NASA Discovery and New Frontiers Program
Oral History Project
Edited Oral History Transcript

Nicole G. Lunning
Interviewed by Sandra Johnson
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Johnson: Today is June 27th, 2024. This interview with Nicole Lunning is being conducted for the Discovery and New Frontiers Oral History Project. The interviewer is Sandra Johnson. Dr. Lunning is at Johnson Space Center in Houston and talking to me over Microsoft Teams. I appreciate you agreeing to talk to me for the project. I'd like to start by asking you to briefly describe your education and your background and how that prepared you for your work with NASA in the Astromaterials Research and Exploration Science Division or as we call it ARES, and how you first came to NASA.

Lunning: My educational background includes I got an undergraduate and master's degree in geology/geosciences, at that point focused actually all on terrestrial rocks and fairly recent ecosystems or rock systems. After my master's I knew I still really liked geology but at that point also knew I wanted to have a change, and I ended up getting a job working as support staff at the Smithsonian Natural History Museum [Smithsonian National Museum of Natural History] in their [Department of Mineral Sciences] Division of Meteorites. That's where I really got hooked and excited about meteorites and asteroids since most meteorites come from asteroids.

I worked there for a couple years, and then went and got a PhD studying meteorites from asteroids at the University of Tennessee, including some meteorites that are thought to be associated with the asteroid 4 Vesta and this was at the same time as the Dawn spacecraft mission was exploring Vesta. I got a little bit of exposure to exploration missions, that was not a sample return mission but combining the samples we do have as meteorites with some of the data that was coming out and being published out of that mission.

After I graduated from my PhD program, I went on to postdoc and I got a fellowship to go back to the Smithsonian and do both experiments melting rocks as analogues for differentiated asteroids, asteroids that have iron cores and crusts and mantles sort of like mini-Earths, as well as a side project studying some carbonaceous chondrites that are undifferentiated. So asteroids that didn't undergo that kind of melting; meteorites from those that also had unique impact melts. That was also part of my PhD, which tied into doing a postdoc thinking about linking how you start with an undifferentiated chondrite and melt it into becoming and evolving into a planetesimal. We have meteorites that come from all those different types, and particularly my postdoc was focused on and interested in looking at more oxidized systems, systems where the metal might be complexed with sulfur and have a core that's more of an iron sulfur core than just an iron-nickel metal core, and also then what the crusts and mantles of those bodies might look like.

From that postdoc I then went on to a second postdoc at Rutgers [University, New Jersey]. There I worked on some lunar breccias that are meteorite breccias as well. Then that's the position I was in when I got hired for this job. Coming to NASA I think it was a combination of having that collection background experience from before my PhD, my time as a postdoc at the Smithsonian, as well as studying a lot of different types of meteorites that come from asteroids and regolith from the Moon, to give me a broad background of different types of materials from asteroids, especially chondrites and carbonaceous chondrites, which is what the position I started at NASA was advertised as, a carbonaceous chondrite curator. I think at the point they were doing the hire they hadn't fully decided if the person they were hiring would evolve into being the

OSIRIS-REx [Origins, Spectral Interpretation, Resource Identification, and Security – Regolith Explorer] curator or whether they would take over some or all of the Antarctic Meteorite Curation position from Kevin Righter, who I know you're going to get to talk to later.

When I came to NASA, Kevin was designated as my official mentor. He and I have worked really closely together because he was the lead OSIRIS-REx curator at that point, and about a few months after I got here, I was made deputy OSIRIS-REx curator. That was summer 2020. I took on more and more responsibilities related to OSIRIS-REx from him, and in 2022 I was made the recovery curation lead for OSIRIS-REx, so the curation lead that was doing the work planning for landing of the spacecraft and the initial processing steps that we were going to do in Utah and that we needed to do to get the sample to JSC, to here in Houston.

Kevin was really good about handing off responsibility to me. At that point the decision had been made that I was going to evolve into being the lead curator for the collection as well. I officially became the lead curator in early 2023, and so then I had both roles, the curation recovery lead and the curation lead going into all the planning for the samples to come back, and finishing the last outfitting of the lab at JSC. Then when the samples landed in September 2023, September 24th, when we brought them back to Johnson Space Center, we started the process of both deintegrating, disassembling the spacecraft hardware and getting to the samples and the early preliminary examination or characterization of the samples.

At that point, I switched into the role of what we call sample curator. I evolved from being the lead, which is all about preparation for the samples to come back and then officially became the sample curator shortly after we had the samples here on-site.

JOHNSON: Thank you for giving that overview. That's really helpful. Let's go back to when you first got here and then you were working for Kevin and you were his deputy. There's a lot going on—well, not a lot going on actually—at NASA, because of COVID at that time. You came in right around the time that the center was going to be shut down for a while for COVID. A lot of people I've talked to, this was going on at various points in their mission. No one knew what was going to happen, how we were going to handle this or be able to get to work, and people were concerned with their own safety and family members' safety by possibly bringing something home to them. Talk about that time period. I'm assuming at that point you had teams that were being put together and that were going to be working on this mission. How do you keep that morale up and keep people focused and motivated but also safe at the same time?

LUNNING: That was a big challenge definitely. I actually arrived, my start date was March 30th, so at that point the center had already gone to full telework a couple weeks earlier. I did my oath of office over a videoconference, and it was quite surreal. They did get me my computer very quickly, which was good, because I know sometimes that takes a little while when people start a NASA job. But obviously I couldn't interact with anyone without the computer and the PIV [Personal Identity Verification] card access. We did have a lot of [Microsoft] Teams meetings and training.

I was fortunate in that I had already worked with Kevin before, so I knew him pretty decently well, and he's a very welcoming person. At that point I was both participating in some of the Antarctic Meteorite Curation meetings and it took a little while to get me approved to join the mission meetings, because there's a process of becoming a mission team member.

It was a unique situation. Especially late 2020 after the sample had been collected, so the sample was collected at the asteroid in October 2020, and then we had these great pictures, we knew there was sample collected, and we at that point were really starting to expand our team a little bit. We also had a lot of work to do. I think COVID did probably delay our team growing because we were in that nebulous telework time, and being on-site was still very restricted.

OSIRIS-REx work did get approved, I think probably in 2021, so we could be on-site more and more. We started to have our early rehearsals for disassembly and things like that. One of my colleagues Christopher [J.] Snead actually got approval to take a spare version, a 3D printed version of the TAGSAM, the Touch-and-Go Sample Acquisition Mechanism, that we had to take apart in gloveboxes. He took it home and put it back together numerous times. That was a really valuable way for us to have that basis for starting to develop our disassembly procedures. I think we did flex and modify how we worked together and still got a lot done.

But in 2021, especially late 2021, our team started to grow quite a bit, especially as we realized we had what was officially called the second curation rehearsal where we practiced disassembling the flight spare hardware. That was the first time I met in-person a bunch of the team who were not at JSC, the team who were from Goddard Space Flight Center [Greenbelt, Maryland] and University of Arizona [Lunar and Planetary Laboratory]. It was valuable from that standpoint, but also, we had that opening up. We had been gradually realizing we had so much to do. I think that's the point at which we all really started to run and sprint at the goal of being ready for these samples to come back, because the landing date was one of those things that never changed because it was tied to orbital dynamics. We always knew the samples were going to come back on September 24th, 2023. Other things got shifted around in the mission. They collected the sample a little later. They left the asteroid a little later. Those were things that they could shift. But that arrival date, that landing date was never shifting.

