DISCOVERY 30TH ANNIVERSARY ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

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INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is November 18th, 2022. This interview with Dave Everett is being conducted for the Discovery 30th Anniversary Oral History Project. The interviewer is Sandra Johnson. Mr. Everett is joining me today from the Goddard Space Flight Center [Greenbelt, Maryland] and we're talking over Microsoft Teams. I appreciate you talking to me today, especially with everything else going on in your life, taking the time out to help with this project.

I'd like to ask you to briefly describe your education and background and how you first came to work for NASA.

EVERETT: I studied electrical engineering at Virginia Tech [Virginia Polytechnic Institute and State University, Blacksburg] and graduated in 1986. From there I went to work at Westinghouse Electric. I was near BWI [Baltimore/Washington International] Airport. They had a facility, the Electronic Systems Group, there. Working on radar receivers. I studied, I did a lot of classwork on radio wave propagation, antennas, RF [radio frequency] kind of stuff. I went to Westinghouse as an RF engineer and worked on radar receivers for five years.

One of my friends from college was working as a contractor for the Special Payloads Division at Goddard and he said, "Hey, why don't you come work at Goddard? There's talk of maybe some hiring going on." I wasn't real happy with the future at Westinghouse. The raises were getting farther and farther apart. The R&D [research and development] money was disappearing. They were still claiming they were increasing their profits at 10 percent a year. I didn't think there was a lot of future in the company. They were eating their seed corn basically.

I interviewed and got a position in the special payloads group as an RF expert. They were hoping to add a two-way radio link to the SPARTAN [Shuttle Point Autonomous Research Tool for Astronomy] free flier that flew. The special payloads organization, it grew out of the Sounding Rocket Division. The sounding rockets went to Wallops [Flight Facility, Virginia], and at Greenbelt the Special Payloads Division worked on the small, attached payloads in the Shuttle bay, SPARTAN, Hitchhiker, and Getaway Specials. We were talking about putting an RF link on the SPARTAN. But there wasn't a lot of other RF work in the group, and so I got on board as a test conductor on SAMPEX [Solar, Anomalous, and Magnetospheric Particle Explorer], which was the first Small Explorer [mission]. After the [Space Shuttle] *Challenger* mishap, the Special Payloads Division wasn't flying special payloads, and so they put together a proposal to do the Small Explorers, and that's how the Small Explorer Program got started.

The initial model was a spacecraft built at Goddard. The announcement of opportunity [AO] went out to the science industry where the scientists would propose the mission to do, and we integrated the instruments here at Goddard and did all the system level integration and test here at Goddard, and then launched.

SAMPEX was the first Small Explorer. Spacecraft bus built here at Goddard. I was a test conductor on that mission and ended up on console for launch. There was one test conductor at the blockhouse. We launched on the second to last Scout [multistage] rocket. There was one test conductor at the blockhouse and I was back at Building 836, where most of the engineers were, monitoring telemetry from the spacecraft and getting the commands out, getting it ready for launch.

After SAMPEX, actually I think even before SAMPEX fully wrapped up, I started working as the electrical systems lead on FAST, the Fast Auroral Snapshot Explorer, that was the second Small Explorer. Then in '95 started working as the systems lead on WIRE [Wide-Field Infrared Explorer], which was the fifth Small Explorer. There were a couple delays with the Pegasus [launch vehicle]. We ended up launching FAST in '96. We launched WIRE in '99. We lost WIRE to a mishap right after launch. The cover deployed prematurely by a start-up transient in some electronics.

I also supported both SWAS [Submillimeter Wave Astronomy Satellite] and TRACE [Transition Region and Coronal Explorer], which were the other two Small Explorers we did in-house. I supported the launches of those. I was here in the ops [operations] center for those launches. Then I started working on the SMEX light bus, which became Triana and eventually became DSCOVR [Deep Space Climate Observatory]. I was working on that, but after the WIRE mishap I needed a change. I couldn't walk through the I&T [Integration and Test] facility without shuddering. I definitely had a little posttraumatic stress going on. I worked in what's now our mission design lab. At the time it was the Integrated Mission Design Center here at Goddard. Over the course of 18 months, we did preliminary designs for 30 different missions.

Then after that I went to work on GPM, the Global Precipitation Measurement, and that was early, that was like pre-Phase A, Phase A work. All the way up to—we were getting into Phase B but the money kept sliding out. The schedule kept sliding out. I got tired of waiting around because I had worked on the project for three and a half years. We were seven years from launch when I started. We were still seven years from launch after three and a half years. I was asked by our division chief to support the Hubble [Space Telescope] robotic servicing mission. I did that for a year. We went from notion to preliminary design review in a year, getting ready to robotically service the Hubble Space Telescope. That was post [Space Shuttle] *Columbia* [STS-107 accident] and Sean O'Keefe had said we weren't going to send a Shuttle to service, and so we worked on that robotic servicing mission. Then we got a new Administrator and they came up with the strategy for sending people back to service with the second Shuttle on the pad. Anyway, the robotic servicing got canceled. They went ahead and did the final servicing mission.

Right after that LRO [Lunar Reconnaissance Orbiter] had already gotten started, had gotten through their system requirements review, and there was a desire just based on the state after the system requirements review, they decided they needed some more systems engineering, and so they put me on the team. The team was all in place when I was put in as the lead systems engineer, and that was a very unusual circumstance for me to step into a team already in place. For the first time in my career I felt a greater level of responsibility to the team than I did to my superiors, because I had a lot of people come to me and say, "Oh, we're really glad you're coming on board." That included the guy who had been the lead, who also said to me, "I'm really glad you're coming on to be the lead." It was certainly the biggest thing I had ever taken on at the time. LRO started out about a $500 million mission and that's pretty much where we ended up. I've got the exact numbers. But we had a launch delay that bumped things up a little bit. That's how I got to LRO. I don't know where you want me to go from there. That was a long time to just get there.

