. When I got there, I forgot exactly what week after the accident, but late February maybe; it was still cold out there. You get up near Dallas, and the nights get pretty cold and rainy, so we had to deal with the cold, the rain, and some of the biggest briars on some of the trees that you've ever seen. Wildlife, barbed wire, lots and lots and lots of barbed wire. The team setup was one NASA person, so that would be me, and either a supervisor from the Forest Service or somebody from the FBI [Federal Bureau of Investigation] with us as we identified things. You were joined by a team of 20 or 40 Forest Service people, and basically you were given a plot of the area that you had to cover in. There's a specific search technique you use where everybody takes a step forward, looks down, looks left, looks right, takes another step forward, and you did the same thing, and this line of people just goes through these fields.

One of the unique things that happened up there was the presence of the press. During the first couple weeks of the recovery, the press was very kind. They realized this was a big story, and it needed to be to be treated with respect. A week after that, they started knocking on NASA's door saying, "Hey, we like to see more into what you guys are doing in the recovery teams." And so some of the NASA PAO [Public Affairs Office] folks called me up, and they asked, "Could we could use your team as the team that escorts the press around and to show them what we're doing?" and I said, "Sure." A day or two later, they gave us a fairly easy part of that part of Texas and so we brought press along with us. Our team of 40 people started doing our job, and we had the press trailing behind us. For the first hour or so, they were very respectful and then they started wanting to look ahead to see if they could see something before we did, and by noon or so, I think we had said, "Okay, well, you guys have seen enough, you can go home now." But I had to be the NASA guy out in the field to talk these reporters, and so I ended up being quoted in the *New York Times* and a few other places.

ROSS-NAZZAL: You mentioned the cold weather, were you spending nights sleeping in tents or were you at a hotel?

CONNOLLY: I was one of the lucky ones. I had a hotel room, but all the Forest Service guys come with their own tents. In the early days of the recovery effort, you just set up a tent wherever you worked, and eventually they found sites that had old warehouses or something where you can set up your tent inside the warehouse, so at least you were protected from the elements. So I was one of the lucky ones, I had a bed and heat, and a few more creature comforts. As time went on with the *Columbia* recovery, the conditions got better; the food got better. The Forest Service is very good at deploying lots of people very quickly along with food services and showers and porta-potties. There's a great book by Michael [D.] Leinbach on the *Columbia* recovery that documents this pretty well [*Bringing Columbia Home: The Untold Story of a Lost Space Shuttle and Her Crew*].

ROSS-NAZZAL: Did you experience the outpouring of love for NASA that so many people talk about when they were up in that part of the country?

CONNOLLY: Absolutely, on my way from my cozy hotel to come to pick up our very early morning's assignments, I'd stop by the McDonald's that was right across from the hotel, and for anybody involved in the recovery, the McDonald's folks refused to take their money. So, yes, we got a lot of love.

ROSS-NAZZAL: I know that there was a lot of outpouring of people just really supporting NASA, the Shuttle Program. I was up there for the 20th anniversary earlier this year and went to the *Columbia* museum out in Hemphill, so they're still very supportive of NASA and its mission.

CONNOLLY: It was a big deal, it affected a lot of people's lives, I mean the folks who lived out there. They're just out living their lives, and literally out of the blue, a piece of the Space Shuttle falls in their backyard. That's a moment.

ROSS-NAZZAL: Yes, definitely life-changing for some folks.

CONNOLLY: Yes.

ROSS-NAZZAL: I did want to ask, you mentioned working in the Astronaut Office, which I also thought was unusual working with Doc Horowitz. You wrote that you were conducting safety analyses at the Orbital Space Plane and EELVs [Evolved Expendable Launch Vehicles], and so I wondered if you would talk about that, and how you came up with safety requirements for both of those vehicles.

CONNOLLY: At that time, there was not an official exploration program. There were scattered ideas on alternatives to the Space Shuttle. Doc Horowitz had one idea of using Space Shuttle Solid Rocket Boosters as the first stage and an upper stage on top of that with a simple capsule on top. People called this colloquially the "Scotty Rocket" because it was Scott's idea, but there were also the Orbital Space Plane, I think that concept came from the Marshall [Space Flight

Center, Huntsville, Alabama] folks. Many of these concepts had to be launched on some kind of launch vehicle.

