DISCOVERY 30TH ANNIVERSARY ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

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INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is November 6th, 2023. This interview with Jessica Lounsbury is being conducted for the Discovery 30th Anniversary Oral History Project. The interviewer is Sandra Johnson and Ms. Lounsbury is joining me today from Goddard Space Flight Center [Greenbelt, Maryland] and we're talking over Microsoft Teams. Thank you for talking to me again. I appreciate it.

There's been some news about Lucy in the last week, exciting news. Let's talk about that. On November 1st Lucy did the first planned flyby by the main belt asteroid Dinkinesh, and they discovered something they didn't expect when they did that. Talk about that and the plan to fly by it. I know you're not on the Lucy team anymore but I know you're still following that.

LOUNSBURY: Oh, absolutely. It was very exciting. Our team decided probably six months or more ago to attempt to collect science data and use the Dinkinesh asteroid as a rehearsal for the future Lucy asteroid flybys. I remember I was just starting to transition off the project at that time when we were planning this, and the team was actually pretty excited about it. We didn't realize this main belt asteroid was along the trajectory. Once the science team recognized that we might be able to study this, get some real science, and exercise our terminal tracking capability, the plan really took hold.

I will tell you the team was still tired at that point from doing all of the solar array redeployment attempts and working that anomaly. I think the team was still kind of looking for a breather. This didn't give them a little time to recover. However, because it was an opportunity to gain some science, especially given everything we had gone through, we needed a win here. So the work began in earnest to get the flight dynamics team aligned, get the guidance, navigation, and control team aligned, get the mission operations center ready, and really prove out that we could in fact fly by an object.

It turned out Dinkinesh was going to be similar in velocity that we fly by to our other asteroids, and so we thought well, this is a good opportunity. Let's try this. It turns out we flew by on Wednesday of last week, November 1st, and turns out Dinkinesh is a binary pair. We did not know that. We had no expectation, and it was exciting, because even though I'm not working the operations phase of this mission, I started getting a flutter of Teams messages with images and excited proclamations from the team. Hey, we're at closest approach. Hey, we've got these images that came down. Here's some raw images. Look at this. It's two objects and not just one. It was super exciting and really and truly the team—you could just feel everyone's excitement, even remotely. There were just hearts all over the chats. It was so exciting because finally the team got to celebrate where they hadn't got to celebrate after launch. Going straight into anomaly after launch day.

We're finally feeling confident. We were confident after we resolved the anomaly to the best of our abilities. We're confident in the mission. But there's nothing like getting real science data back and showing that the centroiding and terminal tracking capability and the algorithms to point at the different objects really truly works. It's nice to see it working in the field in situ.

Not only that. Lucy's binary pair that we're going to image isn't until 2033. To get that validation now in 2023, 10 years ahead of when we need to utilize that capability, that is something our whole team should be proud that we now know we can absolutely achieve the science we set forth for this mission.

I think getting that win was huge for this team. And getting the recognition in the public and in the media. My father called me over the weekend and said, "Yes, I was having my coffee and breakfast and all of a sudden I see you guys on the news. You already told me, and you sent me articles from the Internet. But no, it was being mentioned on the news on television."

I said, "That's awesome, I had no idea that we were in the news." It's just really great to get that recognition after all this time, so very excited for the Lucy team.

JOHNSON: I know Hal [Harold F.] Levison was really interested in binaries, and that was something he definitely wanted to go after. I imagine this was quite exciting for the science.

LOUNSBURY: Absolutely. Hal was sending us emails every hour roughly with status updates. Yes. You could tell he was really excited. I think we're going to try and have a team party sometime in the holiday season, because we want to get everybody back together and finally celebrate our success.

JOHNSON: When I spoke to Cathy [Catherine] Olkin she mentioned that the terminal tracking system, that was one of the most important things that was going to be done during that first encounter, because it set everything up for the rest of the mission. As everything was being put together for Lucy, and we talked about everything that you went through with COVID, was that tracking system something that was ever a concern specifically? Maybe talk more about that system itself.

LOUNSBURY: Yes. That system from day one we had concern first because it was meant originally to be an engineering camera and not a science camera. The original thought and use for that was to help Lucy point to the asteroids. However, it turned into a critical piece of hardware to gather science images and take data at the closest approach to each of these Trojans. Very quickly the team realized how critical this hardware was.

In the systems team we immediately had to not only redefine our requirements but we really had to settle the team down into realizing what we were going to use this camera for. We had to settle the team down, and what I mean by that is everybody was concerned because they thought well, this is requirements creep. Now you're changing the scope of the mission. You're levying requirements on an engineering camera that wasn't initially set forth to be an engineering camera. We're not sure if it can actually handle that capability.

There was some handwringing and consternation initially with the team. Eventually we were able to smooth it over and we had a lot of good conversations as teammates and recognized that the company, Malin Space [Science] Systems, had used this camera on other missions, on OSIRIS-REx[1] [Origins, Spectral Interpretation, Resource Identification, and Security – Regolith Explorer] and others. It's a quite capable piece of hardware and software combined. We realized it can do the job. However, I will tell you the requirements were very tight in terms of how often we needed to snap images using that camera. Depending on the target we would need to take images at a faster cadence or slower cadence depending on how far away we were and more importantly how quickly we were flying by.

[1] OSIRIS-REx is the first U.S. mission to collect a sample from an asteroid. It returned to Earth on Sept. 24, 2023, to drop off material from asteroid Bennu. The spacecraft didn't land, but continued on to a new mission, OSIRIS-APEX, to explore asteroid Apophis.

Some of these targets, we needed images every 4 to 6 seconds in order to get the science that we needed, and there were times where to do that you couldn't use the camera for its core capability of centroiding. One, because you're so close to the target, and two, because you were using a different camera to feed the algorithm. In the further out areas we need L'LORRI [Lucy Long Range Reconnaissance Imager] as part of the centroiding, then as we got close in, we use the terminal tracking camera. At a certain point the terminal tracking camera's usefulness was complete, but we still wanted to leave it running for science. So we spent quite a bit of time making sure we could leave it running but not impact the algorithms such that we were still pointing at the target.

