DISCOVERY AND NEW FRONTIERS ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

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INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is August 7th, 2024. This interview with Dante Lauretta is being conducted for the Discovery and New Frontiers Oral History Project. The interviewer is Sandra Johnson. Dr. Lauretta is in Tucson [Arizona] today talking to me over Microsoft Teams. I appreciate you agreeing to talk to me today. I want to start by asking you about your education and how you got interested in cosmochemistry and hunting asteroids.

LAURETTA: Thank you for inviting me. It's a pleasure to be here and to provide this history. I went to the University of Arizona as an undergraduate. I started in 1988 and I graduated in 1993 with a Bachelor of Science in math and physics and a Bachelor of Arts in oriental studies focusing on Japanese. I received a NASA undergraduate Space Grant research opportunity[1] when I was a senior at university, and that was what really launched my interest in planetary science and space exploration.

Quite honestly up to that point I never even thought it was a career option. It didn't seem like a real thing that you could spend your life doing. When I found out that it was, I knew that's what I wanted to do. I was assigned to a project called the Search for Extraterrestrial Intelligence or SETI, which was funded by NASA in the early 1990s as the High Resolution Microwave Survey Project. My job was to work with Professor Carl DeVito in the math department to think about

[1] National Space Grant College and Fellowship Program

how would we communicate with another intelligence if we were actually to succeed. How would you establish a language? How would you communicate science and, even harder, culture, and so forth. It was a really awe-inspiring thought-provoking project for an undergraduate student and it got me thinking about life elsewhere in the universe. I thought that's what I wanted to do—to focus on SETI.

Unfortunately it was canceled by Congress in 1993. I thought that was a terrible decision. But a lot of my colleagues, especially my mentors, my professors, recommended against pursuing SETI as a career option because it wasn't really viewed as legitimate science. It would be kind of a career dead end.

But the passion was still there, and so I decided to figure out a way to continue to explore those kinds of questions. I settled on trying to understand planet formation. In the early 1990s we didn't know about extrasolar planets. The only planets that were discovered were those in our own solar system. It was a matter of debate whether planets were common, whether planets were unusual, whether the solar system was unique. I thought, what a great problem to go after to solve. It was very timely because the first extrasolar planet around a solar-like star was announced in 1995, just a few short years later.

That really ignited interest in planet formation. The extrasolar planets that were being discovered were really weird. They were very large, Jupiter-sized objects, very close to their host stars. This was not what we expected from our models of solar system formation, which was that the giant planets like Jupiter and Saturn have to form in the outer parts of a solar system because that's where the ices are stable, and ice forms a large mass reservoir to accrete a core that can hold on to the atmosphere of hydrogen and helium.

I went to pursue my PhD at Washington University in Saint Louis, working on the chemistry of the early solar system and trying to understand how did the Earth and the other planets get there. There's a group of chemical compounds we call the volatiles, things that are generally not stable in solid form at high temperatures like the inner solar system experienced. Examples of volatiles are water, carbon compounds, nitrogen compounds, and sulfur, which is what I studied for my PhD thesis. How did the planets get these materials in?

I worked on sulfur for several reasons. One, it's a major element. It controls planetary evolution, in particular the process of differentiation and core formation. If you have a lot of sulfur in a planet it'll melt at lower temperatures and the core will form more easily, and it'll drive volcanism and plate tectonics. It was also an element that was important for life, and I was still interested in extraterrestrial life. Sulfur is one of the big six biogenic elements. I thought it would be cool to understand how it got incorporated into planetary systems.

I did an experimental thesis making sulfide minerals under the conditions of the early solar system, and then comparing them to meteorites, which are remnants from that era that give you indication of chemical reactions that took place. It went really well. I came up with some interesting discoveries. I was able to constrain conditions in what we call the protoplanetary disk, which is the giant disk of gas and dust from which our solar system grew. I got more and more interested in trying to understand the origin of habitability and the origin of life.

Habitability, really, we thought meant water. How did water get to the Earth? Life meant carbon and organic molecules. I continued to study meteorites, but it turns out the meteorites that are enriched in water and in carbon compounds are very fragile and they're very susceptible to terrestrial alteration, including by microbes. As you're trying to get into the details of the organic chemistry and looking for things that are useful to biology, you run into contamination issues. That's really when the idea that we had to go get a sample from an asteroid took hold.

JOHNSON: When was that?

LAURETTA: I moved on to a postdoctoral research associate position at Arizona State University in 1997, and I was there for four years. That's when I started to work on these volatile-rich organic-rich meteorites and started to do work on astrobiology.

The timing was really good, there was a huge announcement in 1996 from scientists at NASA's Johnson Space Center where they claimed to have found signs of ancient life in a meteorite from Mars that was recovered in Antarctica. It was hotly debated. The whole community was fired up. There was a large pushback on the conclusions. But it revealed a lot of ignorance in our discipline—the extreme conditions for life, the sizes that life could exist at. Because a lot of their purported microfossils were smaller than anything we knew about on Earth. Just as a good lesson learned, once we looked, we did find nanobacteria that are of the size of the purported fossils that they found in the Martian meteorite. It led to new discoveries just by putting out that bold idea.

It also got the Agency interested in the field of astrobiology. In 1998 NASA launched the Astrobiology Institute and Arizona State University, where I was doing my postdoc, was one of the awardees. It was great because now I was in the center of an astrobiology community. The idea of looking for life on Mars and around some of the satellites of Jupiter and Saturn was being more and more legitimized. I thought this is perfect, this is the right time to move into origin of life.

Instead of just what I would call cosmochemistry sensu stricto, which is looking at minerals and looking at isotopes, you're now looking at astrobiology, which is how do those minerals, how do those compounds transform into something that's alive. We have no idea. It's still a huge scientific mystery, which is great, because that means there's lots of work to go and do.

JOHNSON: You left there though and went to the Lunar and Planetary Lab at University of Arizona in 2001.

LAURETTA: That's correct, I finished my postdoc and then I was hired as an assistant professor in the Lunar and Planetary Laboratory and the Department of Planetary Sciences at the University of Arizona in 2001.

JOHNSON: Talk about that time period and what you were doing. I know Dr. [Michael J.] Drake, was there and you were working with him at that point.

LAURETTA: Yes. Mike Drake was the director of the Lunar and Planetary Laboratory and my boss. He was the person that I interviewed with primarily. I interviewed with the whole faculty and the dean and all that, but Mike was really who I was trying to impress and who was the decider on all of that. Yes, we hit it off really well.

He was also a cosmochemist. He did laboratory experiments. We had a lot in common. I was building an experimental laboratory. He was really excited about that. We became good colleagues and he was a strong influence on me, a great mentor who really taught me a lot. Not just about science but about life, management, and business, and being the director of a lab and all of the work that it took. We became quite close, quite friendly. He was a huge advocate for me, helping me get established not only at the university but in the bigger community.