We did have that curation rehearsal 2, which was in November 2021. Our team in anticipation of that had built a mock-up glovebox, so we were starting to practice doing disassembly in it. It was made out of foam core with plexiglass windows, so we could mimic the motions, but it obviously wasn't airtight, the way our gloveboxes are that we have now, which have pure nitrogen, no oxygen inside of them, and are held by positive pressure and sealed as well as possible.

I think being able to start to come on-site, some of what we were doing was very tactile. Disassembling, watching somebody disassemble something, watching somebody try to disassemble something in a glovebox mock-up and realize you just can't move that way. Or the TAGSAM, the Touch-and-Go Acquisition Mechanism, has holes on both sides, and it had the contact pads, which were stainless steel Velcro, on one side, and we pretty quickly realized we can't disassemble it with the contact pads down. Otherwise sample from other parts of the TAGSAM will fall into them, and then you'd lose the science that would come from the contact pads, which was all about collecting surface material. There were these things that we realized; there's a specific order of operations we really need to do to maximize the collection scientific value but we also then need extra tools.

At that point we had one engineer who was part of our team, curation engineer, Wayland Connelly, and we started to get him to design special tools that we could use in the glovebox because there were some maneuvers for fasteners that we just couldn't get undone. We very rapidly realized—because of both what you can see and where you can hold your hands and the limitations in the glovebox, especially working in even the glove box mock-ups—makes you realize how much you use the mobility of your shoulder when you do a lot of things. In gloveboxes you basically have the mobility from your elbow down or mid forearm down. There are just things that can be very easy to do out in an open room that then are much more complicated when you try to do them in a glovebox. That was where we were in late 2021, early 2022.

We were also at that point really working on solidifying our glovebox designs because we were doing custom gloveboxes, which now we have in our lab. That was probably our most stressful outfitting item. I think we all realized—and it's now a lesson learned officially—that we got the gloveboxes designed and manufactured very quickly, which it's great we managed to do it, but it was tough and required a lot of pushing and a lot of not letting up on our vendor, who did a great job on them. But they should have a longer lead time, a longer interface time, with the manufacturer. I think some of that we might have started that a little bit earlier if there hadn't been COVID, but we did get there. We did muster, and the team did really come together.

I think once we started to actually take things apart in-person, that was really great for having the team gel, and then the team expanded a little bit more. We just folded those people into the process and they saw the task ahead of us and worked really hard to keep moving things forward at the rapid pace we needed to. But throughout the outfitting period, at that point the lab was fully constructed and it was actually sitting empty, which is what we wanted. We wanted it to be able to just outgas for about two years. That's what happened.

But all the equipment that needed to go into it, all of that we did get hit by all those supply chain issues that came up for a lot of different angles of our economy in COVID. For us there were a bunch of things that we needed custom-made. Some of them we could have external vendors do, but we were just running up against schedule challenges. For us, one of the things that was really incredible is our lead engineer Sal [Salvador] Martinez made a really great working relationship with Building 10, or JSC manufacturing. We ended up being able to work with them where they manufactured and fabricated a lot of tools for us.

They're part of JSC. They have part of that NASA mission mentality. They understood the urgency of our deadlines, that we needed these things before the sample came back. They were really really awesome to us. Having that working relationship where our curation engineers could walk over to Building 10—it's only probably 400 yards away—and touch base with each other as things were fabricated and machined, that was really key for us being able to have all of these different components, specialized custom components, which included tools but also a lot of containers.

JOHNSON: Normally this would have all been outsourced? It wouldn't have been done at JSC?

LUNNING: For curation prior to O-REx most of this would have been outsourced and done outside of JSC and that is actually how we started. We started with a lot of external vendors. We did run into issues where they were just not making their timelines. We were getting increasingly stressed that key pieces of equipment were not going to be here in time for the sample. We always knew that when the sample arrives, that date, is not moving. We can't push that date back. We need to be ready for it. Containers that seal really well, so that we're protecting the sample well, that we seal these containers in our nitrogen gloveboxes so they're sealed with entirely nitrogen atmosphere inside them. Different from ambient air where we have almost 20 percent oxygen as well as humidity. We're in Houston so we also really don't want that oxygen and humidity coming in contact with our samples. Being able to store them in these really well sealing containers—even though we still keep those containers in nitrogen desiccators—but it's really helpful protection for even just the minute or two when we're walking them between a glovebox and a nitrogen-isolating desiccator. Building 10 worked really great with us to get those things done.

There's some smaller items that our team also worked with IDC, the Innovation Design Center. We've been 3D printing models of things so that we can test how well they work before they go all the way to manufacturing. The engineers and our processing team became very integrated with each other. That's not something we'd had in curation before O-REx, to have the people who are hands in the glovebox, removing samples, containerizing samples, weighing samples, preparing samples for us to lend to scientists to study, and having those folks get to work with engineers. It has been a really fruitful relationship. It evolved to that.

A lot of the times when we'd have rehearsals some of the engineers who were designing equipment that we were going to use would come and watch what we were doing and very very frequently have suggestions of like, "Oh, now that I've seen you do this maybe we should design this tool a little differently because I think it will work better for you." As well as the processing team suggesting and talking to the engineers and saying, "Can you make a little thing that would hold our samples containers better?" We have these sample containers that we put samples in for X-ray computed tomography and they're designed to interface with the instrument we have in Building 31 in a different lab from our curation lab but to keep the samples sealed in nitrogen while they're scanned. But they're awkward to hold in the glove box. Designing a workstation that actually has an interface where you can set that specific container in so it doesn't tip over since they're kind of top-heavy, things like that have been really incredible.

For curation that's been an innovation. I think there's a lot of stuff for OSIRIS-REx because we had all this hardware disassembly. That was also pretty new to curation, how much hardware we needed to take apart inside of a glovebox, which we advocated to take all this stuff apart in the glovebox because that was the best way to protect the sample. The hardware that we disassembled wasn't hermetically sealed. We put the part that was sealed in the glovebox, which was the canister that was inside the sample return capsule. That was pretty well sealed and then had a nitrogen flow on it to cover it and prevent ingress of terrestrial atmosphere. But after that was opened there wasn't anything in the sample collector that would actually protect the sample.

The TAGSAM head has multiple holes in it. It has a round perforated plate that is basically two screens aligned with each other. We did want to do this disassembly because it was the best way to protect the sample. We had that challenge, and I don't think most people involved realized quite how much harder it was going to be to take that apart in a glovebox. But with a few hiccups we were able to do it and I think the planning that we had for the two and a half years before made it a lot smoother than it could have been.

JOHNSON: That's interesting because you mentioned the gloveboxes too. I was thinking that NASA curation has used glove boxes for a long time. But I wasn't thinking that every mission would have specific gloveboxes. But I can see now why OSIRIS-REx definitely would have one designed for that return.

LUNNING: Yes. Because we had all this hardware disassembly in our early rehearsals, we quickly realized that one of the ways we needed our gloveboxes to be different than a lot of the previous collections was that we needed gloves on both sides. There were just some disassembly steps that we needed two people on opposite sides to be able to achieve them. A lot of the gloveboxes in curation, historically, have been boxes, big rectangular prism shapes, and a lot of them don't have gloves on one side so that they can be [placed] right up against a wall. Which also means they don't take up as much space.