JOHNSON: It looked like a lot of the work you were doing was systems engineering on those projects. That I'm sure prepared you for the work on LRO.

EVERETT: The other piece of information I forgot to convey is that a lot of the people involved with LRO had history in the Special Payloads Division. Craig [R.] Tooley, the project manager, had managed some of the SPARTAN missions. Joanne [L.] Baker, who was our I&T lead, had some history in that group. Then some of our leads for the subsystems like Quang [H.] Nguyen had worked on all of the avionics for nearly all of the Small Explorers—certainly he did SWAS, TRACE, and WIRE. Some of the other leads, Tom [Thomas J.] Spitzer I think did power on a number of them and also that mission. So, we had a number of people on the team who had worked on the Small Explorers in the ’90s or had worked in the Special Payloads Division on the other special payloads in that organization.

At the same time, we were doing LRO the Solar Dynamics Observatory [SDO] was being built in-house at Goddard and a lot of the people on SDO had history working on MAP [Microwave Anisotropy Probe] before that and working on XTE [X-Ray Timing Explorer] and TRMM [Tropical Rainfall Measuring Mission] before that. XTE became Rossi, the X-ray Timing Explorer.

JOHNSON: Maybe we should start first with what exactly a mission systems engineer would do, especially for something like LRO, when you have of course the orbiter itself but then all of the instruments that went with it.

EVERETT: Right. At Goddard the mission systems engineer is the lead technical person on the mission, on the project. That role includes technical authority. Technical authority is something that was established after the *Columbia* mishap on the technical side. I learned in some training I had to take about how safety and mission assurance came out of the Apollo 1 fire, having a separate organization associated with safety and mission assurance. What came out of the *Columbia* mishap is having technical authority through the engineering chain. It provides an independent reporting path all the way to the Office of Chief Engineer if necessary to ensure that senior management is aware of the risks that are being taken on the mission.

At any rate, the role includes the technical authority and in fact the funding for the mission systems engineer is typically separate from the funding for everybody else on the project. The funding for everybody else goes through the project manager. The funding for technical authority comes through the branch head.

My role was technical authority, so there's a technical aspect to the job, and there's also an engineering management role to the job because it was a big enough team. It was a pretty big team. I had probably a dozen people on my immediate systems team, and then all the discipline leads. Probably another 15 or 20 discipline engineering experts who I interacted with on a regular basis looking across the whole mission.

My responsibility was not only the flight system but also ground and operations. I looked across all of it. My focus tended to be on the flight side because that's where a lot of the risk is. I ended up with two deputies, and they spent a lot of time working the operations aspects of the mission, how we were going to fly the mission. Got folks looking over the ground system and the hardware and software associated with ground system. But all of that was within my domain.

There's the project manager who's in charge of the whole mission. Cost, schedule, and performance. Then the systems engineer is focused on the technical performance, but certainly needs to be cognizant of cost and schedule.

JOHNSON: Let's talk about the goals for LRO and the importance of that mission especially in helping NASA achieve the goal that President [George W.] Bush set out when he announced The Vision for Space Exploration. The idea was to create these missions that would go back to the Moon to prepare for eventual human travel to the Moon and beyond. I was talking to Jim [James B.] Garvin early in this project. He described LRO as a civil engineering mission for the Moon. It's like civil engineering for the Moon, for mapping the Moon, to find out everything that we needed to know about the Moon at that time. Talk about those goals and how they were set out and the things that you had to keep in mind while working this mission.

EVERETT: Like I said, I was not involved at the very beginning, but I know the history pretty well from working with everybody else on it. As you said it was like January of 2004 when George Bush announced The Vision for Space Exploration. At the time we were talking about a series of robotic missions beginning no later than 2008. That date, that no later then 2008, became one of our Level 1 requirements for the mission. June of 2004 there was an announcement of opportunity that went out for instruments. At the time the team was thinking there'd be maybe three instruments. Six were selected in December of 2004. All the instruments that were selected were selected because they had high heritage. The idea was to keep the risk low. The AO included what the interface had to be. We specified a 1553 or a SpaceWire interface. We wanted to have standard interfaces and make it easy to integrate the instruments, so we could do this quickly.

The six instruments were selected in December of 2004. Funding was started in early calendar year 2005. It was like mid 2005 that I came on board. April of 2005 is when Mini-RF was added. Mini-RF was a technology demo. It was one of the instruments that had originally been proposed but was not mature enough to go on board, but somebody decided that they really wanted to fly this instrument. A related instrument flew on the Indian mission that launched right before us, Chandrayaan[-1, Indian lunar probe].

At any rate we ended up with Mini-RF also, so seven instruments in total on the spacecraft. The data rate and power consumption associated with Mini-RF were pretty significant. The interfaces were more complicated, the operations and stuff were more complicated. The technology was still being developed. It ended up probably half of the time that I devoted to the instruments was probably on Mini-RF, just because of where they were in the development. There's a technical authority story associated with that that I can tell you as we get into this some more.

You were asking about the goals. It was all about characterizing landing sites, identifying resources, and understanding the radiation environment. For the landing sites we had the Narrow-Angle Cameras and the Wide-Angle Camera to get context and then the laser altimeter, LOLA, the Lunar Orbiter Laser Altimeter. That's what it was. We had LOLA and we had the cameras, LROC, the LRO Cameras. Those were about characterizing the landing sites, identifying the resources, looking at water, minerals, sunlight. We had an infrared instrument, Diviner. We had ultraviolet, which was [LAMP, Lyman-Alpha Mapping Project from SwRI [Southwest Research Institute, San Antonio, Texas]. Diviner [Lunar Radiometer Experiment] was from JPL [Jet Propulsion Laboratory, Pasadena, California]. LOLA was in-house here at Goddard. The LRO Cameras were from Malin [Space Science Systems] with Arizona State [University] as the PI [principal investigator]. Separate PIs for each of the instruments since it was an in-house spacecraft.