JOHNSON: Was he already talking about going to an asteroid and trying to put something like that together? Were you aware of that before you got that phone call from him? I read about that phone call when he wanted you to come to a meeting.

LAURETTA: Yes. That famous phone call. No, in 2001 he wasn't really thinking about asteroid sample return. The lab was focused on winning a mission in the Mars Scout Program, which was a short-lived program, similar to the NASA Discovery Program, where it was PI [principal investigator]-led, competitively selected, but focused on Mars exploration only.

We were in the finals. We were downselected as one of four possible missions. Our mission concept was called the Phoenix Mars Lander. It was being led by Peter Smith, who was known in the lab and in the community for building the imager for the Mars Pathfinder camera system. We won. We won that in 2004. That was a big deal for the laboratory because it was the first time we moved from providing instruments to NASA flight programs to being in charge of a mission, leading one of these PI-led Mars Scout missions. That was where Mike's focus was, making sure the lab could support that team, making sure the lab was competitive and had the resources that they needed to successfully bid and win that project.

Our aerospace partner was Lockheed Martin. They were building the lander. The NASA center was the Jet Propulsion Laboratory in Pasadena. What happened was in 2004 Lockheed was really excited by that partnership and by that win. They came to Mike and said, "We are working on an asteroid sample return mission concept, and we're thrilled with the success of the Phoenix

Mars Lander and how well that proposal process went and of course the exciting mission that's ahead of us. We want to partner with Arizona again on the asteroid mission." They wanted Mike to be the principal investigator.

He was the director of the lab at that point almost 20 years. Very well known. Serving on the NASA Advisory Council. Heavily involved in Agency priorities and in Washington, DC, working with NASA Headquarters. He was well known there. They thought, and rightly so, he was an excellent choice to put forward as the principal investigator for that program.

We thought we would go back to JPL. Just the same team that had won the Phoenix Mars Lander concept. That would make a lot of sense. But it turns out JPL and Lockheed Martin had a falling out over the asteroid mission. That's what sent Lockheed to Arizona. They said, "Well, JPL kicked us off the asteroid sample return mission. But we've done all this engineering work. We have all these concepts; we don't want to give up on it." Because the company had invested a lot of resources.

For the first proposal they wanted to go it alone, just Arizona and Lockheed, with no NASA partner. That turned out to be a bad idea, but that was the approach. Mike knew at that point that in order to sell it to the Agency it had to be astrobiology focused. It had to be connected to the habitability. How did the Earth become a habitable world? And origin of life. He didn't do that kind of research. He was thinking about core formation and high-pressure experiments and planetary interiors. Magma oceans. Early stages of planetary evolution. But he knew that's what I was doing. I was working in the laboratory. I had an outstanding graduate student, Matt [Matthew] Pasek. We were working on phosphorus chemistry. Phosphorus is another essential element for life. It's used all over biology. It's rare compared to carbon and hydrogen and nitrogen and oxygen and even sulfur. It's interesting where phosphorus came from. How did it get into biology?

Matt and I were doing really well with that experiment. We had some big successes. It was named a top 100 science discovery by *Discover* magazine, which was great for an assistant professor and his graduate student to be getting that kind of recognition.

I think that's what led Mike to call me. He knew it would be important for the lab to continue to compete and hopefully win these PI-led missions. Because it brought a lot of resources. It brought a lot of prestige. It brought a lot of personnel. Laboratory upgrades. All kinds of things come along with running a program like that that just benefits the entire laboratory. He thought yes, asteroid sample return would be a big next step for us.

But if we were going to go into the astrobiology organic cosmochemistry area, then that's what he needed me for. That's what led to that phone call where he said, "I'm talking with Lockheed Martin. We're thinking about bidding an asteroid sample return mission. We want you to join us." He invited me to be the deputy principal investigator.

JOHNSON: Talk about that and when that first started and working toward answering that announcement of opportunity. It was OSIRIS at that point, not OSIRIS-REx [Origins, Spectral Interpretation, Resource Identification, and Security–Regolith Explorer]. Talk about going through that process, joining them, and who the team was that you were working with. I know you mentioned Lockheed Martin. But you didn't have a NASA center with you at that time. Is that correct?

LAURETTA: That's correct. Lockheed wanted to really try to change the model and come up with a management structure that would be successful, that would be cost-effective, because these are cost-constrained missions. We were bidding in the Discovery Program at the time. It was a very low budget. Looking back, I believe it was cost-capped at $335 million including the rocket. It was a really really tight squeeze for what we were trying to do with returning a sample from an asteroid.

We worked on that proposal. That was in February of 2004 when I got the call from Mike. By March we were putting together a science team. We gathered at the Lunar and Planetary Science Conference, the LPSC, which is a big planetary science gathering every year near Houston going all the way back to Apollo 11, 1969 was the first Lunar and Planetary Science Conference. Getting ready for those samples that were coming back from the Moon.

That was moving fast. We submitted the proposal within months. I think we spent a total of five or six months writing the document. I spent a lot of time in Littleton, Colorado, which is where the Lockheed Martin facility was that we were working with. Ben Clark was involved. Ben is a legendary planetary scientist at Lockheed, who has been involved in exploration at least going back to the Viking missions and probably earlier than that. He was one of our big advocates at Lockheed for the concept.

It was a small team. There was probably half a dozen of us that were really working on the idea. Despite having all of that engineering effort, it still seemed pretty nascent to me. It was a very immature concept. They didn't know really anything about asteroids. That was part of what we were doing.

I didn't know a lot about asteroids either. I knew about meteorites, which come from asteroids. I knew about the samples, and I knew about laboratory work and how you study samples. But actually finding asteroids, characterizing their orbits, characterizing their physical properties, I was pretty naive about all of that. I reached out. We fortunately have a lot of expertise in Arizona in that area. To start learning about how you pick an asteroid target.

We kind of just grabbed one off the top of the list. Lockheed had put a list together of accessible objects. We said, "Well, we don't know enough about it. Let's just go with the easiest one." That was a mistake scientifically because it wasn't really well justified why would you go to this asteroid in the first place.

That proposal was submitted probably around July. I could look up the actual date if I go back into my archives. It just tanked. We got what's called Category IV which is the lowest ranking that a mission concept can get.

NASA didn't select anybody in that competition. It was interesting. They picked an instrument called M3, the Moon Mineralogy Mapper, that was being led by Carle [M.] Pieters out of Brown University. That was going to be contributed to a mission from the Indian Space Research Organization, ISRO, and their Chandrayaan[-1] lunar orbiter. No mission was selected. Instead an instrument was selected to support a mission in India.