One of my chores and some my other Astronaut Office colleagues were asked to dig into how you would modify existing EELVs to launch crews because a lot of the launch vehicles are really not designed with the kind of human safety systems that we require for other kinds of space vehicles. We started digging into Atlases and Deltas and spent a lot of time with the folks who fly those vehicles down at the Cape. Generally, it would've been a lot of work and probably a lot of money to qualify those vehicles to carry humans just because if you do it from the start, it's easier. If you have to retrofit an existing vehicle, it proves to be quite a bit harder.

But interestingly, at that time, we were literally at KSC [Kennedy Space Center, Florida] doing analysis on those launch vehicles when Pres. George W. Bush made his Vision for Space Exploration speech. All of a sudden, it was like pencils down on the Orbital Space Plane and on EELVs for a launching crew because we just got a new mandate from the White House to structure a new exploration program. We probably would not have to figure out how to redesign existing launch vehicles; we might have a chance to design one from the bottom up and do it with the human safety requirements from the very beginning. All that work that was underway came to a halt as we listened to President Bush's speech calling for NASA to basically pick up where the Vision for Space Exploration [VSE] had left off. It was clear that he was trying to, in a way, revive his dad's initiative to go back to the Moon on to Mars with a modern twist 14 years later. That sent us off on a new direction. We didn't actually spend very much time on Orbital Space Plane or EELVs, once the VSE was announced.

ROSS-NAZZAL: What were your feelings when you heard this speech? I'm just curious being someone who was so excited about the Apollo program.

CONNOLLY: So this brings in a very interesting roller-coaster effect. Back when I first started with NASA and the first Vision for Space Exploration was announced back in 1989, the agency and many of us who had been waiting for this got very excited about it, and for the next year or two, we're on the uphill ride of a roller coaster. Everything was about human exploration, going back to the Moon, it's very exciting, we're giving lots of talks about it, and it seemed to be that, finally, this reason that many of us came to NASA for was going to happen. Then, of course, the bottom dropped out of that and the roller coaster went back downhill. Now, we get the VSE speech, and we're back on the roller-coaster ride back up the hill again.

By the way, the peaks between the roller-coaster hills are 14 years, which also turns out to be exactly the peak between the Vision for Space Exploration and Artemis that we're currently working. There seems to be a constant of about a 14-year peak to peak in human exploration excitement, planning, budgets, and trajectory. So, yes, we were very excited about that, and we had some hints that that was going on in the background up in Washington. That was really what we were all there for.

Shortly after that, in March 2004, I was asked to come up to NASA Headquarters to start working with the new Exploration Office there that had been put in place under Admiral Craig [E.] Steidle. My first job was helping write the requirements for this new exploration program because that's where we start usually in the NASA world, writing requirements. For the next nine months or so, I was given the job to lead the exploration propulsion group under Admiral Steidle and his troops, so I was working upper stages and launch vehicles and things like that.

That was an interesting era up at NASA because Admiral Steidle came from the Navy, working the Joint Strike Fighter Program, what he was best known for. He had a very DoD way of looking at programs and procurements and things like that, so those of us who were asked to come up and work for him were all sent off to school again to learn about the Department of Defense procurement, the ways that they do procurement, DoD 5000.

We are asked to learn this new way of doing business that he liked called "spiral development." Many folks were sent out to a war college to learn more of the DoD way of architecting things. He was intent on reintroducing or introducing NASA to a different way of doing things that was more like the way he was familiar with from the Department of Defense.

That took a considerable amount of time and effort to retrain a NASA workforce that had been brought up doing things the NASA way. I'd say it was not as effective as had been hoped for because when Mike Griffin was announced as administrator in early 2005 one of the first things he did was to dismiss Admiral Steidle and put a different exploration program organization in place. Again, I happen to be up at NASA Headquarters at the time, and I had worked for Mike Griffin before. The first time we went through this exploration roller-coaster back in the early '90s. He kept me on and asked me to be one of the leads of something called the ESAS study, Exploration Systems Architecture Study. What Mike wanted to do, rather than going through an elaborate new way of doing things DoD style, was to put a Skunk Works team together and come up with the architecture of the program that will get us quickly back to the Moon and have all the right hooks in it to eventually get us to Mars.