I'm not explaining that well enough here. What I'd like to convey is that essentially, we didn't want to use the terminal tracking camera inputs after a certain period of time but we wanted to make sure that the algorithm could still converge on the target. That took a little bit of discussion and some testing by the team to make sure that we're not misusing the camera and confusing our tracking algorithm. Once we figured out we could in fact do that, then the team relaxed a bit more and we said, "Okay, we can meet both of our objectives. We just have to know where's that inflection point where we need to switch over from terminal tracking to science."

We had to do some work with the concept of operations to make sure that that was a clean transition. There were just times where we had to make sure the team was clear on when it was used for engineering and when it was used for science. That theme threaded our discussions throughout many phases of the mission until the team really got comfortable.

JOHNSON: Like we talked about before, that was your job, facilitating those conversations and making sure that everyone was understanding the goal.

LOUNSBURY: Absolutely, and that was really critical because again the science team wanted something. The engineering team was trying to work to their requirements and didn't want to accept new requirements. It was absolutely my job to convince everyone this is in our best interest, and this is in service of the science that we're trying to achieve. Because at the end of the day that's why we're building this mission.

If we've got added capability here, I recognize the push and pull between the scientists wanting to utilize the added capability and the engineering team wanting to make sure that we in fact can fly the mission as intended. Eventually everyone recognized that this added capability was—I won't say at no added cost because it was at the added cost of the GN&C [Guidance, Navigation, and Control] engineers working the problem. They had to work harder to make sure we incorporated this capability into the system.

But it turns out it was worth it; I think it made the GN&C algorithms more robust on the front end and recognizing when we were done using it for engineering and when we could transition to science. It just gave us a sharper focus on how we were going to use this camera. Negotiating with the team and explaining why in this particular instance it was worth the scope creep, because it was scope creep, but it was worth it because when you look at our science traceability matrix and all of the different measurements we're getting from each of the instruments, the terminal tracking camera really had a uniqueness to it that none of the other instruments could provide. I think that's where we all recognized that hey, this critical mission flying by these Trojan asteroids is not something we're going to enter into again for quite some time. Who knows when another mission may go to those asteroids? This is our chance.

I think everybody just eventually rallied around Hal's enthusiasm for the type of science we could get from this camera. I think that's what really made it special and what made the team recognize why we needed it.

JOHNSON: It worked fine on this first flyby.

LOUNSBURY: It did, it was fantastic, because again we got to not just track the primary object Dinkinesh, but also its binary body. That was just an awesome achievement.

JOHNSON: When it went around Earth for the gravity assist, was that camera tested then too, the terminal tracking camera?

LOUNSBURY: Not really. For the Earth gravity assist we really don't take any science. There was talk at one point about whether or not we could see the Moon. Eventually we sort of recognized we weren't going to get good imagery. There wasn't a whole lot we could do calibrationwise. We really largely abandoned those types of opportunities because they really weren't good opportunities in the end.

JOHNSON: Because of the solar array, I think the distance from the Earth was a little bit different than originally planned, and there were other concerns too, for an Earth flyby, that you aren't necessarily going to worry about as much going around these asteroids as far as we know. But all of the debris around Earth, was that a concern? Was that something you remember discussing as far as what would have to be done if debris was in the way when it's going around the Earth?

LOUNSBURY: Yes, we absolutely spent quite a bit of time making sure we understood what altitude we would fly by the Earth for the Earth gravity assist. I will say there were discussions where the systems team was fine with the initial altitude we had selected because the guidance, navigation, and control team had done their analysis and they had margin and they could fly by—I don't remember the exact altitude off the top of my head—they could fly by with margin. However, they, like all engineers, would prefer more margin and wanted to fly a higher altitude than was originally planned.

We went back and forth, and we decided not to trade upon that until we got into operations. Of course it turned out once we got into operations, we had the solar array anomaly and that's when revisiting that altitude became another point of discussion. I think that at that point we recognized what our overall fuel budget looked like and that we could accept flying at a higher altitude, minimizing the risk. Certainly there's always a concern about orbital debris. We worked closely with CARA [Conjunction Assessment Risk Analysis], which is a conjunction avoidance group, they do regular analyses of potential objects that threaten our orbit.

We revisited all this and said, "Well, let's fly at a higher altitude. Let's revisit it." Because the situation had changed. As a group it wasn't really a difficult discussion. The GN&C team did their analysis. We looked at our overall budgets and margins and said, "Yes, let's just go ahead and make that change. Let's err on the side of caution." Because with the solar array anomaly we hadn't analyzed every possible case of flying in that configuration before we launched. Understandably. Why would we? It wasn't an expected anomaly and it certainly isn't a case that one would ever have predicted and then analyzed prior to launch. So we just recognized that there's a lot of unknown unknown flying in that configuration and that we better be absolutely sure if we're willing to take additional risk on. In this case we said, "There's no reason to take additional risk."

JOHNSON: Let's talk about the solar arrays. Like you said, there was no way of predicting that that would happen. These solar arrays have been used before Lucy, is that correct, that type?

LOUNSBURY: Yes. These exact arrays had not been used before Lucy. A similar technology, similar array, is used on Cygnus [spacecraft] for the ISS [International Space Station] resupply missions. However, those arrays, are 3.7 meters in diameter. Whereas Lucy's arrays are 7.3 meters in diameter. So much larger arrays on Lucy.

In addition, they were using slightly different ZTJ solar cell technology. But there were differences and the differences were important, mostly because Lucy was going to a greater distance, so we needed something that could work in the very cold environment. Because Lucy is so far from the Sun, that's why we needed the larger arrays. Cygnus just didn't have this type of need. Cygnus, their deployment was different from ours in terms of the way in which they deploy, I don't think they needed nearly the number of tension mechanisms that we have on Lucy. But also the way that we deployed on Lucy the spacecraft was spinning down, decelerating, and that's not the case for Cygnus. So there are differences in the operations for the deployment and then also in the size and technology of the arrays. Lucy really and truly is the first of its kind for these arrays.

JOHNSON: Talk about some of the ground testing before the flight as far as opening the arrays. I know it's a different environment when you're on Earth opening the arrays or testing. But talk about the risk assessment for that since they were larger and they hadn't been used before as far as that size like you were just explaining. Were there any indications or problems during any of the testing on the ground before launch that would indicate that you might have that problem with the tension on an array?