But we felt good about it. We felt like the spirits were high. We felt like it was an important mission and that we were on to something. We had a big list of major weaknesses but we took those to heart and we said, "The review team did spend a lot of time with the concept and they gave us a lot of feedback on what generally was the concern. But overall they were enthusiastic about the idea. Yes. Asteroid sample return is a high priority mission, and if you can do it right it could be very competitive."

They hammered the management plan. They said, "Not having a NASA center is a huge risk. Not that you can't do it." They wouldn't say you couldn't do it. But that it wasn't compelling, the story that we put forward wasn't a compelling story. I think rightly so, because Lockheed Martin was going to be doing project management as well as the flight system and operations. It did look like the fox watching the henhouse a little bit.

We agreed. We went back to JPL and said, "Okay, we're getting ready for another round of Discovery."

They said, "No, we're going to back another team," that they'd been working with based at the University of Arkansas.

We said, "Okay, thank you."

But we needed a NASA center. We went to the NASA Goddard Space Flight Center in Greenbelt, Maryland. Ed [Edward J.] Weiler was the Director of Goddard at the time. He knew Mike really well. They were colleagues and had interacted on those advisory committees and other Agency assignments that Mike would do.

He loved it. He loved the idea. I knew Goddard wanted to compete in planetary science and that had traditionally been JPL's purview. There was a lot of animosity that grew out of the partnership and the idea that Arizona was now partnering with Goddard and Goddard was now pursuing planetary science. JPL wasn't happy about that. They let us know that pretty regularly, that we had switched teams basically, and that we were going off. But we were like, "Well, it's the only option we have, and it seems great. Goddard is really all in. They're very enthusiastic. They're providing a lot of resources. They're providing a lot of technical support and expertise and making the mission much stronger and better."

That was the new partnership for Discovery 2006. I can't remember which one it was. I think Discovery 11. It was a whole different scene. We came up with a great target. What is now known as asteroid Bennu, the one we actually eventually flew to. We picked that asteroid as the mission target in 2005 as part of that proposal development. It did a close approach to the Earth in [September] 2005 and we were ready. We rallied the astronomical team. By this point I was somewhat knowledgeable about asteroid astronomy and how you find asteroids and characterize asteroids and was working with an individual at the University of Arizona named Carl [W.] Hergenrother, who was an asteroid astronomer and an expert at characterization and orbit determination and discovery. He became the asteroid astronomy lead for the mission and also my teacher. How I learned about asteroids. Especially how you observe them using astronomical techniques.

It was a great target. It was really exciting. Looked like what we wanted, going to be rich in water. Rich in organics. To cut to the chase, now that we have the samples, that all was true. It was all right. We nailed it. It was really really exciting. Much stronger scientific case.

The engineering grew by leaps and bounds. I was surprised by the number of major weaknesses we received on the 2004 proposal in the engineering side of it. But we took it to heart and I became really good friends with a system engineer at Lockheed Martin named Calvin Craig. He was outstanding. He was very enthusiastic about the mission. The two of us kind of taught each other. I taught him everything I knew about asteroid samples. Sample analysis. What kind of cleanliness requirements we would need on a sample. The science rationale for the mission in general.

He taught me all about how you build a spacecraft. How you start with your requirements, how you start to flow it down to your different subsystems. How you look at heritage components across everything Lockheed Martin has ever done. Also anything that NASA has ever flown that might be relevant. Just start to study the field and see where can you use tried-and-true technology and where do you truly have to have development because you're doing something that nobody's ever really tried to do before.

That was a winning combination. Goddard, Arizona, Lockheed Martin. We made it through the first gate, which is the end of Step 1, which is when you submit the proposal, and then you get selected for what's called Phase A. Phase A is the concept study phase. NASA gives you some support for the first time. They're putting some resources behind your team. It was around $1 million. We had one year to push the concept forward.

There were two other missions that were in that same situation. NASA picked three. One was called GRAIL [Gravity Recovery And Interior Laboratory], which was a dual spacecraft to go and map the gravity field of the Moon to enormously crazy high precision. The other was called Vesper, a Venus orbiter, which was going to be a follow-on to the successful Magellan mission that NASA had flown in the 1990s.

That was what we were up against. NASA was going to pick one of those three. It was asteroid, Moon, Venus. It was a really thrilling time. The team grew. We were probably a couple dozen people by then. Bringing in more discipline experts. Especially in some of the engineering challenges. We knew sample collection was going to be the big technology development and we were starting to really work on the concept for how to collect the sample.

The Goddard-Lockheed-Arizona group just came together and became OSIRIS. We were a team. We were focused. We felt really positive. We lost in 2007. We found out that NASA had selected GRAIL. Rightly so. It was a great mission. It was low risk. The technology was already developed and was flying around the Earth. A mission called GRACE [Gravity Recovery and Climate Experiment]. It was low-cost relatively speaking. The science return was going to be really important for any future Moon initiative.

But NASA was really enthusiastic at that point. They said they wanted to select us. The science was very compelling. The engineering was really strong. The cost was where the big concern was. They just didn't feel that it would fit within the Discovery Program. It was too challenging of a mission. The cost was not credible.

They tried to consider things like could they launch with the same vehicle that was launching GRAIL and save money that way. In the end there was just no way that OSIRIS was going to fit in the Discovery Program.

We were dejected at that point. Three years of effort. Intense effort. This isn't something you do as a hobby. This is a full-time job. On top of all my other commitments of being an assistant professor and teaching and advising graduate students and setting up laboratories and all that. But we really felt strong. We put a great concept study together. It was an impressive document.

This is where Mike Drake really went to work, because he knew the New Frontiers Program had now come into existence. It was how they solved the Pluto problem. There was a strong interest in getting a spacecraft to Pluto. It was time-dependent because of the orbital dynamics. It became the first mission in New Frontiers, which was modeled on Discovery but higher-budget, riskier, more challenging targets were accessible.

We had worked as part of a team for New Frontiers 2 on a mission called MoonRise, which was going to return samples from the South Pole-Aitken Basin of the Moon, which is really interesting for Moon formation and interior of the Moon. It was great because I could do some sample science with it. We lost that to Juno, which was a Jupiter orbiter. But Mike knew a lot about the program and he said, "We need to get into New Frontiers. That's going to solve the cost problem. It is a New Frontiers-class mission because of the challenges that are ahead of us."

The National Research Council through the Space Studies Board was launching a new study to determine what should be possible targets for New Frontiers 3. That's where Mike started to really make the case to the community that sample return from a carbonaceous asteroid should be a New Frontiers-class mission. OSIRIS is mature. The cost is where we're challenged and that's exactly what New Frontiers would open up.