In the spring of 2005, the ESAS study was kicked off. I was the deputy of the ESAS study, and my job was to create the architecture that would eventually become the Constellation Program. We were able to handpick folks from all around NASA and bring them up to

Washington for three months for the Skunk Works activity, and it was very high energy. We had 100 percent access to literally anything at NASA, any resource NASA had, any people we needed, any expertise we needed, any analysis we needed. Over the course of three months, we involved hundreds of people at all the NASA Centers to do all sorts of analyses for us and reiterating, and iterating through a number of quick analysis cycles, we came up with what would be called the ESAS architecture, which eventually became the Constellation architecture.

By the time we reached late summer and then Administrator Griffin made the announcement about the ESAS report and the Constellation Program being stood up, we had architecture that had two different launch vehicles: one for crew, one for cargo. We did that because that was a CAIB recommendation coming out of *Columbia*, to separate crew and cargo launches. We architected a lunar program that involved a fairly large lunar lander, larger than the one we had used in Apollo, but much more capable, could go anywhere on the Moon, and stay for longer periods of time with larger crews. We had a new program for the folks at Kennedy to improve their ground processing and launch systems. We had the start of what would be needed on the Moon eventually for lunar surface systems. That all was part of the ESAS report and the ESAS architecture.

I stayed on at Headquarters long enough to finish the ESAS report, that you could get online, and socialize that again through all the NASA offices and up through Congress before it was released. It received pretty good reception because it was very, very complete, and it became the basis of the Constellation Program. Late in 2005, the Constellation Program was announced as being headquartered at the Johnson Space Center and with Jeff [Jeffrey M.] Hanley as the lead of that program, and that's when I returned to JSC.

I returned with the idea of wanting to do a very good job on the lunar lander, and so I created I guess what we'd call the Lunar Lander Pre-Project Office. Nothing is an actual project office until you get all the paperwork that says you're a project office, but I wanted to act as though we were a project office. So I created a pre-project office and invited all the right people to help us further explore lunar lander concepts and get the program ready to go for when it was given a green light as an actual project. Then that got us to about the beginning of 2006.

ROSS-NAZZAL: Can I go back? You had mentioned something that I thought was interesting when you were working at the Headquarters, working under the gentleman who was very focused on DoD efforts.

CONNOLLY: Yes, Admiral Steidle.

ROSS-NAZZAL: You said he was interested in NASA doing things the DoD way, so I wondered if you would explain the difference between the two. What do you mean in terms of style or approaches? I'm not sure what that means.

CONNOLLY: So let's see. In NASA, we have the NASA systems engineering handbook, which basically tells us how to manage programs, and we do this in a linear fashion. We do pre-Phase A studies, Phase A studies, Phase B, CD, all the way through building the flight hardware and operating them. We have our procurement standards as well on how we procure things. The DoD does things a little bit different. They have something called the DoDAF, the DoD

Architecture Framework, they have a standard called DoD 5000, which is their program management and procurement standards, and there are just different ways to do things.

The program that Admiral Steidle had been wanting us to use was called spiral development. Spiral development is quite a bit different than linear programming the way we do it at NASA; you can just tell by the names. I think it accomplishes the same thing in the end, but it just goes through the steps in a different way. It's hard to make an analogy, but if I want to make a literal analogy, it's as though you had been using nothing but linear stairs your entire life and knew nothing but linear stairs, and then someone comes around with a spiral staircase and says, "I want you to use these from now on."

ROSS-NAZZAL: Got you, okay, yes, I was just curious about that. I figured if someone reading this, they might wonder what the difference was. I also wonder if you would talk about when you were working on ESAS. You shared in your CV that you were talking about the key points with members of Congress, the Office of Management and Budget [OMB]. Would you talk about some of those notable conversations or discussions you might have had before finalizing that endeavor?