One of the things we rapidly realized, we felt like we had this big lab, but then when we laid out the gloveboxes with the gloves we were like, "Oh, we pretty much filled it with our two big glove boxes." We can fit a few tables in there and we have some of our desiccators. Having the gloves on both sides does mean they take up more floor space, but it does also give us a lot more flexibility, especially for those hardware disassembly steps.

One of the things that I think may go forward in new gloveboxes built in curation, we also have angled windows. This came out of our mock-up testing, that it lets you lean over and see what you're working on better than just having a flat boxlike shape. That's been helpful, and we still are using that. We did try to put windows on as much as we could, because we also take pictures of the sample through the windows. It gives you more visibility as well. We have on our TAGSAM glovebox, which is where we did a lot of the fine disassembly of the TAGSAM head, a documentation chamber that bumps out. That is built on heritage from lunar where the lunar gloveboxes have a little photo documentation bump out, but ours have some additional windows to help support being able to take images from more angles than just directly above and also to illuminate the sample in different ways, which has been really valuable for us because our samples are incredibly black.

We knew from the asteroid encounter that they were going to be dark. They exceeded expectations that they have a very very low albedo reflectance back. How you illuminate them really helps to be able to see more of the features of the sample. We did have our great photography team led by Erika [H.] Blumenfeld and Joe [Joseph E.] Aebersold who took our archival imaging in a couple campaigns, both as we disassembled but also really focused on the sample, and they really carefully worked on the lighting. Being able to take pictures of things in gloveboxes is quite challenging. They came up with some really incredible pictures. They were rehearsing using the mock-ups, using our spare flight hardware components for about a year beforehand, as well as they have experience photographing meteorites and lunar samples in gloveboxes. They also gave input into the design of the documentation chamber I mentioned as well.

JOHNSON: That's interesting. You were talking about a lot of different types of team members. Then you were talking about when the team finally got to grow after that time period. Let's talk about what it takes to build the team. The type of people, the type of expertise that it takes to build a team for a mission like OSIRIS-REx.

LUNNING: From the curation side you really need a combination of people who can go into the lab and be very calm and methodical even when things are pretty intense, which they were for us. We had a combination of people who'd already had curation experience in other collections, and a few new hires that our contract side recruited and did a great job finding, people who have experience doing really fine scale detailed work. They're our processing team, and also who can do really methodical careful documentation. Recruiting for that, it's a mixture of scientific background but also willingness and propensity to be very methodical and detail oriented.

Curation is not a great spectator sport because it's usually not very exciting to watch even though we did have a video stream to the team that some folks did enjoy watching. But I know we did hear from one of our PAO [Public Affairs Office] people that it was like watching paint dry, watching us work. Because the best way to handle the samples is this very slow methodical way. Recruiting for that temperament but also the engineers were a new feature of our team. I give credit to one of my counterparts on the contract side, Kimberly [Allums-Spencer], for recognizing that actually before, probably about the time I was coming onto the team, that we were going to need some people. Another part of curation, the lunar lab, was doing the Apollo Next Generation Sample Analysis or ANGSA, and in that process they realized that lunar needed some extra engineering support. I think they also started to see that O-REx was going to need it too. That was really valuable.

I think once we had those people, really making sure that everyone feels like they can speak up and be heard and making sure that we're listening to each other [was important]. I think our team dynamic got there pretty quickly actually, that we all recognized the skills everybody else brought and so have been really open-minded and open to taking input and seeing ways to improve and work together and use our different skills together. I think from a team building standpoint, that culture of the openness of the team and the willingness to work together and also folks being really driven, I think our team here was passionate about being ready and then taking good care of the samples, and I know put in a lot of extra hours. We all were putting in a lot of extra hours before landing, and then a very intense period after we had the samples at JSC, where we were working very intensely for about six weeks.

There was a point at which actually we were pushing ourselves too hard and our management recognized we needed to slow down, and we got into a more manageable long-term work dynamic. But that switchover of super high intensity going for months leading up to landing to be ready and then for the initial processing of the samples and hardware disassembly was very very intense.

I think all of our team, we regularly are like, "Oh, a year ago we were doing this. Can you believe the samples have only been back nine months?" We've done so much in that time that it is pretty incredible and it is related to how well this team works together and really their persistence and resilience.

JOHNSON: Discovery and New Frontiers are a mixture of first getting things into space quickly and getting the results back, and the missions are led by a PI [principal investigator] scientist, but there are a lot of engineers involved in building spacecraft and the instruments. The fact that you're doing the same thing in preparation is interesting. You have people that are very science-based and then you have engineers. Sometimes the language is different and they don't communicate the same way. But you're saying it was pretty smooth as far as getting that work done together?

LUNNING: Within the curation team I think it was pretty smooth. We're one small, I think important, but small part of the overall mission. We did still have a lot of interfaces with the science team, which for us has mostly been the sample analysis team that we've been interfacing with. We did develop times at which we were going to get them samples pretty early on because their clock started with landing. They had two years of special access to a large quantity of the returned samples but also a role in the preliminary examination process. There definitely is a lot of interfaces there.

I know sometimes when we encounter things that we weren't expecting, like we had two fasteners that didn't loosen the way we expected them to, and our engineering team designed a special tool to do that. But that did change our timeline. We were able to actually at that point even with the fasteners still holding what remained of the TAGSAM head together, we were able to get sample out. We had parallel paths going where we proceeded with the preliminary examination of the sample we had out, which we now know was over half of the sample. We started allocating some of that to the sample analysis team as well as working through other requirements we had. We had a requirement to put some samples in hermetically sealed containers. We had a late-breaking requirement added for us to freeze some of the samples for long-term curation. Things like that needed to happen relatively quickly for their value to be what it should be. We did work on that before the stubborn fasteners were removed.

But that did change a lot of the timeline. I know that did cause some stress among the sample analysis team because a lot of them had blocked out, "Oh, well, I'm going to be doing O-REx stuff in October but then it will be over," or "I'll have my samples and I'll just be analyzing my samples." At least my understanding of it is that that was a little hard on them to have it broken up in half. Then when we came back and opened the TAGSAM head in January [2024] a lot of people didn't necessarily have that in their schedule, which is understandable. That is a repercussion of having that challenge.

JOHNSON: Since you mentioned the problem with the fasteners, let's go ahead and talk about that. You said it was unexpected. Even after you had practiced, like you said you'd practiced with a version of it. What exactly was wrong or what caused that problem?

LUNNING: They were fasteners that we had never had any problems undoing in rehearsals.

JOHNSON: Of course.

LUNNING: Of course. There were over 40 fasteners we took off during disassembly and most of them went very smoothly. Some of the ones that we expected to be the most challenging were not. But these were. They were torqued and we don't exactly at this point know if that happened from something that happened in spaceflight that the torque on them increased through everything the spacecraft went through. One of the hypotheses that people have put out there is that they might have been cold-welded a little bit in space, making them harder to remove.

But we have those fasteners as part of the collection, so at some point they are available for someone to study. I know our engineers would like to study them when things settle down a little bit because we do actually still have quite a lot of work and they're also being pulled into a bunch of other work for Artemis and other missions. We know that they were tighter than we expected them to be, and our tools that we were using, although we had gotten them to work in the past, we have a very restricted set of materials that we allow into the gloveboxes, and that's all to prevent contamination of the sample.