LOUNSBURY: Great question. We didn't have anything that pointed us exactly to the anomaly we saw on launch day. However, we certainly had challenges. We had one deployment where a panel got stuck. I'm trying to remember. There were actually a couple of things. One was the panel got stuck and I think it was the way that we had some of the—it was like tape I think that had gotten caught, actual Kapton tape had gotten caught and held part of the array back from deploying. That was a good find. It caused us to really look back at our workmanship between all of the different segments of the array.

Another time we had an issue with mechanical ground support equipment, which wasn't flight hardware, but we had some trouble with it essentially getting a little bit tangled up. We were able to stop that operation immediately and not damage the arrays, but these things are so massive that I'm actually surprised we didn't have more problems than we did.

We also deployed them inside a thermal vacuum chamber hot and cold. We experienced a late lanyard release during thermal vacuum deployment and during some ambient deployments but we were able to address these anomalies on the ground. Honestly, they were relatively minor, and nothing that directly pointed us to tensioning of the array. Because we did have five tensioning mechanisms on this array.

But you're absolutely correct that we weren't testing on the ground in zero g. We weren't spinning the spacecraft during testing. You didn't get any of the dynamics nor would you, and that's a test as you fly exception that's pretty standard for most programs. There aren't a lot of opportunities to do something that's spinning an entire spacecraft, especially with large arrays, and deploying them at the same time. That's just not done. The ground support equipment can't support that at all and what may have helped us to be honest, had we spoken to the JWST [James Webb Space Telescope] team earlier in our campaign, we would have learned about some of their anomalies. None of them were directly applicable to Lucy but they did have some array anomalies around tensioning.

I think what that may have done had we learned about it was turned our attention in that direction. I think we would have poked a little bit more and asked more questions. Would we have uncovered it? I don't know. But I think it would have pointed us towards it had we had those conversations before we launched. Unfortunately we did not have those conversations with JWST until after the anomaly had occurred. It was just such a shame because it highlighted to me that we don't do well sharing our lessons learned across programs, and here we are. That mission is inside our doors. They're on our Center. How we didn't learn about any of their challenges, it just baffles me. We need to find a way to do that inside our own gates. Here are systems engineers in my own branch and we're not sharing with each other.

Granted, there's 70 some systems engineers in that group. We don't ever make time to get together other than the occasional lunch and learn, occasionally we would have lunchtime get-togethers. But it was a small subset of folks. Everyone's so busy. When you're the lead systems engineer or one of the lead systems engineers on a program you're working wild hours. It could be anywhere from 50- to 70-hour weeks. You don't have time to pause and meet with your colleagues and share with them the nuts and bolts of anomalies that you're seeing. You don't know which ones are going to be relevant to the other mission across the hall because you're so focused in on what you're doing. It's unfortunate because you don't know their designs and you don't know what hardware they're procuring.

I think one of the things I'll say about that is, and I'm not putting this on anyone in particular, but we do have, now that I'm sitting in our 590 [Mission Engineering & System Analysis] Division, we do have chief engineers in each of the divisions; sometimes, but not always, we have principal engineers sitting in the branches. Right now we don't in our branches because fundingwise we can't afford to set someone there. But I will say that if we had a few more chief engineering positions or deputy chief engineering positions at the division level or at the branch level I think that's a critical position to staff because they're looking across the missions. Whereas the systems engineers inside each mission don't have time to look across. I think that's something that given a different budget profile is a place that I'm advocating for inside all the divisions. I think that's how we might be able to at least transfer a lot of that knowledge and lessons learned because these folks are looking across and these folks have historical knowledge having worked missions previously. Doesn't mean they're the keeper of all knowledge. We do have a database. But I will tell you the database is difficult to navigate. Difficult to find. The search engine that's part of it isn't really useful.

I know Mike and I, my Deputy Mike [Michael] Sekerak, we went and looked when the Lucy anomaly happened. We went and looked for something similar that we can look at. Has anyone else seen this? Of course we contacted Cygnus. We met with them several times. They had had a different anomaly that we recognized pretty quickly didn't apply to us, but we went around looking. We talked with the chief engineers in the divisions at the directorate level, at the center level. In fact on launch day when the anomaly occurred Tupper Hyde our Center chief engineer was at the launch and came over to our control room and sat with us the rest of the day and tried to help us figure out what was going on and what we were seeing in the data. But there wasn't discussion at that time about any similar anomaly that we could look at how did they resolve it or what was the problem.

I think learning from the experience also gave me perspective on where NASA might be able to do better. If we spent time focusing in on how we do knowledge transfer and we do lessons learned. Sure, we're doing some of it, but could we do a better job? Absolutely.

JOHNSON: Lessons learned like the database depends on humans to actually put that in, and like you said you were working 50, 60, 70 hours trying to get the mission going. It's almost like you need a dedicated person working on that all the time.

LOUNSBURY: Yes. I will say we recognized when this all happened for us, we needed to get the data out there. Several of us, myself, Colby [S. Goodloe], Mike, Devin [P. Poland], others, we did a number of lessons learned, engineering colloquiums. We went to specific projects. We actually met with quite a number of engineers and we offered information out to folks right after.

The biggest thing though is doing these lunch and learns and colloquiums. I think it's really important to record these and archive them where systems engineers can access them, because it's one thing to go search a database and find some keywords and find an anomaly. But it's quite another to hear it instead of just reading about it, hear it from someone's discussion of what happened. Being able to go back and play video archives if it applies to your mission, I think would be extremely beneficial. Even just archiving those types of things I think would be a better way of capturing it for future missions. That way it's not living in someone's head.

JOHNSON: After the anomaly occurred with the solar array, talk about the testing and the ground testing. We talked some about it last time. The team was set up and there was a lot of work with the team. But one of the things it made me think about it was when I talked to Arlin Bartels, he mentioned that you have to—I think I wrote it down—first you have to replicate the problem on the ground to create the same condition on demand. Then you have to look at different options to redeploy. Were you involved with that or with the group that was trying to re-create the problem and try to figure out? There were no cameras telling you that look, this strap is there. There was no way to really know. You had to just figure out what was going on from the telemetry and the things that you were getting. Maybe talk about that.

LOUNSBURY: Sure. It was eight months of my life that I am grateful looking back on, but boy, at the time it was the most stressful experience I think I've ever had in this career. I'm sorry, I just have to gather my thoughts on this because we spent so much time, Sandra, it was incredible.