[Lunar Exploration] Neutron Detector [LEND] from Russia. IKI [Space Research Institute] was the organization. Then Mini-RF eventually was delivered by APL [Johns Hopkins University Applied Physics Laboratory]. Originally it was again another company [Raytheon Technology]. They were in the Southwest and then APL took over. I'm not sure what all the politics were behind all of that. It was funded separately from the rest of the project. Oh, and I forgot about our tissue equivalent plastics on CRaTER [Cosmic Ray Telescope for the Effects of Radiation] measuring the radiation environment. The LEND from the Russians was neutrons, which told both neutron albedo and also helped identify where the water would be.

It was all about characterizing landing sites for exploration, not for science. It was for the exploration organization at [NASA] Headquarters [Washington, DC].

JOHNSON: That's a variety of teams from all over the globe and all over as far as working with other NASA Centers as well as universities and some external businesses. Talk about that for a minute. You had your team as you explained with other systems engineers, and then that expanded out, and then you had the different parts of LRO which were these instruments. But talk about working with that large of an organization and trying to keep people talking, keep things moving forward, and especially since you did have a relatively short deadline. You came on around the time I think that the launch vehicle was changing. Is that correct?

EVERETT: Yes. I came on right before all that happened. I was right in the middle of the trade studies that led to that change. That was schedule-driven, that launch vehicle change. Schedule was king. Everything was focused on schedule. When I joined the project, everybody was saying, "There's no way we're making the schedule. There's no way we're going to make the schedule." The review teams were saying, "There's no way you're going to make that schedule." People on our team were saying, "There's no way we're going to make that schedule."

Like I said, we were shooting for October 2008 to give us some room. The requirement was to launch by the end of 2008. It dominated the decision-making process on the project. But the project manager, Craig Tooley, created an environment, he created a culture on the project where everybody believed we were going to make that launch date. Everybody was fully on board by the time we got to the summer of 2008, at which point the spacecraft was fully assembled and we were getting ready to go into environmental testing. Everybody was already well on board a year before that, maybe even longer. Everybody was on board with yes, we can make this schedule.

It was a mindset. Every decision that we made was "Okay, we need to make this decision today because we don't have every bit of information that we could have, but we have enough information to make this decision." The risk is low. The launch vehicle change is a good example of the kind of thinking that was going on. What happened with the launch vehicle, our propulsion lead [Charles M. "Chuck" Zakrzwski], this is shortly after the system requirements review, and we're starting to get deeper into the preliminary design and deeper at the subsystem level. Chuck looked at this custom—I need to back up a second.

In order to get to do the mission we had to carry something like 1,300 meters per second of delta-V [change in velocity], which we did a monoprop [monopropellant rocket] system rather than a biprop [bipropellant] system for schedule reasons as much as anything, to simplify it and get it together quicker. About half the mass of the spacecraft was fuel. It was a new tank, a custom tank, because we were going to fly on a three-stage Delta II [rocket]. The third stage was spin-stabilized at 60 rpm. In order to have a spin-stabilized stage there's requirements on the nutation time constant for the payload that's flying. If there's too much energy dissipation in the payload it will cause the rocket to go into a flat spin instead of staying like a rifle bullet. The spin would go out of control and you'd exceed the authority of the nutation control system.

We had those requirements that we were designing to, and the launch vehicle guys were calling us liquid-sat [satellite] because they had never flown anything with so much liquid on the Delta II before. Chuck said to me, "I think we can get a design that will meet the nutation time constant requirement. But we're not going to know for sure for six months, when we can do a drop test on a test tank or something." Now we were in a situation where if we stayed on the course that we had, we had a risk to our schedule that we would break the schedule. We would get to a certain point and we would say, "Oh, we can't build a tank that's going to work for the mission." We stopped. We paused at that point and we did a trade study.

We looked at different options. One option was to fly a solid rocket motor for the lunar insertion because of the 1,300 meters per second; I think like 500 or 600 meters per second was just getting into orbit around the Moon. We could do that all in one burn with a solid rocket motor, and then fly a lot less liquid and meet the nutation time constant requirements. We looked at that option. There were a couple other options that we looked at. Then one of the other ideas that we threw out that we couldn't choose was fly on a non-spinning launch vehicle. We put the numbers together. We said, "Oh, gee, the nonspinning vehicle that's available is the EELV [Evolved Expendable Launch Vehicle]." Which at the time was Atlas V or the Delta IV. Each of those had a lot more launch capability than the Delta II did. Given that extra capability, we could take a couple of off-the-shelf TDRS [Tracking and Data Relay Satellite] tanks that were going to fly on one of the other programs. They were left over. It was something that

Frank [J.] Cepollina's group was going to fly. Might have been for the Hubble robotic servicing mission. But at any rate we had those extra tanks available.

The story we put together for Headquarters was we can fly two TDRS tanks so it eliminates all the risk associated with developing a new propulsion tank. We get rid of the spinning, and so that eliminates the risk associated with the nutation time constant. We increase our mass capability to reduce any risk associated with trying to pack everything into a really small rocket. And oh, by the way, there's an extra 1,000 kilograms available that you could use for another mission going to the Moon.

That was part of the package that we pitched to Headquarters. What we said was, "We're going to switch to the solid rocket motor. But oh, by the way, if you put us on an EELV this is how it would look."

On the spot the Associate Administrator made the switch to the launch vehicle. I'd never seen a decision made like that at Headquarters. In the meeting he's like, "Can we switch? Is there any reason we shouldn't?" Everybody's like, "Ah, sure, switch." Boom, we switched.