We're sort of the home base of the sample so we want the sample that we take care of and we process in our glovebox to have as little possible contamination vectors so that it has the most possibilities for scientists to use it. Then when the scientist requests it and they get it they can do things that might not be great for another scientific study but are what's right for their study. For the sample we keep in our pristine gloveboxes, we want it to be useful to the broadest part of the scientific community that we can. That does mean we really restrict the alloys of metal that go in. We have a specific set of stainless-steel alloys that we use and we don't use others. The tool we had was one of our harder alloys, but we have one even more hard alloy that we had a version of that bit custom made to also help us achieve that torque as well as the engineers coming up with a design to stabilize it really well so that it was placed well. Because the first time we tried to take it off the bit that we were trying to loosen it with started to deform in the head of the fastener. They are fasteners that are called torque-set fasteners, which they look sort of like a Phillips head but if there was an extra flag on the end of each of the ends of the cross. They're used a lot in aviation and aerospace, but they aren't designed to be easy to loosen. They're either good for being tightened and staying tight, so that also made it harder for us. We were working against the head of that fastener a little bit.

That is a thing that in talking about lessons learned we've discussed with folks that in the future for fasteners that might need to be loosened, those might not be the ideal fastener. It was a challenge. It definitely was a thing where we had contingency plans for some fasteners to get stuck, but because we had all of these different fasteners, for us to have a contingency tool developed beforehand for every single one on the TAGSAM, we would have had to develop about a dozen tools, 11 of which we would not have used. Which to be honest, we didn't have the schedule to do that either. That's part of it. It is a balance because also, even though it did delay our schedule a little bit and it got a bit of press coverage, the sample was always safe. The sample was in gloveboxes. We were able to put the TAGSAM with the second not quite half of the sample into a container, seal it, keep it in a glovebox. We're on the ground. We knew we were going to be on the ground. We're not in space at that point. We do have more of a luxury and flexibility to take some time to solve a problem like this. That's what we did.

JOHNSON: Yes. That's the good news, that it was solved. You're right, it did get the press. So many things that NASA does and we would like press, it doesn't get covered, and then it's those kinds of things that always get out in the news. But that's okay. It got fixed and it showed NASA ingenuity, getting it fixed.

You mentioned contamination is always a concern. That was also out at [U.S. Army] Dugway [Proving Ground, Utah] where you were the recovery curation lead. What was your involvement as far as getting things set up out in Utah?

LUNNING: Curation had a couple different responsibilities for the recovery effort. We were responsible for coordinating and setting up the temporary cleanroom that was set up there to receive the sample return capsule. We were also involved in the environmental sample collection which are part of our extended contamination knowledge collection. We had a curation team member Francis [M.] McCubbin, who was on the team that went on the ground to the sample return capsule where it landed, and they collected soil samples around the area so that if anyone's ever concerned that somehow material from that environment got into the sample return capsule and into the sample, we have those here frozen and part of the collection that somebody could request.

As well as we were there to be ready for very nominal operations which we luckily had of documenting all of the parts that came off the SRC, the sample return capsule, in that temporary cleanroom. Because all of those components actually are part of our collection too. They're part of the OSIRIS-REx flight collection. That's part of the contamination knowledge as well that if somebody's ever worried that there's something that actually came from the sample return capsule, if it could have gotten into the sample, they can request part of that to study it. It also is space-exposed hardware so there are also some folks who are interested in studying those things potentially too. But those are part of our collection at this point as well.

We were there to document all of those components and basically accession them into our collection, so I was in that temporary clean room with my lab manager Rachel [C.] Funk. We were accepting and bagging and doing the first stage of documenting all those components, and then after they were bagged and their bags were sealed, passed to our colleagues outside so they could finish and do additional documentation as well as team members. We had a curation team member Wayland Dale Connelly who was our photographer inside the cleanroom plus some of our team outside the clean room documenting what was happening in there looking in. Those were the roles they started with. There ended up being additional roles that cropped up, so most of those folks ended up with multiple roles. We ended up not having a very muddy day but we were prepared for if the sample return capsule got really muddy that our team would clean as much of it off so that we wouldn't take that mud into the temporary cleanroom set up in Utah. There's a lot of coordination around that.

The other one that is tougher to talk about, which luckily, we didn't have to do, but we were also there prepared if we had an off-nominal landing; if we had a landing where in some way the sample was in danger and that we would do everything we could. There's almost infinite scenarios you can imagine but we planned for several scenarios and had a lot of equipment on-site in Utah that we were ready to deploy quickly to collect samples and to get it into the securest lowest contamination environment we could as quickly as possible, which involved us actually bringing a glovebox to UTTR [Utah Test and Training Range] that we could have put the entire science canister inside of if there was something that happened that damaged it that meant it couldn't be established on that nitrogen flow purge which we were able to do. We got to do everything on the nominal plan, which was great, but we did have a lot of different sample in danger contingencies that we were also planning for because fundamentally the curation team would have been the team that inherited most of the repercussions of something like that.

JOHNSON: Some of that plan, did it come from the lessons learned from Genesis?[1]

LUNNING: Some of it did, and some of it was us bringing as much stuff as we brought and came from Genesis, because they pivoted, they did a great job. Genesis achieved its Level 1 science goals even after the hard landing. But we knew our sample was going to be potentially more sensitive, that these are relatively soft rocks in the scheme of rocks. From what we were learning from the Hayabusa2 samples [Japan Aerospace Exploration Agency, JAXA, asteroid sample-return mission], the longer they're exposed to Earth's atmosphere the more damaged they get by that. Very likely to be very damaged by humidity.

We needed to be able to recover our samples much faster if we had that kind of scenario. We did bring a lot more stuff out as I understand it. Genesis, they did a great job, but people were shipping stuff from JSC. People were going to nearby towns and buying equipment from stores there and things like that. Our goal was to have as much stuff as we could reasonably bring so that we could get some sample into the cleanest possible containers and into nitrogen atmosphere as quickly as possible, while still keeping all the people involved safe. We were ready to deploy two curation teams to start trying to secure sample on the ground that day of if we had to do that, which again thankfully we did not. We were all very very happy when the sample return capsule landed very gently and we saw those first pictures.

I think everybody on the team was really overjoyed that we were glad we did that planning and we jokingly throughout the summer as we were preparing for that and said, "Well, if we do all

[1] Genesis spent more than two years collecting samples of the solar wind. The spacecraft then brought the sample canister back to Earth where it parachuted to the ground September 8, 2004. Despite a hard landing in the Utah desert, the Genesis samples were recovered.

this planning it won't happen." Obviously, that's not how things really work. But it was hard to think about. It's painful to think about but we need to be ready for it.

JOHNSON: I imagine those pictures of it standing upright and relatively close to a road helped.

LUNNING: Yes, it was. It still was carried on a helicopter.

JOHNSON: It was easy for the people to get there anyway to take pictures. You've talked about some of that process once you were in that temporary cleanroom and getting those things bagged up and handed out. Walk through that process from that point as far as getting them ready to go for the flight back to Houston. These were pristine samples that the U.S. has never recovered or had come back before, but you had to fly them to Texas. You had to drive them to JSC. Talk about that process and what you had to go through to get them back and into the area that was built for them here in curation.