Sure enough, the Space Studies Board was receptive to that idea. In 2008 they released a document that identified the targets that would be eligible for the New Frontiers 3 mission opportunity. Carbonaceous asteroid sample return was one of them. I knew right then that it was ours because I thought, "We just rolled off a Phase A study that got very high marks in everything except cost. New Frontiers is going to open up the cost box quite a bit." We were in the pole position. It was a really exciting time. Then we went for it. We went in for New Frontiers 3.

JOHNSON: Talk about the differences between going for a Discovery mission proposal and then going for New Frontiers. Of course more money as you mentioned. But as far as doing the proposal, were you using the same team and basically the same proposal and just adding more to it? How did the mission change from Discovery to New Frontiers?

LAURETTA: The core team stayed the same. It was still Arizona, Lockheed Martin, and Goddard Space Flight Center. That was the three. It was a really powerful combination. I think whenever you get the government, industry, and academia to all work together, they each bring different perspectives and different strengths. That's the whole scope of talent that you need to fly something like this. It was really strong, and so we rolled forward.

We basically took the same approach we did after the first one. The proposal wasn't perfect, and we got a list of weaknesses. We started to work each one. Everybody got assigned a weakness. You are in charge of turning this into a strength. That was our strategy. Take the weakness. Make it a strength. Now you know the review board is concerned about this area. Dust contamination was one. Are you going to get dust on your solar arrays? Are you going to get dust on your optics? Is it going to make the mission infeasible? That's just one example of the long list of things that we had to go and solve.

We had a lot more capability because not only did the cost cap increase, but the launch vehicle that was available was more capable. When we were designing for Discovery, we were planning on a Delta II rocket, which is a smaller class of launch vehicle. Now we were eligible for Atlas V or Delta IV, which were capable of larger masses to launch on our mission. We were able to put more fuel on. We were able to grow the spacecraft overall.

The other thing that we were able to do, when we were proposing Discovery, cost was driving everything, and we were bare bones. There was a lot of risk in the approach we were taking. We had cameras, a sample collector, and that was it. It was like go there, take pictures, grab a sample, and come home. Now we were like, "We can do a full remote sensing campaign at this object and really provide the geologic context like you should for a sample return mission."

One of the big reasons you return a sample is so you have the context. Where did this thing come from? You don't have that with meteorites. They're random. You don't know where they came from, which asteroid, how long they've been in space. Although you can start to figure that out with sample analysis. Now we would know exactly how long the sample had been away from the asteroid.

We added a lot of instruments, science instruments. We added a visible and near-infrared spectrometer. Goddard Space Flight Center was providing that based on their successful Ralph instrument on New Horizons.[2] Arizona State University was providing a thermal emission spectrometer based on the very successful mini-TES [Thermal Emission Spectrometer] instruments which were on the Mars Exploration Rovers. The Canadian Space Agency was brought in to provide a laser altimeter as a contribution building on their heritage from the Phoenix Mars Lander where they had an atmospheric lidar on board. The camera system grew in capability and was being provided by the University of Arizona, building on our Mars Pathfinder heritage and also our Cassini Descent Imager Spectral Radiometer heritage from the Huygens probe that landed on Titan. We got a lot more capable science at the asteroid.

What we really learned was the challenge is in flight dynamics and navigation. You're trying to operate and achieve very precise locations of your spacecraft relative to the asteroid. That requires an enormous amount of planning, an enormous amount of orbit determination and orbit reconstruction. The flight dynamics team grew, and we were working with a commercial outfit called KinetX Aerospace, which turned out to be a great choice, and they came in as the flight dynamics lead on the program as well.

JOHNSON: Talk about when it was chosen. You first were named a finalist. Is that when they gave you more money?

[2] New Horizons was the first spacecraft to explore Pluto up close, flying by the dwarf planet and its moons in 2015. It then passed its second major science target, reaching the Kuiper Belt object Arrokoth in 2019, the most distant object ever explored up close.

LAURETTA: Yes. We made Phase A. It was December of 2009 when I got the phone call. It was right in between Christmas and New Year's. I was sleeping in because the university was on break. The proposal had been submitted and we didn't think we would hear from NASA until the new year. But I got a phone call from Tom [Thomas H.] Morgan, who was the program scientist for New Frontiers. He said, "Congratulations OSIRIS-REx." We were now OSIRIS-REx. I don't think we talked about that. But we changed the name for New Frontiers from OSIRIS to OSIRIS-REx to indicate it's a bigger, stronger, more capable mission than a Discovery-class mission but still acknowledging our Discovery heritage for all the work we had done in that program.

I was a little concerned that he wasn't calling Mike. Mike was the principal investigator. I was the deputy. It turned out he couldn't get ahold of Mike. Mike was in the hospital. Mike had gotten very ill and was battling liver failure. We just found out. I found out about it really at that moment. I asked, "Why aren't you talking to Mike?"

He said, "I couldn't get ahold of him."

I called his wife right after. "Hey, I need to talk to Mike. We got some great news from NASA." It was a bittersweet moment because we were doing really well. We were Category I, which is the highest category you can get. A big jump from the Category IV from that first time. We were doing really well.

We found out the other two missions. Interestingly it was MoonRise again, the lunar sample return mission that we had been helping as well, and a Venus lander called SAGE [Surface and Atmosphere Geochemical Explorer], which was going to go onto the surface of Venus. It was being led by the University of Colorado. Again it was asteroid, Moon, Venus. It was the same three targets NASA was interested in for their PI-led mission.

The other two were Category II missions, which are sound but not as high a priority. NASA was telling us right away that we were the top choice and it was ours to lose at that point. But our leadership situation was really precarious because Mike was seriously ill. I had to go to NASA Headquarters that January for the kickoff meeting, and Mike couldn't make it. I was expecting him there. He has been released from the hospital and was planning on making the trip. I showed up. I was staying at L'Enfant Plaza at the hotel there. I remember waking up that morning. It was a very gray dismal snowy Washington, DC, morning. Mike wasn't there, and I was like, "Where's Mike? He needs to be at this meeting."

I found out again he's back in the hospital in the ICU [Intensive Care Unit] this time and he's been intubated. They didn't know if he was going to make it through the night. I had to go to NASA Headquarters and represent the principal investigator for this mission and really not let anybody on because all the competitors were in the room too. It wasn't just OSIRIS-REx. The MoonRise and SAGE teams were also there. I had to pretend everything was great and that Mike just couldn't make it, which was odd because it was such a big deal that he wouldn't be there. But we moved forward and we had that debrief. It was the rules for how your Phase A will be implemented, how long you have, when things are due, and how you can communicate. Those rules about what you can ask. If you ask a question everybody gets informed about it. That kind of stuff was all covered there.

We spent the next year, all of 2010, working on that concept study report. It was bigger. I think we had $3.3 million from the Agency to spend on Phase A. It was great. We were just refining the concept. Everything was really strong. The cost plan was coming together really well. We spent a lot of time on cost estimation.