The team did a phenomenal job. We pulled together what was called an anomaly resolution team, an ART team. The spacecraft systems engineer Colby Goodloe, we asked him to chair it. Myself and Mike were key members of the board as well. As was a number of members from Northrop Grumman, from Lockheed Martin, and then we had a handful of chief engineers from Lockheed Martin and also from Goddard. We invited Tim [Timothy G.] Trenkle, the Goddard Engineering Technology Directorate Code 500 chief engineer.

What was really great about that anomaly resolution team was that I think we didn't realize it but almost immediately it was almost as if everyone just left their badge at the door. I will say we were a pretty badgeless team to begin with. But here we were bringing in chief engineers from the various companies and from Goddard and we recognized right away we need to figure out—all ideas are good ideas. Let's explore every option we've got here. We don't know what's going on. We don't know what we're seeing.

Immediately everyone just launched into let's problem-solve. It was great because everybody's got their different strengths and weaknesses. People who weren't necessarily the designers of the solar arrays were coming up with ideas. What was great about that is because as the designer and as the engineers working so closely on this design initially, you're too close to it sometimes to actually see what went wrong. It was good to have a really diverse group. Engineers love solving problems. While we all were stressed because our mission was on the line and we'd worked so hard all this time on this mission, even though we were stressed we were all super committed and super excited to go firefight this problem.

The first thing we really did was set out to figure out what happened. How did we get here? What do we know about the state of the system? How can we learn more information about the state of the system? How can we get this data? Because you're right, we did not have a direct camera or measurement of the state of the deployment. We didn't know how far the solar array was out. We could estimate, but our estimations weren't that great. They certainly weren't in inches, or in degrees for that matter. We really had no way of knowing.

I'm probably not going to get this all in the right order because it's starting to be a blur now. We completed everything we were going to do by July, and here we are in November and it's already a blur.

We tried to re-create the problem on the ground. I think we ran something like 45 tests on the ground under various conditions using as much flightlike hardware as we could. I will also tell you though that we had scraps and pieces of flightlike hardware when it came to for example the solar array panel. The different ways in which we bolted the solar array motor to the panel. There were places that weren't quite flightlike because we didn't have the hardware and the lead time for the hardware was months. We thought we don't have months to go get an exact flightlike set and replicate it. We certainly don't have a solar array panel that's the same size.

We spent a lot of time writing down where were our exceptions in the test setup, and would those matter, and why or why not. That's hard to do when you don't even know why the anomaly occurred, and now you don't have a completely flightlike test setup, so you're wondering is that's influencing what I'm seeing. Eventually we did get really comfortable with our setup and eventually, because we did put in those procurements, eventually we did get a more and more flightlike setup and ruled out anything that we were unsure about.

We did an extensive risk assessment that I led that I'm really proud of where we laid out every potential thing that could go wrong with redeploying the array, and everything that could go wrong if we used as is and did nothing further since launch day. I will tell you that the 45 tests that we ran on the ground to show we understood what had happened, we were convinced we understood it well enough to propose a solution to deploy the array further.

We'll never be fully convinced because we'll never have that direct measurement of exactly what happened. But the signature that we saw in the data we were able to very closely mimic. Even though we ran all these tests, no two tests unfolded precisely like another. Every one of those 45 tests that we ran on the ground to replicate the anomaly had a slightly different outcome. I will tell you we purposely pushed those tests to the breaking point. Literal breaking point. The reason we did that is we wanted to understand if we continued to go further with this array what could possibly go wrong beyond what's already gone wrong. Is it safe to go further?

We got different answers from each of these tests. A lot of the answers started to fall in family with another, such as like cracking the panel that the solar array motor was sitting on. But then we started asking ourselves, "Okay, well, if this panel cracked, what would that do? Would the motor fall off of the array? Would it crack to the point of reducing the strength in the overall panel? Would it further harm the integrity of the array? We did extra tests on top of that. We took cracked panels and ran them through thermal cycles to make sure that the heating and cooling the array saw as it's flying over an 11-and-a-half-year period would not further propagate cracks in that panel. Turns out after multiple cycles it doesn't. The propagation stops pretty quickly, usually after about two cycles.

Each one of these tests turned into a risk statement. Okay, if we went this far here's what could happen. Then if we got to this point what would happen over a 12-year period of the array sitting in this condition? We really ran every thread to ground in terms of what could potentially happen if we attempt something further and what could happen if we got stuck there.

The Kevlar lanyard was of course of concern. So many people were very worried that the strap was going to break. If the strap broke, the solar array would refurl on itself and we would not have any cells exposed on that array. We had one array that was completely out 360 degrees and then the other array eventually we estimated was about 330 degrees deployed out of 360. That's great for the power that we needed for the mission. It's not great for the mechanical stability of the actual structure of the array. While we knew we could fly the mission from a power perspective, we weren't sure we could fire the main engines and that the transient loads from the starting and stopping, more so the stopping of the main engine burn, wasn't going to crack solar cells, wasn't going to somehow disturb the integrity of that array.

The ADAMS [Automated Dynamic Analysis of Mechanical Systems] simulation or modeling videos that Lockheed put together—Russ [Russell N.] Gehling, he was phenomenal. He came out of retirement, came back on the project to help us solve this problem. I will tell you his contributions were invaluable because not only did he analyze how the array would behave based on its current condition, but he uncovered that it really probably was not stable enough to handle those maneuvers.

When you watch the video, the simulation of what the array might do, there were parts of it that just bent back and forth from a V shape to a W shape over and over in quick succession. It was quite scary to watch this array folding and bending in all these ways that it was not intended to operate in. We quickly realized that the more we pulled the lanyard in and tightened up the array, even if we didn't get it fully latched, the more we tightened it, the more stable it was, and the less susceptible it was to these bending and these waves that would be created by the engine firing.

That really helped our risk posture in terms of understanding why it was important to keep trying to close the array. Turns out the lanyard that everybody was worried about breaking, these lanyards were rated to a strength of 1,500 pounds. Kevlar is extremely strong material. We took it and we actually had the engineers at Goddard who work in the radiation group, we had them expose pieces of those lanyards to the UV degradation and radiation that it would see over a 12-year exposure for the life of the mission, and we did that accelerated testing to make sure that those fibers would not degrade to a point where the strength of the lanyard would cause it to break and the array to furl back on itself.