CONNOLLY: Okay, so an important part of ESAS was doing the homework to get everyone socialized up in Washington on what this new program was going to be. What that usually means is talking to members Congress and congressional staff, talking to the OMB, and folks in the West Wing of the White House because you don't want to surprise anybody who has a political vote. As part of the of ESAS activity, I and some the other members of the team would be asked to come up to Capitol Hill and brief congressional staff to go to the EEOB [Eisenhower

Executive Office Building] and brief the folks from OMB and some of the other offices in the White House. That's all just pretty standard stuff in how you socialize bigger programs up through the chain in Washington. I have an easy time doing briefings personally, so no problem with who's in front of me, talking about what I have come to talk about. But, yes, we got to see some pretty high-power personalities along the way.

ROSS-NAZZAL: Any interesting anecdotes from any of these presentations that stick with you to this day?

CONNOLLY: None that I like to put on record.

ROSS-NAZZAL: I understand. Did anything change after you had come up with the plan and you rolled it out? Did anybody balk at the plan you had come up with, and you had to make any changes or tweaks?

CONNOLLY: Yes, there were a couple things. First of all, the plan was rolled out by Mike Griffin, the NASA administrator at the time. We worked very hard to put a very nice video together that can illustrate the architecture. He may have made a bit of a tactical mistake by calling the architecture "Apollo on steroids." It's those kind of things that the press picks up on and wants to highlight and dig into. We did want to put together and put an architecture together that went beyond what Apollo can do, so there's no doubt about that, and it may even be far beyond what Apollo can do. But I think there's probably terminology you can use that's less aggressive than Apollo on steroids. So, yes, that maybe hindered us a little bit because that became the headline: NASA announces Apollo on steroids.

The other thing was that as we were doing the ESAS assessments, we had some pretty good cost and risk analysis folks working with us. You have to work hand-in-hand with the people who are figuring out how much this is going to cost and with people who are figuring out where are the risks in this program. We literally had people online as we would make changes to the architecture telling us what the new cost profile would look like and where we had introduced or taken away risks, and that's really a great way of doing any kind of work in the space business. You want to know how every change you make affects cost and risk and schedule to some extent.

When we tied a bow around the ESAS report, we had a specific architecture, and the cost folks were still working on tweaking their numbers. I think that within three or four months of introducing the ESAS report to the public, it was determined that some of the propulsion systems we had proposed were going to be very costly. Propulsion is often the most costly part of what we do in space. That's actually only changed very recently as some of the new launch vehicle companies are bringing the cost of launch down, but generally propulsion is more than half the cost of everything else.

So some changes were made late in 2005. Some of our NASA Headquarters managers changed many of the propulsion systems that we had originally specified for the ESAS Program. They changed the main engines of the launch vehicle that we wanted to use, they changed the second-stage engines, they changed the engines of the lunar lander and what became the Orion service module from methane propulsion to storables again. It wasn't always cost that drove these changes, it was schedule as well. It takes a lot of time to develop a brand-new rocket engines. If you could use engines that had heritage, for example the Space Shuttle main engines or some of the orbital maneuvering engines from the Space Shuttle, then there's cost savings and schedule savings there. HQ management was looking at both saving money and how can you bring these systems online more quickly. So, yes, there were technical changes made to ESAS that became then part of the opening deck for the Constellation Program.

ROSS-NAZZAL: Did that have a domino effect then because you had mentioned and I've heard people mention configuration control. When you make a change to one item, that has an effect on other systems as well, so did you have to go back to the drawing board or was it pretty much we'll just start from here and move forward?

CONNOLLY: Yes, we didn't have to go back to the drawing board, but it did have a domino effect. Basically, every propulsion change that was made for cost or schedule reasons led to a new propulsion system that had a lower performance. It had a domino effect through the architecture because anytime you lowered the thrust or the Isp of an engine, the vehicle that it's propelling gets bigger and heavier. We had to go and recalibrate the entire architecture based on these new propulsion systems. Rather than having a very robust amount of margins in the masses of these vehicles, we ended up with very little or a negative margin and so it was a challenge throughout the Constellation Program to try to figure out how to work with these very low margins.

ROSS-NAZZAL: There was one other item that I wanted to ask you about. You invited gray beards to come talk about lunar landers when you were working on that up at Headquarters. I wondered why did you decide to establish those workshops and what lessons learned from them did you apply to your program?