LUNNING: In that temporary cleanroom we were working with our colleagues from Lockheed Martin who designed the spacecraft. Actually two of the technicians who were in the lab with us were people who did a lot of the assembly before launch of some of these parts, so that was cool.

They were taking stuff off, handing them to us, and we were bagging them. The biggest things that they took off were the heat shield and the backshell in that temporary cleanroom. Those are kind of dirty items; they're not actually items we want to bring into the pristine clean room. But also, they needed to take the backshell off in particular to attach the purge line, the nitrogen flow, which was connected to a compressed gas bottle that we had tested the quality of. That is another thing that curation was responsible for providing, was the nitrogen, to get nitrogen flowing over the sample. The canister, it's not fully hermetically sealed. It's what we call a torturous path. That nitrogen was basically making it hard for the atmosphere to ingress. Before the nitrogen flow was on the canister, we also had a filter that was designed to keep humidity out of the sample. But getting that purge on was one of the big things in Utah for us working in and around that cleanroom because once the purge was on, we could all take a little breath and be like, "Okay, the sample is as protected as it's going to be until we get it to JSC in the glovebox."

That purge on that sample canister, science canister, that went into a box, then that supported and let the line with the gas continue flowing into it, continue protecting the sample. It was this large aluminum box that actually was also used for Stardust[2] because OSIRIS-REx the sample return capsule has heritage down to that sample canister. What's in the sample canister is quite different. They actually reused that same purge box from Stardust that Lockheed Martin had kept it in storage, which was great because that heritage design canister fit right in there. It worked well. We did a few things a little different about how we packed stuff around it because we worry a lot about organic off-gassing and how we packed it. The canister which still had the sample inside it, inside the TAGSAM head mostly, went into that purge box. It was connected to a compressed gas line and from that we took it to an airplane, a C-17. This was still at the Utah Test and Training Range in Utah obviously. It was strapped down. It was the first thing that went on the plane.

[2] Stardust was the first spacecraft to bring samples from a comet to Earth. After a five-year journey, the spacecraft flew within 155 miles (250 kilometers) of comet P/Wild 2 and collected samples of dust and volatiles from the comet's coma. En route, it also collected samples of interstellar dust and flew by asteroid 5535 Annefrank. Stardust sealed its collected matter inside a sample reentry capsule, which separated from Stardust and landed in the Utah desert on Jan. 15, 2006

Then a lot of us actually got to ride with it which was cool. That was a neat thing about having the C-17. It's a U.S. C-17. We almost had to do a C-130 instead. Because maybe that C-17 was going to go transport the President's limos or something. But it ended up working out that we were able to have the C-17, which was great. It was a really cool experience to get to ride with the sample, to be able to see it there also on the plane. My team makes fun of me because I put on my sunglasses and put my hood up and I was like, "I just need to rest a little while because I know once we get on the ground, we're going to be doing more stuff," and we were. But it was really amazing to be there with it.

When we were in flight the military pilots let us go up and peek into the cockpit a little bit, which was really nice of them. It was a really cool and special thing to be there with so much of the recovery team and going with the sample. We landed at Ellington [Field] here just a little bit north of Johnson Space Center. Then from there the purge box with that sample canister and its friend, which was the compressed nitrogen bottle, those two things were basically a train coming with it onto a JSC box truck. We rehearsed with JSC transportation the path and the way that the sample would be transported. The rest of us were in JSC transport vehicles following it and ahead of it we had JSC security involved. But I got to be in one of the cars that was right behind the box truck. I got to keep my eye on it, which was a good peace of mind, a pretty short drive, but it was rehearsed and carefully planned. Then exactly the pathway we would take that canister into the building, we followed that.

We did change the procedure with a fair amount of discussion a little bit. We had originally discussed bringing the sample canister into a secondary clean lab, but we realized we had overengineered ourselves, that had been planned for cleaning the canister. But we had in our procedure, and this is something curation had advocated for, we had quadruple bagged the canister.

We could just remove the bag, because we had done that in the temporary cleanroom in Utah. Put four bags on it. That basically took the place of needing to have an additional cleaning step because we had really thoroughly vetted the packaging material that was inside the travel box for the sample canister, and then that additional layer of bagging. We weren't worried about needing to clean it in a secondary lab, and so that streamlined bringing the canister into the pristine lab that was built specifically for these samples and put into the airlock of the canister glovebox, which is our largest volume glovebox. It has a very large airlock specifically so that canister would fit in it. It's the largest airlock we have on a glovebox in curation because we knew we wanted to do that step of opening the canister in the glovebox.

When the canister went into the glovebox, that's when its nitrogen flow purge line came off. We shut the airlock door. The airlock itself started to purge with pure curation nitrogen that allowed us then, after that purging of the airlock, to bring that canister into the glovebox, and that's actually where we called a stop for the day. For those of us who had a lot of fine-tuned knowledge of the procedure, we were a little bit frustrated because we were like, "Just let us take the lid off. That's the last step of this procedure." We had a lot of stakeholders. They were worried about fatigue. It had been a very long day. Our team had gotten up very early to make the plane, the flight. At that point we put the canister in the glovebox. I think we were pushing six o'clock or something like that. It was late in the evening. It was a good call for recognizing fatigue and that we could open the canister the next day. It was going to be there. But I know for those of us in there we were like, "But it's just a 5-minute step. Let us do it."

JOHNSON: I can imagine it was hard to leave it at that point.

LUNNING: Yes.

JOHNSON: You mentioned it a couple times, and I've thought about that too, the documentation as far as you had to prepare a lot of documentation and have it approved and the whole plan ahead of time. But also everything had to be documented as it was being done and you had to keep track of every step. That is before you even start getting to the sample. Talk about those processes and if these were new for OSIRIS-REx. Or if they were adapted from another mission.

LUNNING: Oh, it was a lot of documentation. The recovery procedure which took us all the way from actually pre-landing because there's spacecraft maneuvers and things in it, through that canister lid coming off was a couple hundred pages. I don't remember the exact number. There were some spaces in it. There were diagrams and pictures and maps and things. It was very detailed. It was designed so that not just the people who had done it, but also if they needed to swap somebody out, there would be enough detail, they could understand it. That also got reviewed. I was one of the signatories here for it, but there was probably at least eight signatories of people who reviewed it. Our lead on recovery was Lockheed Martin. They were the lead in writing that. I was a signatory but we all, a bunch of our team read it, probably five of us read it, put inputs in.

I think it started with the Stardust document but there were definitely things that needed to be changed for OSIRIS-REx. Just the guidance, from for instance UTTR, about how to collect the sample return capsule was a little different for us than Stardust. For Stardust the sample return capsule basically went inside the helicopter. For OSIRIS-REx after talking with the folks at UTTR and the specific people who were going to be coordinating the helicopters and the OSCAR [On-

Scene Commander], the officer in command on the ground at UTTR, they encouraged us, and the mission ended up agreeing, that we should transport the sample return capsule on a longline. So that was one of those things that was an evolution.

Stardust was 17 years before we did this. It was a starting point but then a lot of things got modified both based on recommendations from the people we were specifically going to be working with and then for us the Stardust canister was opened inside a cleanroom but not inside a glovebox because the aerogel targets, they have oxygen in them. They're stored in nitrogen but those samples were not thought to be nearly as sensitive to oxygen and humidity as the OSIRIS-REx samples. That was one of the things that we worked out I think probably about two years before return, that agreement that we were going to open the canister in the glovebox.