What that meant was we had to redesign the spacecraft.

JOHNSON: Talk about that, switching and redesigning the spacecraft, and how you had to do that. What exactly had to be redesigned? Was that the reason that the time schedule got pushed?

EVERETT: There was already a preliminary design. We were coming up on PDR [preliminary design review]. We were like a month from preliminary design review. We already had a pretty good design for the spacecraft. We had worked thermal. We were running into problems. The thermal environment of the Moon. We had multiple review teams warn us about how hard the thermal environment was, and I don't think it was till we got to the critical design review that we really understood how hard the thermal environment was. But we had done enough work to that point where we understood where some of the challenges were with the thermal design we had. We had a very optimized spacecraft design, in order to fit in the space and mass that we had, but the thermal was very challenging and consuming a lot of power. We had tried to go with an all-passive design with no heat pipes or anything. The thermal lead, who had previously worked with heat pipes, was very enthusiastic about using heat pipes, but the project manager at the time, or actually the program manager—just to step back for a second the original [Robotic Lunar Exploration] Program was at Goddard. Then this was the first mission in the program.

Then at some point the program got moved to Ames [Research Center, Moffett Field, California] and then it got disbanded and then it moved to Marshall [Space Flight Center, Huntsville, Alabama]. That's a whole nother story. But at any rate our program manager, who was actually the systems engineer on the first three Small Explorers, and then he was the program manager for Small Explorers after that, Jim [James] Watzin, he didn't want the complexity of the heat pipes in the design.

All this work had been done with the structure and a lot of learning in the process of going through all of that. Then we changed launch vehicles and we changed fuel tanks. The fuel tanks are in the middle of the spacecraft for center of mass balance reasons. We had to redesign the whole spacecraft. We were starting with a clean sheet of paper but we were a lot smarter about where the challenges were. What we did at that point was establish some guidelines on how we were going to design the spacecraft. We wanted it to be modular so that we could do parallel integration. We decided to go with the heat pipes and couple everything together to use the thermal mass of the whole system to spread out the heating and cooling as you go around the

Moon in that noon-midnight orbit. We had quite a few meetings working through the architecture and figuring out how to lay it out in a way. We ended up putting nearly all of the avionics for the spacecraft on a single panel. We were able to lay that panel out flat and do all the integration on the tabletop before we installed that on the spacecraft. That greatly sped along the integration of the spacecraft.

We had a separate instrument module. We were able to get all the heaters and everything on that and get that all ready to go separately from the rest of the spacecraft. The propulsion system was an integral system that could be tested by itself and brought in later. We ended up with a very modular design.

What we ended up doing, the structure and thermal were behind. The avionics, the mission design, the instruments, they were all moving forward. We decided we need to have the preliminary design review in February. This is February of 2006 now. We need to have the preliminary design review so that we've got good consistency across all the avionics and the instruments. Then the mechanical is just going to have to catch up. We did a review of mechanical and thermal in April of 2006. Then after we checked that box off then we did the confirmation review in May of 2006.

Everything kept moving. We ended up in November of 2006 doing our critical design review. We held the schedule. We continued to work toward the October of 2008 launch date through that time period. That's how we recovered from the launch vehicle change. It actually helped us and I think in the long run greatly reduced our schedule risk and enabled us to stay pretty close to the schedule.

In terms of the schedule, what ended up happening, we got to the summer of 2008, and we had the spacecraft fully integrated. There were some competing priorities with the

Department of Defense. They wanted our launch slot. There were some discussions between Craig and the folks downtown. I think Craig made sure the people downtown understood that there was a high probability that we would be missing the December 2008 date. Not missing it by much, but it was okay for them to swap our spot. I think we ended up in the next slot after. It was going to be February. I think we had been talking October of 2008. In like June or July of 2008, we moved the launch date to February of ’09.

When Craig announced that to the team, it was not relief in the room, it was disappointment, because by that point everybody was on board with the schedule, and we were all pushing hard to make the schedule. It was relief for me, but most of the team was really excited about demonstrating that we could meet that schedule.

We were shooting for February. The payload ahead of us had some issues. We got pushed to April, and I think there was some more issues with the payload ahead of us that pushed us out of April, and then we were going to go the first window in June, I think is what we were looking at. But that didn’t work for LCROSS [Lunar Crater Observation and Sensing Satellite], which was the payload that got added when we switched to the bigger launch vehicle. So, we ended up going in the second window in June, when we finally ended up launching.

One of the things that that did, it really stretched the team out. We ended up spending that extra six months doing a lot of operations testing. We didn’t really take a break. By the time we launched everybody was really burned out. One of the systems engineers on my team said to me multiple times, “I’ve never had this much fun on a project before and I’m never going to have this much fun again.” He understood, we all understood, how special the team was. It was just a wonderful team to work on.

JOHNSON: You mentioned that Craig Tooley created that culture that everyone bought into. It was a special team, and there were so many teams involved like I mentioned earlier. What do you think made it that way? What made this a special project, a special team?

EVERETT: There were several factors. Craig was amazing. He was an amazing project manager. He was very good. One of the things that I took away from LRO was the importance of hearing all the perspectives on the team and having diverse perspectives on the team. When he selected Cathy [Catherine L.] Peddie to be his Deputy, he deliberately picked someone who was very different than him. He deliberately picked somebody with differing personality types. After the fact I think we looked at Myers-Briggs and all of them were opposite. He was an I and she was an E. Anyway, I don't remember them all off the top of my head.