CONNOLLY: Well, there were two sets of gray beards, if you will, that we wanted to get involved in lunar lander work. First, we wanted to talk to every Apollo astronaut who ever touched the controls of a lunar lander in actual flight. We had Neil Armstrong, John [W.] Young, Gene [Eugene A.] Cernan and Fred Haise from Apollo 13, and a number of others all come in and brief us on not only their experience flying the Apollo lunar module but what they would suggest as changes for the next generation of lunar lander, and some of those guys were just amazing. Fred Haise was the astronaut representative to Grumman, the company that built the lunar lander, and so he came in with probably a 3-inch-thick notebook of thoughts he had had since working the Apollo Program on how to make a better lunar lander. We had him brief us in the old Apollo control room, in Mission Control, which made it even more special.

We had one meeting where we had Jack [Harrison H.] Schmitt, Gene Cernan, and John Young, and Neil Armstrong all in one meeting with us—a third of all the humans who had ever walked on the moon in one meeting talking about lunar lander design. Those were special get-togethers.

We also took trips up to Grumman in Bethpage, New York, where they had built the lunar modules. They keep an active group of veterans together, veterans meaning the people who built the lunar modules back in the ’60s and ’70s. They can gather these folks together if people want to benefit from their Apollo lunar module experience. So we would schedule regular meetings with the Grummies to ask them questions about why did you do this in the lunar lander design or what would you do different if you were designing it today? We had some great technical collaboration meetings with those guys, and they were very forthcoming in sharing their views on the design of the lunar module and what they would suggest we do in the future. To a person, they were very, very proud of the fact that they had built these machines that went to the Moon and operated perfectly every time.

ROSS-NAZZAL: Was there anything that the crew or engineers and technicians were in agreement on that you took forward as you were working on this?

CONNOLLY: A lot of things obviously. The Apollo crewmembers were all pilots, of course, all military pilots, and they wanted the control of the vehicles to be very military, they wanted to fly the vehicles. The Apollo lunar module was flown by a computer, but with inputs from the crew, a fly by wire system. There's a big unknown when it comes to landing, and that's why the crew wants to be able to have control, so they can pick a landing site that's as flat and as unobstructed as they can find, and that involve sensors and having time to hover and look around. In general, they loved the Apollo LM [lunar module] design.

ROSS-NAZZAL: I'm wondering if this might be a good place for us to stop just because it would be easier for me to know that we're going to start talking about the lunar lander pre-project. I know you started talking about it a little bit, but that way, we don't have to repeat some of the same material. Would that work for you?

CONNOLLY: Yes, it would. This is probably a good place to break—the lunar lander pre-project ran from 2005 through 2006 and so that's probably a good place to start up again.

I did want to end with one thing that you kind of scratched at before. I've had that the good fortune of working with a lot of amazing people, and sometimes, we don't fully appreciate how special our position is. The first year I started working for NASA, I was doing a lot of public speaking because I was really excited about NASA and what I was doing. After about a year of that, I was awarded a NASA Speakers Bureau award for public speaking, and the person who gave that award to me was Al [Alan B.] Shepard.

ROSS-NAZZAL: Oh, wow.

CONNOLLY: Okay, so wow, and at the time, oh, okay, Al Shepard, that's cool. Then working the Astronaut Office, I would bump into John [H.] Glenn any time he came by to visit or when he'd come down for his annual physical. Then I'd be in meetings with Neil and Buzz, that was just because the astronauts have a reunion every fall. I've just worked with all these extraordinary people; I've worked with a lot of folks who have walked on the Moon, now that's just crazy. I mean Buzz Aldrin still calls me about every month or so just to chat about spacecraft and space missions. When you think about that, we live in a unique, amazing bubble, right? At NASA, everybody who lives in the Clear Lake area has some connection to NASA, and we all know astronauts and flight controllers. But, boy, you back away from it a little bit and look from outside the bubble, it's a pretty special place.

ROSS-NAZZAL: That is true, yes, I always think about that when I'm walking into work and I see a tram go by. How many people have someone who pays money to come watch what you're doing?

CONNOLLY: That's true.

ROSS-NAZZAL: Thank you so much.

[End of interview]