My Lockheed Martin colleagues, we had some discussions about that back and forth in 2021, and understandably they at first wanted to do it the way it was done in Stardust because they knew it worked and they don't necessarily work in gloveboxes all the time, so that wasn't something they were immediately comfortable with. But they listened to us and as we explained our reasons why we really thought it needed to be opened in a glovebox they were supportive and afterwards some of them have very generously brought it up.

We took the canister lid off. Or our Lockheed Martin colleagues I should say. Mike [Michael Kaye] and Levi [Hanish] took the canister lid off, and there was a bunch of sample on the avionics deck. I don't want to brag but I think our team, everybody then understood why we had advocated for that two years ago. They had been on board for two years at that point but they were like, "Yes, we're glad you guys nudged us to change the procedure from Stardust to opening it in the glovebox." That was I think an example of people working together and having a dialogue. We all came together and made the right decision together and it just takes some time talking it through. I'm glad we had those conversations two years before so it wasn't like oh, we're all overwhelmed and stressed. We were still fairly early in the planning stage when that part of the procedure got solidified. Because it also then fed into our glovebox design that we were in tandem designing so that we could put the canister lid inside, and that kind of planning needed a couple years in advance.

The TAGSAM disassembly procedure, which curation was the lead on, we started really developing in detail in 2021 with those first rehearsals of if we take the TAGSAM apart this way, there was a couple different ways we could take it apart, realizing, "Oh, we really have to take off the avionics deck and flip it over to protect the contact pads so we don't lose the science associated with the particles on the contact pads." That got solidified. The big parts of the procedure got solidified and then we filled in the details. But it did become very detailed.

In the end our procedure had lots of things that we had rehearsed enough times that people could have talked you through it but also, there were little things, and this procedure ended up stretching out over combined probably six weeks. And even in the smoothest scenario, it still would have taken three or four weeks to do the whole thing. That's a lot of little details for even the people who practiced it many times to remember. It was useful for the procedure to have to be, "Okay. This is the thing we do next." We wrote this procedure in this specific order because we tried a bunch of different ways. Usually the best path forward is to keep following the procedure and not try to change it on the fly. Obviously when something changes, when the behavior is not what you expected exactly in the procedure, you need to pivot a little bit.

But it was valuable to have, and it was incredibly detailed, mapping us through all of that hardware disassembly and early sample collection and containerization. It was a lot of work to put together. It was a lot of feedback from folks and time working on it over the course of about two and a half years, but it was really valuable to have. Especially when things get stressful it's really useful to have a procedure so you can say, "Okay, we already did the thinking about this. If everything's behaving as we expected we just continue with the plan."

JOHNSON: Having that to fall back on, like you said if people get stressed, I'm sure it made it easier. Going through this documentation you mentioned having to communicate, and there's a lot of communication with a mission like this, early on, but during the return, and then afterwards. Talk about how you in your position facilitated communication within your team, between those various teams, like Lockheed Martin and also folks from Goddard. Then afterwards you've had to deal with other people from different institutions, all the stakeholders that were involved in getting these samples back and available.

LUNNING: I think it's really important and there is a lot of room for misunderstandings and it's been really important to keep those channels open. I think within our team I know because basically from the day of landing to about mid-November we were working very intensely, we were working alternating shifts with people in the cleanroom, processing in the morning, and then some of the folks with hands in the glovebox switching out to different folks in the afternoon. We were pushing pretty hard all the time to keep going. There were a few points especially when we had some of the challenges where it was like, "We have to stop our cleanroom work so we can all have a meeting about this."

I know we had lots of meetings beforehand. Sometimes we all can feel like maybe that meeting took longer than it needed to but it was a little surreal at points in October when it was like we haven't had a meeting with all of us together in a couple weeks and we've done so much.

We do just need to stop and get the curation team together and have a short meeting to discuss what is going on.

We also basically ended up realizing we needed to have regular lookaheads scheduled so we were having this revolving a couple-days-ahead like this is what we think we're going to be doing the next couple of days, and sending that out internally to our team, because we were pivoting a lot. There were lots of things changing. That let everybody have something they could look at and be like, "Okay, what changed today, what stayed the same, what do we think we're doing tomorrow and the day after at least?"

A lot of times things would change on the time horizon farther ahead than that, at least a little bit, because we were pushing hard and realizing new things were being recognized. We were getting new requests from either the science team or some things were working really well but needed to take a little longer than expected. Some things didn't work as expected. Stuff like that.

I think internally it was very intense but also making sure and making some time to consciously communicate with each other. We're still at a fairly intense standpoint where our team doesn't have tons of meetings. We have a meeting every week or sometimes every other week, but we always have a lot of productive things we need to discuss with each other for the internal team.

For communicating with some of the external or at least non-curation folks, they're still part of the mission, there has been an evolution of what the interfaces are because the sample analysis team is over 230 people. There's a half dozen working group leads, plus the mission sample scientist Harold [C.] Connolly, the PI Dante Lauretta. There's a lot of different people. The goal is for them to communicate in one voice to us, and we've evolved to a point where Harold

Connolly, the mission sample scientist, is the main voice, so that there's a clear pathway from that sample analysis team to curation, so we know what the prioritization is, what they're asking for.

Sometimes with especially us scientists—I say this as a scientist myself—but sometimes it can be a herd of cats. That's something that's evolved over time and seems to be working well at this point. We communicate out to them both in informal ways of having weekly tag ups with the mission sample scientist and also weekly reporting where we tell them what we've been up to, and more formal documentation. In the early days we were pushing hard and there were some things that we were still recording and documenting, but having conversations and having people have requests, but sometimes when people are tired, they don't remember what the request was, and so we have gone to making sure if it's an actual request from the sample science team to curation that we do it in writing. We'll talk about it together to iron out the details, but we make sure we put it in writing so that we can really avoid miscommunications. That has been, I think, overall working pretty well for communication with the sample analysis team.

For our international partners, we have some of our NASA Headquarters folks involved as well, but we do also have meetings with them and focusing on making sure that we're doing some written documentation to make sure that we fully understand and both agree on what was communicated and what was approved or requested and consented to do. It is fairly complicated because it is a bunch of different stakeholders who mostly all want to move in the same direction but making sure people understand what we're doing and what's happening and balancing different requirements and different commitments from NASA.

Right now one of our highest priorities is finishing containerizing the sample that will be transferred to JAXA, the Japanese Space Agency. Because part of NASA's international agreement is to deliver that sample by the end of the first year after landing. That's a timeline that we're methodically working towards. We're still allocating to the mission sample science team at the same time, but we're making sure that we're not getting off target to transfer those samples to JAXA. Then later we'll transfer samples to the Canadian Space Agency, because their international agreement didn't have that year timeline. They aren't wanting their samples quite yet. They're still building their facility, so it works out for us to take a little bit longer as we containerize their sample but also containerize the sample to go to Japan.

JOHNSON: As the curation lead for OSIRIS-REx it's more of a high-profile mission for NASA because it was unique and a first. What are some of the other pressures that you faced in keeping this team moving forward? Like you said it was trying to get these samples out to JAXA, but also getting the sample catalog itself out on time. Keeping things documented and tracked, getting the samples ready to go. Talk about some of those other pressures you feel.