He valued that diversity on the team, diversity of perspective on the team, and created that culture that I really picked up in terms of understanding and appreciating hearing everybody. Because when you're going fast, you have to be careful that people aren't making bad technical decisions to save schedule. You need to understand what the risks are associated with the decisions that you're making. That's really the environment that he and I together created. I worked with the team. He worked with the team. Hearing their risks, hearing their concerns. Identifying which things we needed to do something about, which things we needed to mitigate, which things we needed to handle at the system level. Making sure that the decisions that we made didn't add too much risk to the integrity of the mission.

I've done a number of talks about the systems engineering on LRO. One of the things I show is a fortune from a fortune cookie that somebody got. It was really telling. "People forget how fast you did a job. But they remember how well you did it." It was perfect for LRO. It was something that we kept in mind, even though schedule was king, it didn't do us any good if it didn't work.

JOHNSON: That wouldn't be helpful.

EVERETT: Just one more thing on the launch delay, and how it would have played out had we not had the launch delay. We hit environmental testing in the summer of 2008. We got the launch delay about that time, so we relaxed the schedule a little bit. We didn't hit thermal vac until Halloween, but we spent six weeks in thermal vac. We found a major design flaw with the thermal design of the solar array gimbal. Somewhere along the line there was a factor of 14. There are 14 circuits through the cable wrap, and the thermal design was off by a factor of 14 in how much heat was going to be dissipated by the resistance in the wires. I looked back at the calculation. I didn't see where the error was exactly, but the answer was wrong.

Anyway, the point is the gimbals got really hot as soon as we got into thermal vac and we knew we had a problem. It didn't show up in air because the air takes the heat away. But in vacuum the problem showed up really quickly. We added an extra radiator to the gimbal to keep it cool enough, and to this day we're flying the spacecraft with a 30-degree offset on the solar panel to minimize how much heating we get. We've got enough power margin that we can do that.

We had that hiccup that stretched thermal vac out a bit. It was December of 2008 that we finished the comprehensive test at the end of environmental testing. At that point we could have shipped to the launch site. More delays had already kicked in by then. We ended up shipping to the launch site in February for an April launch and then didn't launch till June. We weren't off that much from our original 2008 target. Certainly not nearly as much as most people predicted beforehand.

JOHNSON: Going back to all the different team members and the different people involved with the instruments, and the PIs, and the people working on the spacecraft, sometimes there's a lot of difference between the way an engineer or a scientist will approach a problem or a project like this. Then LRO itself, the purpose was to do one thing. Then because it's continued to fly, it actually is a science mission now. The engineering drove it, and then the science is getting the benefit of it. But talk about the importance in a mission like LRO of balancing that engineering or that technical side and the science to make sure that everything comes together.

EVERETT: Yes. Although we weren't a science mission, there was a principal investigator associated with every instrument that we had. From an engineering perspective we certainly listened to the scientists and tried to get as much performance out of the system for them as we could and understand what their requirements were for each of the instruments.

Something like laying out all of the instruments in a way that stray light wouldn't go from one into the other. The ones that needed cold detectors had clear view to deep space. There were a lot of constraints that we worked through in order to optimize the performance of the instruments.

Even thinking through the operational aspects and what's happening when, we designed the system for the scientists. The PI for the LRO Camera wanted to be able to look off nadir and get oblique views. We came to a compromise of we're not going to do any more than three of those per day. We designed the operations to be able to handle those slews and those offsets.

There was a lot of back-and-forth with the scientists to work through and finalize the requirements. What we had in the Level 1 requirements was very much a product of—the scientists were on board with what exploration was trying to get. The Level 1 requirements ended up being a compromise between what exploration needed and what the instruments could do and how exactly that was going to manifest in the hardware and how doable it was to achieve those requirements.

It was different because it was not science-driven. It was driven by "Okay, we need to map the polar regions. We need to look for resources." But the scientists understood all of that. They're part of the ones that were defining with Headquarters what we were going to get out of the measurements we were making.

JOHNSON: You were working across not only between scientists and engineering, but there were other disciplines involved that you had to work with. You had managers. I imagine you worked with procurement people. Different people you had to report to, and then of course the teams that were looking at what you were doing and making suggestions or worrying about things that might go wrong. But talk about your position and having to work with all these different factors that go into a mission like this. When we look at it sometimes, we think oh, it's just scientists or it's just engineers that are building this to go forward. But there's a whole lot of other things that go into this, and other disciplines within NASA that you have to deal with.

EVERETT: Oh yes. The public affairs people too. The outreach folks. Certainly, most of my day-to-day was among subsystem leads. Because we were building the spacecraft here at

Goddard, the discipline engineers here, a lot of them were product development leads delivering particular pieces of hardware to the system.

I got into a monthly routine of going around with our risk manager and meeting with everybody one-on-one and gathering their concerns and talking about it and updating the risks in the database, figuring out what new risks we should be carrying. It really helped us head off some problems before we ran into them. There was that role.

But on the other side, the project manager, Craig, and Cathy worked more with the financial and schedulers than I did. But the financial people are the ones who make sure the money keeps flowing. You end up near the end of a fiscal year, and you need to have all your contracts in place. You need to forward-fund all the contracts in case there's a delay in the funding coming from Congress at the end of the fiscal year. The financial folks would do all of that. They're working with each of the product development leads to make sure that they're staying on budget and keeping track of how much money we have available to spend on risk mitigation, and where it's appropriate to spend money and where it's not appropriate. That was part of the risk process too.

The contracts folks are critically important because we've got all these procurements for various pieces, the star trackers, the solar array. Each of the instruments is on a different contract. Having the contracts in place and making modifications to the contracts, as you learn more about the system, you end up having to do some modifications occasionally. The transponder, we didn't get an interface test into the original contract with the transponder. It was an oversight. Later after the critical design review, Headquarters really wanted us to stay on schedule. They're like, "Can we give you more money if you stay on schedule?" At that point it's hard to spend a lot more money because all the contracts are in place. Everything's out being worked. But that was one place where we said, "Yes, we should put a little more money on the transponder contract and do an interface test with it."