I dove into that. I actually loved it for some reason. I was just a numbers geek. I wanted to see how you could spend $1 billion. I was like, "Sounds like a lot of money. Where I come from that's a lot of money." How are we even going to do something like that? How are you going to manage a program of that scale? I got really interested in cost estimating. We had a lot of work going into a very credible cost plan, tied to our risks very tightly. Large reserves on the technology development items. It was we felt a winning proposal by the end of it all. We submitted that in early 2011.

JOHNSON: When did you hear that it was chosen?

LAURETTA: May 25th, 2011, we got the phone call. I was sitting on the beach with my family. I thought it was still early. We were waiting to hear back from the Agency. We had a site visit in April, which is where you go in front of the big review board and they can ask you questions all day long about anything they want related to your mission. I thought no way NASA is going to make the call this quickly. I was with my family. We were just enjoying some time off. I got the phone call from Mike that said, "NASA made the decision early and OSIRIS-REx is going to fly."

JOHNSON: That was certainly something to celebrate at that point. It was a lot of years in between.

LAURETTA: Seven years since we got that first proposal. Yes. It was a long, long journey. Just to get to the starting gate.

JOHNSON: I was reading some of the science objectives, which you've talked about some. But also one is that Bennu is one of those asteroids that we keep an eye on because of the effects that it can have on the Earth. Talk about that for a minute and what you hoped to find out about the asteroid to help NASA, hopefully, at some point in the future.

LAURETTA: Yes. When we were selecting the target, one of the key criteria was its orbit, because we needed to launch off the Earth, rendezvous, spend a lot of time there. We knew we wanted to spend time because we'd been watching the JAXA Hayabusa mission, which was attempting to sample an asteroid in the 2005 timeframe and having a lot of trouble doing it. Part of it was because they were trying to move really quickly. We thought you need to spend a lot of time at your asteroid. Then of course you have to leave the target and return back to Earth. That immediately drives you to objects in the near-Earth asteroid population as opposed to the main asteroid belt where most of these objects reside out between Mars and Jupiter.

Bennu was a great target because it's in a very Earth-like orbit. Relatively speaking it's low energy to get there, get a sample, and get back. But by virtue of that it's also very easy for it to get to us, meaning it's a potentially hazardous asteroid. It turned out as we started to study it, it's the most potentially hazardous asteroid. Meaning it has the highest probability of impacting the Earth of any object that we're currently aware of.

The odds are low, 0.057 percent, and that's a number that the mission generated, so part of our science objective was to assess the risk. What is the probability of an impact? Especially to include forces beyond gravity. We know Newton's laws and Einstein's laws. They work really well when you're trying to determine where an object is going to be in the future. But if it's really small, like less than a kilometer in diameter, then there's other forces that are substantial including sunlight and thermal emission. That's called the Yarkovsky effect. It does change the acceleration of the asteroid, slowing it down in Bennu's case. Therefore it changes where its orbit is going to take it in the future.

If you want to very accurately predict where an asteroid is going to be, and for a potentially hazardous asteroid you do want to predict very accurately where it's going to be, because it influences the likelihood of impact, then you need to account for the Yarkovsky effect. That was great because it led to a science investigation where we needed to measure the thermal emission, we needed to measure the reflectance of the surface, and then actually measure the deflection of Bennu's orbit, which we did, because we detected it with ground-based radar first in 1999, then in 2005, again in 2011, and the spacecraft arrived in 2018 and stayed through 2021. We had over a 20-year baseline. We saw that the Yarkovsky effect was changing the orbital velocity of the asteroid and therefore influencing the likelihood of an impact in the future.

JOHNSON: When you won it in 2011, as you mentioned, Mike Drake was also dealing with health issues. As deputy PI, and then you took over as PI, unfortunately in that situation, and it wasn't a good situation to be in. But in one interview I read you describe talking to Dr. Drake and saying that it was a red risk, losing him. You weren't sure how the mission was going to mitigate that problem. Talk about that for a minute, as much as you're comfortable with. How do you as a team continue that same drive forward when all of a sudden that person can't lead anymore. Talk about that effect on the team and on the mission and what you did then as the acting PI to mitigate that problem.

LAURETTA: Mike first got sick in 2009. As we were wrapping up the Step 1 proposal. He was ill throughout all of Phase A. He was in and out of the hospital. He got a liver transplant and was feeling really good. What was happening was I would step up as the acting principal investigator when Mike was out of commission. Then Mike would come back and I would step back down into the deputy role. Then Mike would get sick. There was a bit of a yo-yo going on throughout Phase A where I would be the leader and then I would be the deputy and then I would be the leader and I would be the deputy.

It was a highly uncertain state because there were many instances where Mike's health, his challenges were so severe, the doctors were warning us that he may not make it. We were constantly preparing ourselves for that. It was enormously stressful, and heartbreaking. I loved the man, straight up. He was like a father figure for me. A huge influence on my life. I learned an enormous amount from him. He helped me in my career and he helped me in my family life. He just was always there for me.

When we lost him, it wasn't a shock because he'd been ill for so long. But still you're never really ready for something like that. You try to be. But the emotional toll was enormous just on me personally. Then on the mission, because it wasn't clear what we were going to do. It wasn't clear that NASA would accept me as the principal investigator. I was still pretty young as these things go. When Mike passed away in 2011, I was 40 years old. That was on the young side for these leadership positions that the Agency usually appoints people to. I wanted to. I felt like I had led the team and I had earned their trust. We were a unit. We were very much a family. That is what the team wanted to do. First of all I had to get Mike's blessing. That was the first thing, and that conversation you alluded to in the hospital was the last one we had together.

He was having trouble talking about what would happen if he didn't make it, because it's not an easy thing to deal with. But I kind of had to force the issue because at that point the surgery was very risky that he was going into. The likelihood of survival was shockingly low. I was like, "We have to talk about this." It was really difficult to broach. When I asked him, "What's the mitigation for this risk?" He said it was me and that he was entrusting me and that I had earned it and that it was my mission and he was hoping and expecting I would take the team forward.

That gave me some confidence. Then I went to all of the partners. I went to the Director of Goddard Space Flight Center. At this point it was Rob [Robert D.] Strain. I went to the vice president at Lockheed Martin, Jim [James H.] Crocker. Basically I interviewed with them and I said, "This is what we're thinking of doing. Do I have your support?" I got a letter from Rob and I got a letter from Jim. I went to the president of the university as well, University of Arizona, and technically it's the University of Arizona that holds the PI position. That's what the contract says we will provide for the mission. The university was behind it as well.

I went in with pretty strong backing from the major partners on the mission. NASA accepted that recommendation, and I was appointed the principal investigator in October of 2011.