We also had them do pull tests, strength tests, things of that nature to show that if we did in fact continue a redeployment attempt using redundant motor windings, so higher torque than we had originally used on launch day and than we ever intended to use, it wouldn't then further degrade the lanyard. It turns out we had tons of margin. Something that was rated to 1,500-pound strength was degraded only to—I don't remember the exact numbers—1,100-pound strength at worst case. The lanyard itself sitting there holding the array only needed to hold something like less than 10 pounds. So gobs and gobs of margin. Knock on wood, this lanyard should not have a problem holding that array in place as we go through the rest of the mission.

But that doesn't calm everyone's internal uncomfortableness and fear surrounding it. It just doesn't. As humans when we start thinking about risk, people don't have a very good internal calibration in terms of risk. Oftentimes people gravitate to the things they understand. In my mind as we went through this campaign for me the lanyard possibly breaking was more of a green risk, but in the minds of many others it was a red risk. Folks that were a little bit outside of the project and weren't down and in.

I will also say though that by rewinding or redeploying and pulling in more lanyard the way the lanyard was attached to the outside of the motor spool, it was cinching down and tightening the threads on that. Kind of like a fishing line on the outside of a spool. It's tightening down and tightening down. The layers that are on the innermost portion of the spool, we found during our redeployment attempts sometimes those layers would break. They would start to fray and fray and they were tightened down so tightly that they did break down on the inside of the bundle, all the way in. However, the upper portions of the bundle were so tightly wound around the outside that anything that broke deep down inside didn't matter. The whole bundle wasn't moving. People had data to point to and say, "But it did break on the inside."

We said, "Yes, however, it didn't lead to and couldn't lead to the array furling back in on itself."

To go back to what I was saying, we spent a lot of time figuring out what the problem was, and then once we were reasonably comfortable, we understood it through those 45 tests, then we ran a whole bunch more tests to show if we redeployed it what could happen, what's the worst. We wrote up all of these risks and we spent a lot of—by we I mean I spent a lot of time articulating why each of these risks was okay to proceed with a redeployment attempt. It took a lot to really get down to the nitty-gritty on every single one of these scenarios.

I will tell you we were being very conservative, because as I said the tests that we ran to redeploy the array, we took them to failure on purpose. Most of the risks that we were mitigating were failure scenarios that were well beyond how we were going to do the redeployment. It was really conservatism on top of conservatism, and then convincing everyone that those risks of failures that we never intended to get to were still okay if we did get to those, and why that was okay. That's how I was able to bring the team along and all the chief engineers along and Headquarters along and management and the PI [principal investigator]. I spent so much time having those conversations and convincing folks through the data and through the what-if scenarios why we were okay to proceed and why the return on investment was worth it. Because that array was not going to be as stable as it could be in the configuration, we landed on on launch day. Honestly, I wasn't confident if we stayed in that configuration that we wouldn't have greater problems.

Eventually I will tell you, Sandra, there were a lot of conversations that involved bringing people along in the background, having one-on-one conversations. At no point did I expect to get consensus from the team for the redeployment attempts. I didn't require it. However, certainly it's in the best interest to get as close to consensus as possible. I don't think we could have gotten any closer. The engineers that worked the ART team, not all of them were in consensus. But I would say more than 98 percent of them were willing to go forward, and those that weren't comfortable expressed that they weren't going to stand in the way, and they were happy to go on record that they dissented and why. I spent a lot of time, it was very important that everyone's responses got documented with their name, with the date, for every one of the seven redeployments that we did. I made sure everyone went on record. And when we presented all of this to our chief engineers and to the AA [Associate Administrator], Thomas Zurbuchen at the time was the Associate Administrator at Headquarters, we went on record with there were dissent opinions, here's what they are, we want those folks to have an opportunity to speak and to share with you, because we're not taking this lightly. While we don't have full concurrence from the whole team, we need transparency.

That was something that I'm really proud of the way we handled that, and it's important to me for all future missions. It's something that as I'm mentoring systems engineers now, I'm referencing that. Because the last thing you want to be accused of is not hearing another person's opinion and not considering another viewpoint or position that maybe you hadn't thought about. In this particular situation we had no 100 percent certainty, knowledge that we were correct. But I was confident enough in moving forward and I was willing to put my technical authority on the line to say, "I think this is the right move for us for return on investment for the mission."

Do I know with certainty today that that's the right call? No. I still don't with absolute certainty. I will say though that we're going to have our first main engine burn in February 2024. That will uncover some of the uncertainty. We did many maneuvers on the spacecraft after launch, just small ones, to understand the dynamic behavior with the array unlatched. That helped inform us quite a bit, but nothing to the magnitude that we're planning with the first main engine burn. That one is going to be particularly important, and the only thing I can say is if we end up in a further anomalous situation, I'm sure glad we're getting data at Dinkinesh.

JOHNSON: That kind of helps, doesn't it?

LOUNSBURY: Just a little bit. It's not the science we set out for. It still would not be considered mission success because we're not going for main belt asteroid data. But surely spending $1 billion on a mission and getting nothing back is much more heartbreaking than getting something back.

JOHNSON: Hopefully, we'll see what happens in February, but you mentioned seven redeployment attempts. Did it get further each time? Or did you have to go backwards before you went forward?

LOUNSBURY: Good question. First of all, the solar array motor could not go in reverse, so that was one capability limitation, one limitation we had, or capability we did not have. The first several redeployment attempts actually brought in more lanyard than the subsequent attempts. As we pulled in more and more and the bundle of lanyard, cinched down further and further, it eventually wasn't bringing in more than an inch or two toward the end. We decided on attempt number seven when we only saw one to two inches that that was it. We were hitting diminishing returns, and we didn't want to go further, because doing one more inch wasn't going to really give us any bang for our buck.

At that point after the seventh attempt we estimated that we were somewhere around 357, 358 degrees deployed. Being within two or three degrees of completely deployed we showed by analysis was good and plenty good for the stability of the array. We didn't need it for power, though it's nice. It was really all about stability. Once we realized we're not going to be able to latch it, which was heartbreaking a little bit because the first couple of attempts we pulled in so many inches. We thought oh my gosh, we might get there. But the trend just wasn't in our favor.