LUNNING: Yes. Those are big ones. Getting the first catalog released, it's one of our big mission milestones. We were basically doing the work for supporting that catalog throughout all of the process of interfacing with the samples. We were putting information and taking pictures and logging what those pictures were in our database. Then our curation database fed into the public catalog. But there was a fair amount of review we needed to do and interfacing with our IT folks Lina Mueller and Todd Smith who designed our database and have worked with a lot of the curation databases which also do this, which also take information that we input into the database and then build a public catalog from that database.

OSIRIS-REx certainly has some aspects that are different than other collections. We're an in-between size collection where the Antarctic meteorite collections and lunar collection have kilograms and kilograms of samples. It is easier for those collections to allocate grams of sample to researchers when they request them. Then we have our collections that are more what we sometimes call small particle collections like cosmic dust, Stardust, Genesis, where the masses are very small and so small that for Stardust and cosmic dust it doesn't really make sense to weigh them. They track them by particles. We're in between that where we have a lot of very small particles including particles that are too small for us to weigh, but we also have enough mass that we are weighing and tracking. Whenever we take something out, we're weighing it in a container and recording the weight of its container when it's empty, the container with the sample, and keeping track of the sample weight that way. When we break a sample, we have a fairly involved documentation process for naming the splits in that sample and documenting it in our database, which then later can get pushed over to the public-facing catalog.

We were doing that work all the time. We also were doing that work of developing the database beforehand—for instance I mentioned the hardware part of the collection. Before landing we had actually preloaded at least the names—not pictures because we didn't have them yet—of all of the hardware items that we were expecting into the database. Then the pictures and things could be added to those and additional notes and documentation. With the samples obviously we didn't know exactly what they were going to look like.

We had some samples that we had prenamed because we have our bulk sample trays and eight of those, we basically reserved sample numbers for those. Then we had some triangular bulk sample trays that had placeholder labels that could be more flexible because we were prepared for there to be sample in a couple places. Some places where it didn't end up being, and some places like we didn't anticipate that we were going to be scooping sample out of the TAGSAM head when we had those fasteners initially refuse to come off.

But we were able to use those flexible trays that didn't have exact sample names but had designations. They're A1, A2, A3, A4. We actually designed those thinking about the TAGSAM head was in the capture ring on the avionics deck. That's how it was when Mike and Levi took the canister lid off. We thought there might be a bunch of sample that would fall out of the TAGSAM at that point because before the TAGSAM was stowed at the asteroid, so after the sample collection but before it was stowed into the sample return capsule, there were all of these fairly decent size rocks—a couple of centimeters, a couple of inches in size—wedging open the Mylar flap of the collector head. We thought it was possible that those and other sample would just fall out into the capture ring in the area below where the TAGSAM was stowed. We were prepared to potentially have to collect a bunch of sample from there.

When we took the TAGSAM head off the avionics deck there was nothing there. That was one of the things that we did a bunch of different things preparing for of like well, there might be a lot of sample. At some point I think as anxiety was ramping up getting close to landing there were discussions of like well, what if all the sample falls out and if all of the sample is on the avionics deck and in the capture ring area. That didn't end up happening but that was one of those contingencies. It would have still been nominal to us but we were prepared for it when we'd done our fairly big rehearsal with sample where Lockheed Martin had loaded the qual TAGSAM up and then put it in a facsimile of the canister and then shipped it from Colorado to us, a bunch of sample had fallen out into that area. We had been prepared for that to happen and then it didn't.

We took it off and it was like oh, there's maybe a few hundred-micron particles here but it's not like lots of the collection has fallen out. We planned to have the flexibility by having extra trays with flexible names and then we ended up using them in a different way. It was still great to have the flexibility, and I think that planning benefited us that way, even though the thing we most expected to happen didn't happen.

JOHNSON: One thing that happened is you got about twice as much material as was expected going into this. I think they wanted at least 60 grams and you ended up with over 120.

LUNNING: Yes, which was great. That was really great. That was one of the things that we did end up doing that we had an interface with one of our balances so we were able to unofficially weigh the TAGSAM before we opened all of it, and the estimate we got from that was pretty close actually to what it ultimately ended up being officially. Those of us who were working had a little preview; we're in the ballpark of 120 grams. It was nice that worked out. Then we were able to do some of our planning using the estimate number. But it was considered a rough estimate with a fairly large error bar. I think the error was 20 grams plus or minus or something at that point. That's why that wasn't publicly released. We did really want to wait till we could release the completely official "We have weighed all this with a balance in the glovebox and they're weighed in containers that they were transferred to that we weighed with the same balance." It was good. It was really exciting.

We had practiced with a whole different range of weights and masses. Because since we saw that the sampler head at the asteroid in the pre-stow imagery was full but also sample was leaking out of it, so there was an estimate at that point, but we were prepared for a lot of scenarios where maybe we got a lot more or got a lot less. We were really happy to get twice that baseline. That was really good.

JOHNSON: I think it would make a lot of people happy as far as being able to get those samples too.

LUNNING: We made a lot of people happy when we did that scooping the sample out of the TAGSAM head by getting 70 grams out at that point. It wasn't conscious. It wasn't like this is how much we can get out. Because that meant we'd achieved that mission Level 1 that we knew we'd gotten more than 60 at that point. That also meant we could start getting more samples out to the science team, because we knew we could at least allocate up to 15 grams to them. At that point even the people involved in the mission I think were overjoyed when we got the first 70 out. Then the rest was gravy when we got up to 120 and we're like, "Oh, twice as much as expected, that's great."

JOHNSON: Yes. I can imagine. I imagine they were happy when you got that first 70 out. As far as the process of getting samples for other people using that sample catalog, I think the first-round deadline for sample requests was a couple days ago.

LUNNING: It was.

JOHNSON: Explain that process and how people request the samples and what happens after that.

LUNNING: We have basically an open call that people can request the samples in the catalog. We still have a lot of samples that are what we call aggregate. They're samples with a lot of particles in them. Some of them are even 9 or 10 grams that they can request, "Oh, I would like a half of a gram from sample 800,002 because that sample has enough that maybe you could take that out."

Then they explain why they want it. They have to justify why they're asking for the mass or the weight they're asking for. Because we are in this kind of Goldilocks collection; we have a lot, 120 grams feels like a lot to us, but a decent amount of our scientific community is used to working on meteorites where they might have kilograms of material available or lunar samples where there might be kilograms of material available. They do really need to provide a justification for why they're asking for as much as they're asking for. That's one of the things that will be peer-reviewed. The peer review panel will consider is this the right amount of sample for the analysis that they want to do, are they asking for too much or an unreasonable amount of the collection for what they want to do?

They will be really carefully reviewed in that way because we have a collection conservation plan that lays out the maximum sample mass we can allocate this year, which is 8 and a half grams, the most we could possibly make non-pristine to fulfill the approved requests this year. That will feed into, because we got a lot of requests, which we're glad that people are excited about the collection. But also all of the requests combined exceed the mass that we could allocate this year. The reason we have that steady cadence of how much we can support at a given time is so that all of the sample doesn't get consumed immediately. That we still may retain enough of the collection that it's there for decades to come for when new analytical techniques are developed, new scientific questions get asked that we're still retaining some of the collection. We have this balance of we love supporting and making sure that lots of cool science is getting done on these amazing returned samples, but we also want to make sure that we're keeping enough back here for the future too. That's definitely part of the review process for these requests.