JOHNSON: One of the things the PI does, of course they lead the mission, but also you have to know how to work with a variety of people, a diverse team. You mentioned that it's perfect because it's the university, it's NASA, it's this company in that sector working together. That's the perfect group. But you're also working with NASA management, with whatever their backgrounds are. You're working with these engineers that are building the spacecraft. You're working with scientists, a whole team of scientists. One of the scientists I talked to said it's—and I've heard this before—like herding cats when you're working with a group of scientists. But I imagine it's like that in any group. But talk about that and as a PI what you have to do as far as communication and as far as facilitating that communication also. You mentioned Calvin Craig. You were cross-learning with him. How do you get everyone to do that with each other and to communicate?

LAURETTA: Yes. That absolutely is the key role for the principal investigator. You have to establish the team culture. Mike and I worked hard on this for seven years when we were in the proposal phase. That's one of the big things that we were focusing on. Mike has a famous quote. He says, "We're not Arizona, we're not Lockheed, we're not Goddard, we're OSIRIS-REx." It was that identity. Yes, we all have our host institutions but really this is who we are. We are OSIRIS-REx and everybody is a member of this team and everybody has an important role to play and your voice is valued.

That was one of the first things that I learned, was that you have to create this common identity and you have to remind everybody about it constantly, because you often will faction off. If there's a challenge in front of you and there's different ideas on how to approach it or how to solve it, you might see the team splintering a little bit. A lot of what I would do is shut that down right away. It's like no, we're going to solve this. I said, "I'm not worried about it. It's a technical problem and that's what we do and we're really good at it. Let's not diverge into our institutional identities. Let's maintain the OSIRIS-REx identity."

Keeping NASA Headquarters informed was always a key part of my job. Establishing strong communication pathways. For example Jim [James L.] Green was the Director of the Planetary Science Division. John [M.] Grunsfeld was the Associate Administrator for the Science Mission Directorate. I needed to have access to them and I needed to let them know how things were going. Especially I learned early on to broadcast your concerns well ahead of time. Number one rule is don't surprise your bosses and those were my bosses. Those were the people that I was responsible to, that I had committed to delivering this mission to. I wanted to make sure. We had challenges just like any mission. You're trying to do something. When you look at it it's pretty nuts. You're going to an asteroid and getting a sample and bringing it back to Earth. It's not a simple thing to do. We were going to run into challenges.

Some of them were going to have cost implications or schedule implications. I made sure NASA Headquarters always knew well in advance. That saved us so many times, because then they're helping solve the problem. They're like, "Okay, great, what can we do?" Thinking across the Agency and expertise that might be relevant that they're aware of on another program they could bring over to take a look at certain things. That was great. A big part of my job was you're the diplomat of the mission and you're keeping all your stakeholders comfortable and informed about your progress and confident the team is in good shape to solve them. That worked really well.

I also spent a lot of time on Capitol Hill. Because the budget is always susceptible to congressional disfavor. They're looking to cut things and they might not see the value in this particular program. New Frontiers is a line item in the congressional budget. I learned before confirmation, which is when you strike the final deal, which is a couple years after selection, you're at risk of congressional cancellation. I learned with my federal relations group here at the University of Arizona how to go to the Arizona delegates, how you get a key message across to them, and how you do it effectively so that they're aware of the program. "It's important to Arizona," is what you say. This is an important program for Arizona and we want to make sure that it continues. They're very receptive.

Usually you're talking to staffers, science or education leads within these offices. But sometimes, like [Senator] John McCain was a big advocate for us. [Representative Raúl M.] Grijalva was a big advocate. They would come out if they knew we were visiting and say hi and welcome us. I started to establish relationships at those levels as well, which was great because they also help you celebrate. John McCain has multiple statements on the floor of Congress congratulating the OSIRIS-REx team on certain milestones. He was a big fan of the mission and we kept really in good contact with his office throughout all of that.

That was a lot of learning for me. How do you do those kind of things? I never thought I'd be talking to senators and congressmen about what we're doing. But it was great. They really appreciated it. It was something that everybody could celebrate. Very bipartisan. Everybody was generally supportive of it. I never ran into real resistance to the program. It was just education and awareness, is really what my job was.

I do a lot of public engagement activities. I'm the spokesperson for the program publicly. Tons of media. Tons of interviews, podcasts, classrooms, other organizations like our university partners, our government partners. I mentioned the Canadian Space Agency, keeping them informed. We also worked with the Japanese [Japan Aerospace Exploration Agency, JAXA], partnering with them on their asteroid missions and inviting them to partner and become part of our mission as well.

All of these things are in the bucket of the principal investigator. Not to mention I'm supposed to be the scientist and keeping an eye on the science and getting the science done, as well as delivering the program on cost and on schedule. I'm very proud to say when we delivered the spacecraft to the launch site, we came in $55 million under budget and were able to return that to the Agency for other missions.

JOHNSON: That's amazing. Especially when the first time you wouldn't have been able to do it for the amount of money in Discovery, and they're telling you you need more. Then to come in under budget under New Frontiers. That's great.

Talk about the instruments. I know you mentioned some of the instruments but let's go through the instruments and what they were used for on the mission.

LAURETTA: It started with the camera system because those are your eyes that are out there. That was provided by the University of Arizona. It was a suite of cameras. There was the PolyCam which is an 8-inch refracting telescope, and it sees the asteroid when you're 2 million kilometers out. It's first light. You know where your target is. You can refine your approach trajectory. But it has a focus mechanism. It actually has a secondary mirror that can move. It becomes your microscope when you're up close to the asteroid surface. You can get really high-resolution shots like millimeters per pixel resolution. It's the PolyCam because it has multiple jobs for us.

Then we have the MapCam, which was the mapper. It was specialized for color imaging. It had a filter wheel. You could put in a red filter, an infrared filter, a green filter, and a blue filter. Then you could build up color images of the entire asteroid and then regions of interest.

Then the SamCam was there to document the sampling event. It's the camera that has the sample collector we call the TAGSAM [Touch-And-Go Sample Acquisition Mechanism] in the field of view when it touches the asteroid. Then it does checkouts of the sample collector after to see if you have sample that was collected successfully.

We added two spectrometers. The OVIRS instrument was the OSIRIS-REx Visible and Infrared Spectrometer that was provided by Goddard Space Flight Center. That measured the spectral properties of the asteroid surface, which is basically taking reflected sunlight and splitting it through a prism and looking at all the different wavelengths or colors of the light, and it went from the visible, 0.4 microns, out into the near infrared at around 4.3 microns. It was a spot spectrometer. It wasn't an imager. You just got whatever was in the field of view of the instrument; that's the spectrum that you collected. Then we would scan it around. We would raster north and south and the asteroid would rotate and we would map all the different chemicals and minerals on the surface using that technique.