I will tell you we estimated, again all of this is an estimate, huge asterisk on estimate. But we believe we pulled in somewhere around 72 inches in total, which was a huge amount. We were shocked. On the first attempt we pulled in just shy of 43 inches – we were so excited and we thought oh, this is great, this is trending in the right direction. We were like, "Oh, oh my gosh, we might make it." Then slowly but surely we were like, "No, we're not, we're not going to make it."

But that's okay because in the end we, I think, made so much good headway, it was all worth it. In my mind it was all worth it.

JOHNSON: We talked about the fact that it's even in the news now because of this first flyby. But at that time did you have to deal with any of the PR [public relations] around that and dealing with any kind of news reporters?

LOUNSBURY: Absolutely. Yes. I was getting phone calls from reporters, from the media. We were asked to edit articles that went into the media and in the news. Yes. For the most part in the first week was really where a lot of it bubbled up.

We kind of agreed, because we didn't know enough, we could only give top-level information to say the array did not fully deploy. We're working on it. The spacecraft was in a safe configuration to continue with the mission. I don't want to say we had a party line, but we all agreed ahead of time what we could share. We kept it very high-level because to be honest with you, it took us months to really figure out what really happened and prove it on the ground. We didn't want to speculate and then have to walk back something that we said in error. We didn't want to guess how far we were deployed. That was the number one question people kept asking. How far are you deployed? How much further do you have to go? How are you going to solve this?

We didn't have those answers. All we could really continue to say was the spacecraft is stable, the hardware is fine. We have time to work this issue because our first encounter isn't until 2024 when we go to the main belt asteroid and even then, it was a rehearsal, it wasn't science. At the time we weren't even fully aware that doing the main engine burns was going to become a primary concern. It was pretty nerve-racking from the media. All that media training that you go through before launch to be careful about what you say really came in handy. That's for sure.

I almost forgot this. I remember sitting in a couple of our early meetings. We were still at the launch site. There were media and there were press at the launch site. I remember sitting in one of our early anomaly investigation meetings and someone from the media was in the room with us. I think we were all just so busy trying to solve things and it was just all a bunch of engineers and no managers in the room.

Eventually it dawned on me, "Oh God, guys, we have someone from the media sitting in here." I went upstairs. We were at Astrotech in Florida. I went upstairs to the manager up there and I said, "Hey, we need to talk. I know the media wants to know what's going on, but it's not appropriate for them to sit in our anomaly team meetings into our discussions where we need to be open with each other and throw everything at the wall and see what sticks. That can't go in the press. We're just playing a what-if game right now and trying to understand the data that's in front of us and do our what-ifs make any sense with the data that we're looking at."

I will say he got a little upset with me and said, "Well, they need to know too."

I said, "I understand that, but how about you and I sit with them after the meeting and decide what we can share in terms of where our investigation stands at this moment?" He did agree to that eventually, but it wasn't because I convinced him. He was one of our Lockheed Martin managers. A lot of the press folks were Lockheed Martin. I will have to say I did eventually have to call our project manager and I got her on the line and the three of us sat there. I'm going to choose my words here to say that she made sure he understood that that was unacceptable and that the press was to no longer be invited to those meetings.

I was relieved that I recognized it because we were running so fast and furious at that moment, we were still at the launch site, and we had been up for hours at that point, several days in a row working very long hours. We were all just really focused on what we were doing. When it dawned on me that this person that shouldn't be in the room was sitting there, I had to do the hard thing and get him kicked out. It's not that we didn't want to be forthcoming. We did. But when you're in that mode where you're trying to figure things out, you don't want your words to be misconstrued. That's how it went down.

JOHNSON: Let's talk about that project manager and that management position, because on Lucy that changed a few times during the mission. Talk about the importance of having a project manager especially during a time like this, during an anomaly, and when everyone's like you said working hours and hours and hours with no sleep. Talk about the importance of that project manager in that type of situation.

LOUNSBURY: Oh, wow, yes. Keeping everyone levelheaded about the situation is probably the most important part of that role. The prior project manager who retired, Mike [Michael] Donnelly, and the project manager that was part of Lucy during this investigation was Donya Douglas-Bradshaw, both of them had the personalities and the experience to handle that type of situation. Donya in particular is very good at clear messaging to the team, to the PI, to the media. She is very good at managing expectations. She was integral in keeping Headquarters informed but calm. It was very important to keep them from sending us extra help that we didn't need or incorrect type of help. I will say we absolutely leveraged those chief engineers and we leveraged the NESC [NASA Engineering & Safety Center] for specific tasks to help us along the way. But what she did was keep them from declaring a mishap. Once a mishap is declared, it's out of your hands. The project is taken from you, and it is given to a Headquarters tiger team. We didn't want that to happen because we were the closest to it. We were very invested in understanding what had happened and in correcting it.

Obviously at times you're too close and so maybe that's a disadvantage, but I think that's where bringing in a few folks, chief engineers, NESC members, pulling folks out of retirement, things like that, that helped us to get the outside perspective without taking it out of our control. Donya was really instrumental in that. In making sure that communication path was open. We were sending daily—sometimes multiple times a day—updates to Headquarters to keep them abreast of the situation because that helped them feel like they were being brought along with the investigation. You're feeding them enough information to keep them comfortable with our approach. Eventually as it dragged further out and we realized this was going to be a longer investigation, we held a multiday review in, I think, April of 2022. I think it was a three-day review we held at Lockheed Martin and we invited chief engineers to come and essentially be panel members at our review.

We self-imposed a solar array anomaly review is what we called it. We had chief engineers from everywhere: Headquarters, the program office at Marshall [Space Flight Center, Huntsville, Alabama], Goddard, Lockheed, Northrop, folks from outside our organization. That helped a lot. Then eventually when we got close to redeployment attempts, we held essentially an all-day meeting at Headquarters and walked through our position as a team, and the dissenting opinion that we had from Lockheed Martin.

All of this communication path was just so important. I think that I learned the most through that experience and through what Donya did. She had worked the ICESat-2 [Ice, Cloud and land Elevation Satellite] ATLAS [Advanced Topographic Laser Altimeter System] instrument. She had gone through a similar exercise when they had an anomaly. Theirs was prelaunch, but she learned at that point how the communication path needed to be fostered with Headquarters, with all of your stakeholders, so we were reaping the benefits of her lessons learned from a previous mission. It opened my eyes to how to collaborate with your stakeholders in a tumultuous situation and keep them calm and keep them informed so that it's not taken out of your control.