We did that test and found six or seven interface issues where it was some miscommunication. It was easy to fix. It didn't impact schedule. It didn't impact the cost. We ended up saving money because we would have had a marching army sitting around waiting for the transponder to show up if we hadn't spent that little bit of extra money. It was like a week to do the test.

The contracts people make all that stuff happen. They work through. Our contract specialist was very good at understanding what the rules are and what you can do to expedite the procurement process if you're trying to move things along. When you're doing a source evaluation board and trying to figure out where you can shorten that process, what's acceptable and what's not acceptable, having good contract specialists is critical for that sort of thing. Occasionally you run into issues where you need some advice from lawyers.

Then the outreach folks, I worked a lot with our outreach folks. I'd do presentations at schools. Even after launch I worked with them a lot, with teachers coming to visit during the summer, doing presentations. They're doing a lot of work in helping educate the public with what we do.

JOHNSON: How important do you think that is, that education and outreach, especially for these type of missions?

EVERETT: The taxpayers are spending a lot of money on these projects. That's one of the big values that we get out of it, is inspiring the next generation of engineers. There were people working on our project. Giulio [G.] Rosanova, our mechanical lead, left SDO [Solar Dynamics Observatory] to come work on LRO because we were going to the Moon. He grew up watching the Moon landing, he was a kid when the Moon landings were happening, and he's like, "I want to be part of going back to the Moon." It was exciting for him.

There are a lot of people working at NASA today who were inspired by our achievements in the past. I've recently hired people who are just really excited about working for NASA. Doing that outreach helps bring along that next generation and get them excited about what we're doing. Because what we're doing, there are big impacts. NASA saved the planet with detecting the ozone hole. The plants would be dying right now if we hadn't stopped dumping chlorofluorocarbons in the atmosphere, and the reason we stopped dumping CFCs was we had the science data from satellites to demonstrate that we were doing that.

There's two pieces to what we do at NASA. One is the practical stuff, weather satellites and telecommunications and all these things that grew out of the space program that are applicable right here today on Earth. Then there's satisfying the need to explore, to go out and beyond and understand what's out there. That curiosity is part of what keeps us going. I've always loved the space program. I was a fan when I was a little kid. I think making sure we continue to make that connection to the public is critical for what we do. It helps the country. It gets people interested in math and science that have other applications.

One thing I didn't mention when I was talking about when we redesigned the structure on LRO—I talked about how we partitioned it, made it so we could do parallel integration. I remember one day standing in front of the clean room where we did the integration of the spacecraft and we had the avionics deck laid out, and there were a couple people working on that. The other side of the clean room, somebody was working on the instrument module. In the next clean room over the propulsion module was being worked on. So, we had all of that stuff going on in parallel.

Then we pulled it all together. There's a video of the assembly of the different pieces. We did it all in one day. The instrument module went on later, but we put the box around the propulsion module, that all went up in one day, including the avionics module. There was one panel that had the reaction wheels on it. Then everything else was on another panel, and that all went together in one day.

JOHNSON: In the presentation you did in 2008 there was something that you put in there that I found interesting, that your team didn't spend a lot of time looking for other options if you found one that met the schedule, cost, and performance requirements. It reminded me of that proverb which I've heard in other oral histories especially with the Apollo guys, that perfect is the enemy of good. I wanted you to maybe just expand on that thought for a minute and talk about what you meant by that and how it applied to what you were doing with LRO.

EVERETT: Yes. When we were looking for solutions, with the propulsion tank issue, the nutation time constant, that led to the vehicle change, we did a trade study there. I laid out a spreadsheet, and we had different options. We assessed those different options. We had a bunch of different parameters that we looked at and said, "Okay, this is the best of the solutions we've got available."

We did that on a couple of different things along the way. We were going to fly commercial hard drives for memory on board the spacecraft, and in order to do that we were going to need to qualify them for flight. We bought like 200 hard drives, and we were going to run them through destructive testing and a bunch of testing to figure out whether we could actually fly them or not. First thing we did was radiation testing, because that's a problem often with commercial electronics, and it failed. It wasn't a clear hard failure. It was a you've now got a 4 percent chance that your hard drive is going to fail before the end of the 14-month mission. Do we really want to fly with a 4 percent chance of losing the mission and not achieving our objectives?

That was a hard conversation and we looked at other options. Our avionics lead had a preliminary design ready to go for a solid-state, more conventional chip-based solution, and that's what we ended up going with. But those were really the only choices we looked at. He had something, it fit, he was going to be able to meet the schedule, so we just added it to the design and we kept going.

If you spend an extra week doing some analysis and you come up with another solution that gets you a little more performance, so what? You've lost a week. You're still meeting requirements. You're still meeting cost. But you've just lost a week of schedule. Once you have a solution that meets cost, schedule, and performance, you're done. Doesn't matter if there's a better solution.

Certainly, if there's a lot of risk associated with that you might want to look at other options. But yes, like I said, that's just the mindset that you have to have. Really I think we should do all of our projects with fixed launch schedules. That was the culture I learned on Small Explorers, even though we had the ability maybe to slip launch dates. Actually, FAST only had a six-week window every year, but the other missions could have slipped. But Jim Watzin drove home the idea that we had to hold schedule to stay in the cost box. In order to hold schedule, we had to decide, "well, how are we going to do that?" If we skip this test to save schedule, what's the risk associated with skipping that test? Is there some way to reduce some of that risk?

On Small Explorers we were doing faster, better, cheaper back in the '90s when faster, better, cheaper was cool. But the way we were doing faster, better, cheaper was we're going to hold schedule and we're going to figure out a better way to reduce the risk and still meet the performance.