There was a complementary instrument that went out into the mid-infrared, called OTES, the OSIRIS-REx Thermal Emission Spectrometer. That was built by Arizona State University. That measured from 5 microns out to 50 microns. That's measuring the heat that's coming off the surface of the asteroid and there's also mineralogical information in that signal as well. Similar to OVIRS, it was a point spectrometer. Whatever was in your field of view, that's what the spectrum was. It wasn't an imaging spectrometer.

The Canadian Space Agency provided the OSIRIS-REx Laser Altimeter [OLA], which had a two-axis scanning mirror. You shoot a laser at the asteroid. You measure how long it takes to hit the asteroid and bounce back and hit your detector. Since you know the speed of light you know how far away you are. Then the mirror allows you to scan all over the asteroid like a raster and build up three-dimensional topographic maps of the surface with centimeter-scale precision. All those beautiful three-dimensional data products of Bennu are from the OLA instrument.

We had a couple of navigation cameras provided by Malin Space Sciences. There were two NavCams [navigation cameras] and a StowCam, which was there to watch the spacecraft stow the sample into the return capsule. The NavCams were put into science use as well because they were very wide-field imagers and they provided complementary information to the other camera systems.

I think the star of the show was TAGSAM. That's the Touch-And-Go Sample Acquisition Mechanism. That's a 3-meter-long robotic arm. At the end of the arm there is basically an air filter [with a chamber for sample collection] that you push down onto the surface of the asteroid. Then on the forearm there are three bottles of high-pressure nitrogen gas. The strategy, it's kind of like a leaf blower. You just blow high-pressure gas into the soil and it pushes all the gravel and the rocks and the dust into that air filter in a very short-duration surface contact. Our plan was to sample for about 5 seconds. That was built by Lockheed Martin as part of the overall flight system.

Then finally you have the sample return capsule, which is the only part of the spacecraft that comes back down to the surface of the Earth. It looks like a mini version of the capsules that astronauts come back in from the International Space Station, like the [SpaceX] Dragon capsule. It's a tiny version of that. It has the TAGSAM sample chamber with the sample inside of it when it's doing its final entry, descent, and landing back down to the surface of the Earth.

JOHNSON: The sample return capsule was taken, the design and everything was very similar or taken from like the Stardust sample return capsule, correct?

LAURETTA: That's correct. Way way back in the early days, even 2004 era, we were looking at what has flown, especially what has Lockheed Martin built that has flown successfully that we could use so we're not developing new technology. Right away we decided we're going to reuse the Stardust sample return capsule design because it was successful. The parachute opened. The comet dust was delivered to the Earth. It made a great compelling engineering story.

JOHNSON: Yes. It worked really well too.

LAURETTA: Gave me a little bit of a heart attack at the end there. But eventually that parachute opened.

JOHNSON: Yes. At least it wasn't like Genesis, right?

LAURETTA: No. No. No. That was fresh in our minds because that was 2004 when that crash happened.

JOHNSON: We talked about some of the instruments and the different teams. Having quite a collection of teams. Were there any issues when you were dealing with all these different places and all these different instruments as far as working towards launch and getting things going on time? Also just making sure that all the instruments were ready in time to get them integrated into the actual spacecraft. Talk about that in-between time and working towards that.

LAURETTA: I would say the instruments were really easy to develop because the teams were very experienced. These were versions of things that had been built before. I'd say the biggest challenge was the Canadian instrument, the OLA. That wasn't their fault. That was really their funding agency, and they were having trouble getting what we call authorization to proceed, or you can start moving forward in development. We were selected in May of 2011. We were going through our preliminary design review, our early PDRs, in 2013. They still hadn't started yet. The

Canadian Space Agency had not given them the authorization or the funding to start building their instrument. I thought they weren't going to make it. I was like, "We're going to have to figure out how to fly without them." Which would have been a tragedy because it's a beautiful instrument and the data were phenomenal.

I remember I took them to a cancellation review. I said, "Look, we just can't wait anymore. You're way delayed. I know it's not your fault. My heart is breaking for you because we want this instrument, but we've got to be successful here."

During that meeting the Canadian team members were literally running through the hallways of Canadian Parliament getting the final signatures that they needed for the approval to get the funding to start. Right as I was about to declare that they were off the mission they burst onto the teleconference and said, "We got approval. We get to start building the instrument. We get to move forward."

I was like, "You guys couldn't have made this any more dramatic, could you? You're killing us here. But great. Go. Start. You're on. You've got a chance. We're going to keep you on the program." That was a real heart-stopping moment.

I think the biggest technical challenge came with trying to figure out how we were going to safely get down to the asteroid surface. What was the guidance system going to be? We were using different lidar systems. We call them guidance, navigation, and control lidar instruments, built by a company in Santa Barbara, ASC [Advanced Scientific Concepts, Inc.]. At the critical design review there wasn't a lot of confidence that that technique was going to get us down to the surface. First of all the vendor was having trouble in development. It was their first flight hardware for a NASA program. They were really learning how you deal with NASA, all the mission assurance that's required. It was really a big push-up for them. They were in education mode.

But overall the review board said, "It's single string and it's experimental. You need a backup system. You need a second approach." Classic NASA belt and suspenders. Any one thing can break and you can still fly your mission. "Right now you're not single-fault-tolerant against your closure with the asteroid surface."

We had to go and come up with a new idea. Lockheed brought their natural feature tracking system forward, which was an optical-based navigation system. It was late. It was after CDR [critical design review]. That's when we decided to add the navigation cameras. Because they would support that system. But there was a lot of software that needed to be developed, and they said, "Well, the good news is we can still develop software after launch if we need to." There was a plan to continue to develop a backup navigation system after launch.

JOHNSON: The natural feature tracking, a lot of that software was after launch and before you reached the asteroid.

LAURETTA: After we reached Bennu actually. Because it was the backup system, the plan was to go with the lidar. Then we saw Bennu. Lidar was not going to work. It was obvious. A lot of the development had to be done. It needed to be done while we were flying around the asteroid because it's a model of the asteroid surface that needs to be developed, for upload to the spacecraft, so you had to wait until you got to the asteroid, and decide if you were going to need it, and then bring that whole team on board to implement.

JOHNSON: I think your team was good at figuring out the shape of the asteroid. Just not necessarily the surface of the asteroid.

LAURETTA: That's right. That was one of the big misses from our astronomical data interpretation, was the average boulder size and overall the roughness of the asteroid surface.

JOHNSON: You went through the preliminary design review, the critical design reviews. You got the feedback from all of that, and the flight readiness review. Let's talk about launch. After all this time, and now you're talking about even more time between that first time you started working with this to actual launch in 2016. Talk about that, where you were, that feeling of finally getting this through all the trials and tribulations, getting this to that point, and how that felt.