I think that was just the number one thing Donya brought to the project that had she not been there and brought that, I think it would have been utterly chaotic. Hal being a first-time PI was very nervous when this happened. Even though he and I had developed a rapport and he understood the value of the systems engineering team and what we did, it took the whole mission timeline for him to really understand what we did and why we could be trusted. But during this anomaly we were the ones front and center on trying to solve it. Having that project manager handle the communication piece with me and teach me how to do that was so important, because I know I would not have known how to handle that on top of trying to solve the anomaly. The communication and the technical combined were both challenging. I did a lot of watching her and then emulating that. I got very good at it after eight months. I will say that it worked out the way that we needed it to in the end, but I think without Donya we would have been in a world of hurt, a real world of hurt. She always says, "Words matter." She lives by that. You see her in every meeting, could be the most unimportant meeting, but she's still careful in terms of how she manages people's expectations.

JOHNSON: You talked about having those mentors, and you mentioned Dave [David F.] Everett and his mentorship [in a previous interview], and getting on the Lucy team with his help, getting you to the point where you felt like you could move on by yourself. You mentioned that you mentor people too. Talk about how important those mentorships are, especially in engineering, in getting people prepared for the next mission. In Discovery you don't want the same teams working on every single mission. You want to keep growing those teams and bringing new people in to have those experiences.

LOUNSBURY: Sure. Yes. Having been mentored over the years, I saw the value in it. I believe in mentoring wholeheartedly because you need to see different leadership styles. You need to see what works and what doesn't work and from those experiences carve out your own leadership style.

That's something I'm always learning. I will still forever be learning how to be a better leader. Every single leader that I come in contact with has some influence over my ability as a leader. I've still seen that to this day. Knowing that, it became extremely important to me to make sure that I'm giving people growth opportunities, mentorships. You have to stretch in order to grow, and so on Lucy we had a number of younger systems engineers that I brought in over time. Colby Goodloe was our spacecraft systems engineer. Bringing him aboard was fantastic because now he's leading the in-house descent sphere build for DAVINCI[2] [Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging], which is huge. I joke with him all the time. I think that's the best job on Center, and I actually mean that. He's going to have so much fun. Such a challenge to build a descent sphere that needs to survive through the Venusian atmosphere. There's no one that's better suited for that. He's just fantastic as an engineer. His leadership style, it's fun to watch it blossom over all these years, having worked with partnerships, having worked with subject matter experts at Goddard. His approach has changed over time and it's really fun to see.

[2] NASA's DAVINCI mission will study the origin, evolution, and present state of Venus in unprecedented detail from near the top of the clouds to the planet's surface.

Devin Poland. We brought him in essentially as Colby's deputy spacecraft systems engineer. He eventually moved over to become our mission operations manager who's been leading the Dinkinesh encounter. Devin again is a really strong technical person and it's fun to watch his leadership blossom. He and I have had many conversations, some heated, just in terms of his leadership style. There were times where he was not instilling confidence in Hal when we were going through some of the anomaly work, and I had to call him and have these conversations and said, "Devin, you're joking a lot during these meetings and I know you're doing it because you're nervous, but you laughing and making light of this is making Hal really nervous. I don't know how to tell you this but I need you to stick to the facts. I need you to actually be a little more serious in these meetings and I need you to notice your tone of voice and how you're presenting yourself, because Hal is freaking out."

Devin took the feedback and it was great. It's funny. Devin and I have a friendship outside of work. He used to live with my husband when they both first started at NASA before he was even my husband. It's just funny because here I have to give feedback to colleagues that are also friends and it's tough feedback. But they need to hear it in order to grow. Hal and Devin have been working together now in operations for more than a year at this point and they're doing great. Sometimes it's just tweaks that we need to make in our leadership style, but mentoring people and getting real feedback is so important. I long for people to actually give me critical feedback, and not in a negative way. It's very hard to see yourself and what you're doing or not doing that could be tweaked to benefit. It's very hard to give feedback to people. You always want to be kind and generous and you want to gravitate towards the positive. But giving the hard feedback is actually what mentoring is more about.

I'm mentoring three different people right now that are systems engineers, and I've given them some tough feedback too. I will also say I'm being mentored right now as well. It's awesome because if you're able to continuously have mentors and different mentors along the way, there's nothing more valuable I think in a career path. Especially as a leader, but certainly in any role, if you're willing to be open enough to accept feedback and act on changing.

Some of the feedback you don't want to act on. Some of it is not good feedback or may not serve you in the way that you want it to serve you. But it's still better to have that opportunity than not. I'm a big believer in mentoring and in bringing people forward and giving them stretch opportunities. I'm really excited about it and it certainly has paved the way for my career. I believe in it.

JOHNSON: Yes, it's so important to pass that on. Like we talked about with the lessons learned, passing the information on is part of it, and we talked about the database not being as good as it could be, but are there any other lessons learned you feel after working on Lucy that you want to mention here?

LOUNSBURY: Oh, wow, lessons learned. I'm trying to think. I'm sure there are. There's no doubt they are buried in there. There were lots of lessons learned in terms of teaming. For me personally, back to giving that hard feedback, I did have to let one of our systems engineers go from the team before we completed the mission. I could have done a better job with that individual. I think I tried to mentor them the best way I knew how. We had many conversations and many opportunities. I don't think I could have changed that person's style. I do think though that I could have probably let that person go sooner because it caused a lot of consternation on the team. They butted heads with many engineers, many managers. Really over a two-year period I cataloged a lot of difficult conversations between myself and that person. I really did try my hardest, and I think I just really wanted that person to come around and compromise somewhat. Their style was more in a black-and-white lawyer type of approach that can't be changed. I think they weren't suited well for the position in the end is really what I came to realize, because they're a great engineer, very sharp. They did have benefit to the project, but the leadership position they were in is what didn't work. I think there's certainly a better role for them. I could have done a better job in what I say. What I mean by that is that I should have recognized earlier the need to tackle it earlier, because it just made it so much harder for the rest of the team.