A lot of other people doing faster, better, cheaper in the '90s were saying, "Oh, we don't have time for that test so we're going to skip it." They just kept going without really understanding the risk that they were incurring and deciding if there was some other way to retire that risk. We brought that culture to LRO, to continue to do that. I forget what your question was and whether I answered it.

JOHNSON: That was actually the next one I was going to ask you about, is balancing schedule against technical risk and how do you keep on a tight schedule but without compromising that technical integrity and risking things.

EVERETT: We had multiple times where Craig sacrificed schedule to avoid a risk that would manifest after launch, to avoid losing the mission or losing an instrument. We accepted risks that would manifest prior to launch. If we were taking on some risk but the failure would manifest prior to launch, that was okay. If the failure was not going to manifest till after launch, we needed to look a lot harder about that and we did not take risks as much in that case.

As an example, on the Diviner instrument the mechanism on there—so the instrument rotates around and it's got a mechanism—the mechanism was being made by a subcontractor and it was a rebuild of something they had built before. They used the same test fixture that they had used before to mount it to the vibration table to do the vibration test on it. Turned out that the test fixture had been used for something else in between, and it had been modified a little bit, and so the fasteners, the screws that they used, the bolts to bolt it onto the test head, were too long for the new setup, where they had hogged something out or whatever. The bolt went through the bottom of the place where the bolt is and into a lubricated part of this mechanism. We basically created some debris inside the lubricant in this mechanism.

We had two options. One, go in through the hole with a vacuum cleaner and clean out whatever we could of the debris. Or tear open the mechanism, clean out all the grease, and repack it with new grease. We chose the path that was going to cause a month of delay because the other path was going to leave us with the risk that the instrument would get up there and some piece of metal would get jammed in the gears and stop the instrument.

There were several places like that where we made the choice. We had a layout issue on one of our boards where the part was too close to a trace. I don't think it even shorted out. I think the technician spotted it and said, "Hey, we got a problem here. The only thing keeping it from shorting out is the solder mask that's on the layer of metal there, which you can't really rely on."

We looked at several options including flying as is, we opted to re-layout the board. That was for our reaction wheels. There were a couple times like that where we made decisions for the integrity of the mission. Like I said, it was, generally, is it going to manifest before launch or after launch?

JOHNSON: We've talked about it a little bit, but let's talk about the addition of the LCROSS mission to LRO and how that affected the schedule. You added another team that you were working with. How did that get integrated? How did those teams work together to make sure everything was integrated and it didn't affect LRO and the launch vehicle?

EVERETT: When we switched vehicles Headquarters went out with a competition and then selected LCROSS to fly with us. We weren't involved with that process at all. I don't know if we even were able to insert any requirements associated with contamination control or anything. We ended up with LCROSS. The one area was the launch vehicle. The guy on my team, Tom [Thomas M.] Ajluni, who worked the launch vehicle interface, spent a lot of extra time in meetings making sure that LCROSS wasn't doing anything that was going to be a problem for LRO. That's where most of the interface was focused, in that one person in that one environment with the launch vehicle ICD [Interface Control Document] and making sure that our requirements all got captured in the launch vehicle ICD. But the other thing interesting that happened with LCROSS is somehow they bid using our avionics on their spacecraft, like a copy of our avionics, because our local contractor who was building the boards and stuff for us was going to just like make another copy for them.

Without anybody asking us, this extra burden ended up on our contractor who was building this hardware for us. They bid it. They were involved with it. We were not involved with it. That created a little bit of friction, but it was handled. We had one interface with the project, Craig and Cathy had one person from the Ames team who came and worked with us, and we worked through. At any rate, that helped a lot to just have a point of contact, and we worked through.

Craig was very collaborative, and so he built the relationship. He could have taken a completely different tack with all of that. He could have said, "You guys didn't consult us. This is your problem. We're not helping you. We got our own problems." But he did whatever we could. We created an environment where we were doing everything we could to make sure they were successful too.

It took a little while to build that relationship but by the time we launched everybody was a big happy family. But the interaction with me was very minor. I had very little interaction with the LCROSS team. Like I said, Tom handled most of the interface issues, and then Craig and Cathy had some programmatic issues associated with the fact that they were using some of our avionics designs and some of our build capability.

I feel like somewhere along the way the fact that they were building another copy, I think some things came up where maybe they spotted something that we hadn't spotted that helped us catch a problem that we worked through. It worked out fine.

They did not impact our launch schedule until the very end. There were two windows each month, and one window was much better for them than the other window. The two windows were for us, for the lighting conditions that we wanted. Headquarters said, "All right. If it's not optimum for LCROSS we're going to just move to two weeks." It was basically a two-week slip that they induced at the end. It was very annoying after being ready to launch for a while to have another two weeks imposed on us.

My family had planned—when our launch was in April, we planned a trip to the Grand Canyon in June. I had the whole thing all laid out, a two-week trip we were going to do and visit the Grand Canyon and the areas around there. Then the launch slipped, and we had to cancel all those reservations. We had done everything but the airline tickets. We ended up canceling all of that. We ended up going on a cruise to Alaska in August, I think that was what we ended up doing. My older daughter graduated from high school that year, which was another thing. I told the project, "I don't care when we're launching. I'm going to my daughter's graduation. It's on this day in May. You guys need to schedule around me if you want me there."

JOHNSON: You do have priorities. We actually did that Grand Canyon trip after my daughter graduated. It was a good trip. Hopefully you got to go back and make it eventually.

EVERETT: My kids haven't been to the Grand Canyon yet. But my wife and I just went this year.

JOHNSON: It's amazing. Were you there for the launch? Did they go around your schedule enough that you were actually able to?

EVERETT: Like I said, the team was pretty burned out late in the game. Craig basically handed a lot of the operations off to Cathy. Cathy had a lot of experience on the ops side in some of her former work. She had certain ideas about how things should run, and she and I had a little bit of friction in a couple of places there. But that's all history now.