We did get a lot. I think we got more than some people thought we would get. I had had a few people tell me, "Oh, well, the sample analysis team, it's pretty big, it's 230 people. Maybe most of the people who want to work on Bennu samples are on that team. Based on the amount of requests we received that's not true. But that's good. We're glad there's a lot of enthusiasm and excitement and scientific interest in these samples. That's why this mission went to bring them back. Obviously, the mission sample analysis team is really excited to do their work. But it was also to have samples for the rest of the community too and for a long time to come.

JOHNSON: The idea of being able to work on a sample like this isn't something that comes around very often or at all up until this point. That is exciting. NASA does outreach, some education, but mostly outreach to the public to try to get people interested, and also with STEM [Science, Technology, Engineering, and Math education] to get younger people interested in the STEM careers that NASA offers. Do you have any of that responsibility? Is that something that you've been involved in through curation?

LUNNING: We definitely do some. I think both curation in general and this mission, I think there's a lot. For me it's the mission, I have a lot of desire to share what we're doing. I think that that's infectious in its own way. I've gotten to participate in some outreach activities and we have an outreach team that's part of ARES and part of curation who this week supported doing a bunch of tours for schoolteachers, taking them around the outside, the hallway of our lab—we have some windows in there that they can see through—with a variety of different members of the curation team, who worked on OSIRIS-REx in a bunch of different ways, leading those tours. Because I think they had several hundred people come through so they needed to rotate different people leading those tours.

We are a working building, so our outreach people do have to balance. They reached out to us months in advance to ask if they could do it this day because we can't have hundreds of people walking through our building all the time for security of the samples and things like that. It is a balance. We definitely like to do it. We like to share what we're doing. A lot of times I've had good feedback from people. People are excited to learn about what we do and what we do is pretty unique. The level of gowning, the bunny suits that we wear to go into the lab, the gloveboxes, that's a pretty unique thing that a lot of people haven't seen in other contexts. It certainly does happen other ways but we are kind of unique among NASA in the way we do this and protect our samples by handling and processing them this way.

We do get a chance to do some of that and we try to take the opportunities we can. One thing also we did that took a lot of planning beforehand is we were able to loan out three public display samples. It started with the Smithsonian getting one and that had been something that had been in discussion for a long time from early conceptions of the mission for the Smithsonian to fairly rapidly get a sample. The Smithsonian opened its exhibit in early November, so we, five weeks after landing, were able to lend a sample to the Smithsonian that they immediately put on display, which was really cool.

JOHNSON: Yes, it is.

LUNNING: That did take a lot of planning beforehand. Otherwise, it wouldn't have all come together like that at such a busy time. Along with planning for the Smithsonian sample, we also planned and ended up loaning a sample to Space Center Houston here right by us in JSC and to the Alfie Norville Gem & Mineral Museum at University of Arizona since the science team is led out of University of Arizona. That's been a neat thing to get to hear about and participate in. I supported some of the Space Center Houston public YouTube produced event around that, which was fun. It's fun.

I know for our team here, because we have a lot of different mixtures of folks who grew up around the Houston area and now work at NASA, having gone to Space Center Houston was part of their being passionate and excited about space. I know that was a really special thing for my team when we were able to loan them that sample and when it went on display. That's been cool too for us on the local side. Getting to see people check it out, interact with it at Space Center Houston has been cool.

JOHNSON: Yes. Space Center Houston does have a lot of people coming through there every day, so that's exciting. Looking at your experiences with OSIRIS-REx now, what are some of the lessons learned? I know things are still progressing and you're still the curator there for the samples and things are going to continue going. But what are some of the lessons you've learned up until this point as far as your work and everything you were involved in?

LUNNING: I think we've actually worked on Phase E—so the phase that ended a month after landing—lessons learned document. There are a bunch of things. I think some of them are straightforward but also worth saying that when we make these detailed documents of procedures that we're going to do a lot of times there is a very strong inclination for people in the event either sometimes people are a little external who are not involved in developing them to be like, "Well, why are you doing it this way, that way? Maybe we should do it in a different way." It's good to have that discussion a little bit, but also sometimes it's like we've got to stick with the plan. If something hasn't changed, we won't be able to get all of the work that we've had planned to do done if we relitigate every step of the procedure. Balancing things like that out, which it comes from a place of people wanting to make things better, but—also we had some things about the fasteners and thinking about designs.

We did a lot of rehearsals in the last three years. There was one rehearsal disassembling a prototype of the TAGSAM in 2013, so that was well before launch, before the design was locked, and realizing that it would have been beneficial to do more of that. There was some good feedback the people involved gave, but at that point I think that hadn't fully solidified that they were going to do all this disassembly in glove boxes, and aspects like that, which would have probably given some extra flavor and extra benefit of inputs into that design. Some of those things to make it easier to disassemble in the glovebox.

Nobody expected all the supply chain issues that we had. They were worse than normal but any time we're buying stuff, do it earlier. Especially for a curation lab it's better for things to be in place longer so things can off-gas as much as possible so you can do rehearsals in the space with all the equipment in there, which we were able to do, but it was tight. We got our gloveboxes installed a month before we did a dress rehearsal in June 2023, where we did all the disassembly steps in the gloveboxes, and some of the photography steps without any sample. Even though the gloveboxes were recleaned after that [rehearsal], we didn't want to put any asteroid simulant or anything that could look like our sample into our gloveboxes. That was really about the disassembly of the hardware.

We used Teflon balls in place of the sample in that rehearsal. They did not behave like the sample at all. They were like Super Balls bouncing around the glovebox when we did our pour-out step. Having more time—those rehearsals were really valuable. Also recognizing how busy the last six to nine months were going to get. We were really thankful that we did so many rehearsals in 2022 because even though we still managed to find a little bit of time to rehearse and stay fresh, we were so busy getting other stuff ready, the constant list of things we needed to do both to be prepared in Utah and also to be prepared here, that we didn't have as much flexibility and time to rehearse in those last nine months. Spending time rehearsing two years out, almost three years out, in 2021 and 2022 really paid off, because then when we actually did the real disassembly all the team still had that muscle memory. They'd practiced enough. They had that base. But they still had retained it without being able to be constantly drilled because we were so busy in those last six to nine months.

JOHNSON: If you had to look back over this so far, what do you think you would be most proud of?

LUNNING: I think I'm really proud of how much the curation team got done, how flexible we were, how we pivoted. I think there's so much that the O-REx curation team did within the last year and a half. Both with that nine months leading up to landing, we were incredibly busy, and in the nine months since. I think we're still working pretty intensely, but it's not quite as stressful as it was a year ago. Because we were still in that "Got to do all this to be ready. How are we all going to get this done?" phase.

I know there's a ton of drive within our team. The team was pushing themselves really hard and really committed to being ready. I am really proud of everything that those folks did to be prepared.

JOHNSON: Is there anything we haven't talked about that you'd like to mention?

LUNNING: I feel like I've talked a ton. I think I need to drink some water. But you were right. You were right that once I got going, I got chatting.

JOHNSON: Yes. It's exciting getting to talk about something that you're happy about or you're excited about. I appreciate you talking to me today and thank you for doing this.

LUNNING: Thank you. Thank you. It's a cool thing. I know Judy Allton is a great proponent of the oral history, so I'm happy to support it.

JOHNSON: I appreciate that.

[End of interview]