It wasn't that the person had a dissenting opinion per se. Because I will also say that when we did move that person off the project, they were upset about it understandably but they also—when people leave a project they don't see their shortcomings, and so the blame was transferred to me, which was fine. I was fine to accept that. But the one thing that really upset me was that they said that I hadn't considered their opinion and that they were being let go because they didn't align with my opinion. That really upset me because it wasn't the case. I was really upset because I thought gosh, I gave you two years of many attempts, and every time we had a difference of opinion, I was very clear to document their position through our risk process. I knew that I think they were just upset when they left. Because it was there. We had many risks entered into the system that we either bought down or the project manager who led the risk board decided not to go forward with. So it wasn't just my opinion that they weren't aligned with.

But it was really upsetting and it was a lesson learned for me that I want to make sure everyone's voice is heard. When we did go into that anomaly investigation, that became a primary focus for me. In some ways having gone through that lesson of letting an employee move to another project, it did in fact help me to do a better job to make sure dissenting opinions or differing opinions were heard in that anomaly. I don't know if that person ever got lessons learned out of the experience, but it certainly gave me an experience that I'll carry with me. I think there's always going to be a time where someone's got to get moved off of a project because it's not working out for one reason or another. I think that was the most important lesson to me was making sure they're heard no matter what. I think that I did that but the importance of that really struck me more in that experience.

JOHNSON: On a completely different subject, I'm looking at the posters behind you, and there was a lot of outreach during the mission or the buildup to the mission, and a lot of the public engagement, the cartoons, all the little things to get people interested in it, which I think is really cool because it's an interesting mission, and it does have that appeal to all ages. The budget for education and outreach isn't what it was 10 years ago but did you have any involvement in any of that outreach? Did everyone on the team do a little bit of that?

LOUNSBURY: Yes, a lot of people had the opportunity to do outreach. The L'SPACE [Lucy Student Pipeline Accelerator and Competency Enabler] Program that we had for Lucy was amazing. Sheri Klug Boonstra and Dan Brown at ASU, Arizona State University, pioneers. Just absolutely wonderful program. They have engineers from across the nation tapped into what Lucy was doing. They would call us and ask us to do, what I joked and called TED talks, virtual sessions with 300 to 400 students at a time. I did a lot of these, and so did several other team members. We would get online with all of these students virtually and we were on the east coast, so it was usually from like 7:00 to 9:00 p.m. We would get online with them for two hours and describe where we are in the mission, what's going on, what are the challenges we're facing, what questions do you have for us. Of course they always wanted to know how we got into the roles we were in and what was it like to be a systems engineer.

I did that all along the way for several years, starting around the PDR [preliminary design review] timeframe all the way through post launch. Did many of these sessions. I know Hal and Cathy, Donya, and others did as well. That was just amazing because these students, it was great, you'd talk to 400 students, you'd hang up the phone, and all of a sudden, your LinkedIn is just blowing up. Everyone wants to be your LinkedIn friend. They want to follow you. They're following Lucy on Twitter and Instagram. Katherine Kretke at Southwest Research Institute did a lot of the public affairs work and she was constantly interviewing us, putting our pictures out on Instagram, doing little articles, coming by, and just taking our picture, and calling us all the time asking, "What's going on?," and really keeping the public engaged. Certainly did other things. Everybody did the things we always do where we go to our old middle school or high school or our old university and we tell everybody about it. It's really fun stuff.

But yes, I think Southwest Research did a ton of the public outreach. They were really open to our ideas. We just had a lot of fun with it. We made sweatshirts that looked like a concert lineup with all of the different asteroids and the years and all that kind of stuff. We had a lot of fun with all the swag, and different stickers, and it was fun.

There was a European group that followed us around for years and did a documentary on Lucy that they released. It was a company called Somadrome. They really wanted to get picked up by the Discovery Channel. I'm not sure they ever did. But they got picked up by Curiosity Stream and did a documentary on Lucy and released that around Christmas of 2022. That was really cool. They followed us around for years, they interviewed us. Just different clips at different times. It was kind of neat to see over the years what we were working on and how things went. It was a lot of fun. The outreach piece to this, it made things more exciting.

Even when we were in the media after launch, even though it was an anomaly, it was still really exciting that the world wants to hear about our mission. Right now hearing that Dinkinesh is in the news is huge. We want students to understand how we're changing what we know about our universe. I actually did an outreach at my old middle school last Friday and it was really fun to talk to these middle schoolers for their career day because they're just so excited. They don't understand the fact that we don't know everything. It's just fun to watch their faces when you say, "I love working here because we're answering questions or learning something in an area that we know nothing about." A scientist will propose a mission to understand the origins of the solar system because we're not sure if our hypothesis is correct or not, and we're going to go find out. Either prove or disprove our hypothesis. We might not find out how the solar system formed but we might find out that our idea of how it formed is wrong. They just look at you like wait, so there's still more to come that's not in the textbook. It's so cool. The questions they have. It's inspiring. It's surprising. You are humbled by it. I'm humbled by it.

JOHNSON: Kids will do that to you.

LOUNSBURY: They humble you for sure.

JOHNSON: Yes, they do. Is there any one thing if you had to point at one thing that you're most proud of as far as Lucy is concerned?

LOUNSBURY: Oh, gosh, to be honest with you I'm just proud to have had the opportunity to lead the mission and lead 400 engineers and honestly, I wasn't sure I'd ever get that opportunity. It was the most amazing experience I've had to date working at NASA. Getting the trust and building the relationships and the rapport with the whole team, with the PI, with all the engineers, with our management team, I think I'm just most proud that I earned their trust and respect and was able to lead the mission successfully. I think for me that was the most honoring thing to be a part of. I'm still humbled that I was able to serve in that role. It's a team effort. Certainly our success and failure was probably not hinging on my role in particular. It's a collection of everyone. But I think for me the ability to set the environment and the culture that we worked in and have it be a positive experience for our team even in the face of an anomaly, I think that's what I'm most proud of is being able to create that environment for our team to work so well together.

JOHNSON: Is there anything we haven't covered that you wanted to cover while we're talking?

LOUNSBURY: I don't think so. I think we hit quite a bit of the mission.

JOHNSON: I think so too. Okay. I'm going to turn off the recording but I appreciate you talking to me both times. It's really helpful to get everybody's perspective.

LOUNSBURY: Sure, absolutely. Thank you for reaching out to me and letting me be a part of it.

[End of interview]