At any rate, I ended up at Goddard for launch, so that if there were any issues right after launch, it was me and my two deputies, the three of us were the three shift leads for the early orbit operations. We were in for each of those. She had me on the backshift, which I was very annoyed about. But Martin [B. Houghton] and Rick [Richard S. Saylor] had done all the planning for the operations and the commissioning of the instruments. They understood all of that part.

I was in the ops center here at Goddard for launch and watching. We had three launch slots available to us, three instantaneous launch opportunities in a 20-minute window, and we ended up using the very last one. The weather was iffy. I forget if there was a boat. I don't know. The weather was certainly iffy, but we ended up pulling it off on the first day.

We launched. Everything went well. I was on shift for powering up the spacecraft, then I was on shift like 24 hours again later. I stuck around for the launch and then I went home and went to sleep so that I could come back in for the late shift.

JOHNSON: Talk about experiencing that as far as the success of the launch. Maybe because LCROSS was with it, I know LCROSS got a lot of attention from the media and people seemed to be more aware of what was going on with LCROSS. I don't know if they were as aware what LRO was doing, or that it was also viewing what happened with LCROSS later. LRO was monitoring it. That attention seemed to be more focused on what they were going to do. Or did you feel that?

EVERETT: LCROSS's impact was like months later. It wasn't right after launch, so I didn't feel that. I didn't feel that at all. We launched and we had worked for four and a half years. Not necessarily me. But we got funded in 2005, we launched in 2009. It was a relief for the whole project. Let me just back up a little before the launch.

We shipped in February. I went down with the spacecraft. I was down in Florida like two weeks out of four up until like May or late April. I was down there. There might have been three-week stretches or so, but it was easy to come back. It wasn't like being at Vandenberg [Air Force Base, California, now Vandenberg Space Force Base] when I did the Small Explorers and you couldn't come home for a weekend. When I was down there, I could come back for a weekend now and then.

I spent a lot of time in Florida. There was a core team that spent a lot of time in Florida getting the spacecraft ready for launch, doing the final checkouts, getting it fueled and all set to go on the rocket. I was down there through all of that. Then I had a minor health issue. I had a hernia and I had to come home for surgery. Then I didn't go back down after that. That was like late April. I missed the fairing encapsulation. It was kind of disappointing that I didn't get to see that and didn't get to be in any of those pictures. I missed the fairing. That's my favorite thing, to see the spacecraft half in the fairing. You're there. You're ready to go.

I wasn't down there for the launch or any of the parties right around launch. One of the things that I haven't talked at all about was the Tooley vortex and the party atmosphere associated with the project. We worked really hard and we played really hard. It was part of the camaraderie of the team. To finally see it launch and finally gone, it was a relief. But we went to the Moon in five days, so launch was not the end of it. We had to do a course correction maneuver 24 hours after launch, and then we had to do a lunar orbit insertion burn that lasted 45 minutes to get into orbit around the Moon. We needed to get in like 25 of that 45 minutes to be in orbit around the Moon and get some kind of mission.

That was our focus from the moment the spacecraft was launched, getting it checked out and getting that course correction burn done, and getting set up and getting all the planning done for the lunar orbit insertion. The big relief was the lunar orbit insertion. When we got past that point where the burn had been long enough and we were in orbit around the Moon, that was a huge relief. That was the big event. The whole burn went successfully, and we got to the end of it. We were in a nice safe lunar orbit.

Then from there like I said I was working the backshift, so I didn't get to talk to people much for the next couple months. I was working with all the other people that were on the backshift. They weren't most of our leads. But I don't know. It feels like a letdown. Because we had so much fun doing the project. Then you're done and it's over. But you made it and you accomplished it. It's really bittersweet.

JOHNSON: What were you doing on that backshift for those weeks or months afterwards? Was it just monitoring, making sure everything was working correctly?

EVERETT: Yes, looking at the telemetry, looking at everything, making sure it was working the way I expected it to work. Asking people, "Hey, did you see this? Is this right? Is this working the way it's supposed to?" Just keeping an eye on things.

I could look at what the plans were coming up and making sure that all made sense. But the folks running things, they're the ones that had planned that all out. I wasn't really a part of that. I was making sure the hardware got built, and got built right.

It's interesting because I put so much energy into it, and I was tired. The break that I got having the minor surgery, it actually came at a really good time, because then I could go into the launch and operations having actually taken a little bit of time off. LRO was the only time that I've been at NASA—I've been at NASA 31 years—it's the only time that I ended up exceeding my use-or-lose limit and getting leave extended. It's the only time that I had leave extended. I'm generally pretty good about taking my leave.

But LRO took a lot of time, but I had a lot of fun doing it too. Everybody else was kind of in that boat. I don't know who else you've talked to and what you've heard about some of our holiday parties.

JOHNSON: I haven't heard anything about those.

EVERETT: And travel. The warning that new people on the project got was to watch out for the Tooley vortex because if you were on travel with Craig, he just had a way of saying, "Let's stay out a little longer. Let's go to one more bar." We didn't do anything illegal. There was a potato cannon at the launch site that got made.

JOHNSON: That sounds intriguing.

EVERETT: There was nothing destructive. Nothing terribly illegal.

JOHNSON: It sounds like a special team, like you said at the beginning that your coworker said he'd never had that much fun on any other team or project. Probably led by a special person. I'm sure he had a lot to do with it.

EVERETT: Oh yes.

JOHNSON: We've gone about 2 hours, and I still have some questions. But if you'd agree to come back and talk to me again, we can finish up on this.

EVERETT: Sure, I'd be happy to do that.

JOHNSON: Okay. I appreciate you talking to me today.

[End of interview]