LAURETTA: The launch campaign was one of my favorite periods on the mission. We flew the spacecraft from Colorado to Kennedy Space Center in May of 2016. We were flown by the United States Air Force on a C-17 Globemaster. It was really cool. The pilots were really excited. They thought it was a great mission and they were just honored to be part of it. I remember we got to land at the Shuttle Landing Facility. Very historic famous landing strip where the Space Shuttle had made dozens of touchdowns. Everybody was just in awe that we were coming in and landing in the same strip the Shuttle had landed on for so many years.

What I liked most about it, first of all my whole family went to Florida. We moved to Florida for the summer, since the kids were out of school. We got a condo in Cocoa Beach. The whole community, the Space Coast community, they're just really into rockets and launches and space missions. They knew all about OSIRIS-REx. I would go get my hair cut and the barber would recognize me. It was, "Wow. Oh yes, we're so excited. You guys are launching OSIRIS-

REx." I was like, "This is so cool." Just to have that community support, for them to be so enthusiastic about what we were doing was wonderful.

But what I [also] liked most about it was that it was the first time the entire team was colocated. We had a bunch of offices right on Kennedy Space Center. All the Arizona team, the instrument teams from Goddard, Arizona State, Canada were all present. Lockheed Martin had a big contingent there. Goddard had a big contingent there.

We had been a geographically distributed team for years, 12 years at this point. Now we're all together and we're all working together. Of course the mood is really high. You're in Florida. You're watching the rocket get assembled, the spacecraft is checking out, everything looks great. Lots of media interest. You're doing media days and giving tours. The family is enjoying it, getting historical moments. It was a really wonderful time.

Everything went well. We didn't have any major issues leading up to launch that affected us. We had SpaceX explode a mile away from us about a week before we launched. That was a nerve-racking experience. Just to see black smoke emanating from a launchpad is never a good feeling. Let alone when your spacecraft is right next door. But that was not our failure; that was our neighbors'. But we were worried about them and also the impact it might have on us.

But overall it was a smooth campaign. The launch day, it was beautiful. I was worried because it had been really stormy. There was a hurricane that rolled through like a week before launch. I was like, "I don't know how we're ever going to get off the pad with this kind of weather." It was crazy. But it cleared up. It was a beautiful evening in Florida. No clouds in the sky. The launch went right at the beginning of the window, literally within a few hundred milliseconds of opening the launch window, we were out of there. It was really flawless. Perfect launch. The Atlas V delivered us right down the middle of the lane. It was great to finally be on our way to Bennu.

JOHNSON: I imagine that's a lot of buildup to that moment. I know the actual getting to the asteroid is the big moment. But just getting it off the ground.

LAURETTA: Yes, it was huge. It really changes the whole flavor of the mission changes at that point. You're no longer in development. You're now in operations. That's a whole different ball game.

JOHNSON: Talk about that change and the change because now like you said you're in operations. Those are different people than the people building the spacecraft. The whole team dynamic changes too, doesn't it?

LAURETTA: Absolutely. Yes. We did a lot of cross-training. One of the things I think that really helped us with our success was that we brought the operations team in early, during the ATLO period—assembly, test, and launch operations. The mission operations center at Lockheed Martin, they'd been talking to the spacecraft for about a year ever since it got powered up and the C&DH—the command and data handling system—was brought on board, they were running commands, they were running scenarios. They would run long. Like over the holidays they would run weeklong command sequences because that's what we would need to do when we were in flight.

It kind of was a natural gradient of a transition. It wasn't a sharp, this whole crew leaves and this whole crew comes on. We had started to integrate them seamlessly starting at least a year before launch. Some of the people from development went into operations and some of the people that were in operations started talking to their development colleagues really early on. But yes. The flavor changes.

One thing that I liked about it is we put science operations in Tucson on the University of Arizona campus. We had science operations, which meant all the instrument operations were centralized. Not only did we operate the camera system, but we operated the spectrometers and the laser altimeter and everything in one location.

I liked it because I didn't have to travel as much, because so much of the action was happening at home. I could be at home a lot more often. The spacecraft operations were based in Denver. Even when I did need to travel it was just a short hop from Tucson to Denver.

That team went through changes. I had a deputy PI through development, Ed [Edward] Beshore. He was an asteroid scientist and an asteroid astronomer. He was nearing the end of his career and he decided to go out on a high note and he retired after launch.

Heather [L.] Enos, who'd been with us on the team since 2008, came on to the deputy role. Mike brought her onto the team as what we called the project planning and control officer, which is a NASA position. Really part of the strategy to meet the challenge of managing $1 billion was to bring Heather on, because she was an MBA. She thought about budgets and finance. She was really an expert in that kind of stuff. But she also was the project manager on one of the instruments on the Phoenix Mars Lander, so she knew spaceflight and aerospace and hardware development too. She became my deputy after launch. She had a lot of experience in operations from Phoenix as well as Mars Odyssey. She'd worked on that program too. She was a really good complement to me, because I'm like, "I don't know anything about operating a spacecraft." I didn't know anything about building a spacecraft when I started either and I came on board and learned.

But Heather had that deep experience not only in budget and project management but also in spacecraft operations. She was a really great person to serve as the deputy at Arizona, because she brought a nice complement of skill sets for me.

JOHNSON: There was a change in the project management also after launch. I know that Rich [Richard D.] Burns came on prior to launch but then he took over as that management part of that.

LAURETTA: Yes. Rich Burns is at Goddard Space Flight Center and he runs the SSMO, Space System Mission Operations. They run dozens of missions for Goddard. All the astrophysics missions and heliophysics missions are run out of the SSMO Branch. It was great because they're kind of a one-stop shop in terms of how you operate a mission. They have a ton of expertise already in the organization. Rich runs all of SSMO but he really took a special liking to OSIRIS-REx and self-volunteered to actually be the project manager for the mission, not just the SSMO. He was a fantastic person to work with. Really exactly what you want in your NASA project manager. Very rigorous. Very disciplined. Very calm under stressful situations. I knew if Rich was feeling good things were going well. He was just a great barometer for me. We became fast friends.

Mike [Michael] Donnelly had been our project manager through most of development. He really likes to build spacecraft. That's what his thing is. He doesn't want to do operations. He's like, "Okay, great. I got you guys off the pad. I'm on to the next development program." I believe he went and worked the Lucy mission, which is kind of our follow-on.[3] A lot of heritage from O-REx rolled into Lucy and helped that mission be as successful as it has been as well.

[3] The first mission to explore the Jupiter Trojan asteroids.

JOHNSON: Do you want to stop here? We can end at launch and then next time talk about turning everything on.

LAURETTA: That makes a lot of sense.

JOHNSON: Okay. That sounds good to me. I'll go ahead and stop the recording. But I appreciate you talking to me today.

LAURETTA: Sure.

[End of interview]