DISCOVERY 30TH ANNIVERSARY ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

ARLIN BARTELS
INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is August 25th, 2023. This interview with Arlin Bartels is being conducted for the Discovery 30th Anniversary Oral History Project. The interviewer is Sandra Johnson, and Mr. Bartels is at Goddard Space Flight Center in [Greenbelt,] Maryland, and talking to me again over Microsoft Teams. This is our fourth interview, and we're going to talk about the Lucy mission today. I'd like to start just by asking you when you first started working with the Lucy mission.

BARTELS: Right. So I joined the Lucy mission in basically August/September of 2019, right at their critical design review, and so what was an interesting thing. I'm sorry, would you remind me who you've already talked to about Lucy?

JOHNSON: Hal [Harold F.] Levison and Keith [S.] Noll. That's who I've talked to so far.

BARTELS: Fantastic, fantastic. Yes, so the Lucy mission was selected basically in I believe it was January of 2017, and one of the interesting things that happened with it—at least now I'm going to be talking from the Goddard/NASA side since you've been getting already the PI's [principle investigator's] perspective and our project scientist's perspective. One of the interesting things that happened with that was the leadership team on the Lucy folks mostly came over intact from the OSIRIS-REx [Origins, Spectral Interpretation, Resource Identification, and

Security – Regolith Explorer] development team.[1] We'd been working on the proposal in parallel with the end stages of I&T [integration and test]—we call that ATLO [Assembly, Test, and Launch Operations] in our speak—and through the launch campaign, and then most of the OSIRIS-REx team, like I say, just moved over from the Goddard side, took the OSIRIS name off the door when we handed over to the mission operations organization, and put the Lucy sign on.

I was a little different: I stayed with OSIRIS-REx when it launched. It launched in September of 2016, and then I moved with the mission into operations, took over the role as the daily management lead. I was the operations project overall DPM [deputy project manager], focusing on OSIRIS-REx. Meanwhile, though, the Lucy team moved over, met a new PI, new organization to work with. That group that had done OSIRIS-REx had worked a lot with University of Arizona [Tucson] PI, Dante Lauretta, and their organization, so they were off building the new relationship with the folks from Southwest Research [Institute], like Hal, and I think you mentioned you'll talk to John [P.] Andrews and others. And so that team was working straight through, and almost seamless. It was really amazing how well that worked out. It is rare in our industry for a team to be able to finish one job, or at least get it through launch, and transition to operations, and then just transition over in as an intact team to the next mission on competitively selected missions. That's extremely rare, and the team was very lucky to be able to do that and get off to a good start.

Now, the project manager for OSIRIS-REx is named Michael Donnelly, and he also started as the project manager on Lucy as well and took it basically up that CDR [critical design review] timeframe. The OSIRIS-REx deputy project manager, John Loiacono, retired just a little

[1] OSIRIS-REx is the first U.S. mission to collect a sample from an asteroid. The sample return capsule returned to Earth on Sept. 24, 2023, with material from the asteroid Bennu. After dropping off the sample, the spacecraft was renamed OSIRIS-APEX (Apophis Explorer) and sent on a new mission to explore asteroid Apophis in 2029.

before Mike, so we had that great continuity over from OSIRIS-REx management leadership at the start of the mission, which took us up to basically confirmation. It was basically a confirmation mission PDR [preliminary design review], roughly, that John Loiacono retired, and at that point then Donya Douglas-Bradshaw came on to the project as the deputy project manager reporting to Mike. Then, when we got closer to CDR, when Mike Donnelly followed John Loiacono into retirement, then Donya was elevated up to being the project manager, and so the DPM position was open, and I slotted over from being the operations group, SSMO's [Space Science Mission Operations] DPM, back over to Lucy as the Lucy DPM. So my first real activity of knowing the Lucy team was joining them basically just prior to the critical design review, and then I stayed throughout the mission, through launch, and through the post-launch anomaly they had with the solar array, until we knew that that was in a good, safe space. Then we had what we call our PLAR, our post-launch assessment review, hand it over to SSMO for operations.

I was with the project from basically right about this time of year—end of August, start of September—of 2019, full-time through the launch on October 15, 2021. Then myself and some members of the technical team stayed with the project for the first nine months post-launch to make sure that the solar array anomaly was resolved enough to permit the mission to continue. I realized I give you very long answers to very short questions.

JOHNSON: No, that's exactly what I want, believe me. That's what oral history is; it's not a short answer. And that clears up that whole timeline. One of the questions I was going to ask you, but you've basically already answered it, is if you'd worked with this team before, but obviously that was something that worked out really well. As you said, it seems like it's very unusual for a

competed mission to have that luxury of having those same people from a previous mission. Maybe talk about some of those relationships and how that team worked together. I know you had some change-outs with the management during that first couple of years, but talk about those relationships and how that team worked together, and compare—even though we haven't talked about OSIRIS-REx yet—but maybe compare it to the other missions that we have talked about.

BARTELS: Yes. Now, one of the interesting things here about the Goddard-led Discovery missions—and New Frontiers, as well—we had that Mars scout called MAVEN [Mars Atmosphere and Volatile Evolution] that was our first real foray into managing a planetary mission after LRO [Lunar Reconnaissance Orbiter], and then OSIRIS-REx, Lucy, and now DAVINCI [Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging].[2] [3] [4] Along those lines, we've had some real continuity of team partners, going all the way back to MAVEN. Our main industrial system integrating partner has been Lockheed Martin in Waterton [Canyon campus], Denver, Colorado, and they are a really extraordinary group of folks that have a group called DSE, Deep Space Enterprises, that does all the planetary missions. Lockheed Martin has been the primary industrial partner for planetary missions, going back to the days when they were Martin Marietta and even all the way back, like the Viking landers in the '70s.

[2] The MAVEN mission will determine how much of the Martian atmosphere has been lost over time by measuring the current rate of escape to space and gathering enough information about the relevant processes to allow extrapolation backward in time.
[3] LRO was the first U.S. mission to the Moon in over 10 years. LRO created a 3D map of the Moon, as part of a program to identify future landing sites and resources – including deposits of water ice shadowed in polar craters. LRO continues to orbit the Moon.
[4] DAVINCI will study Venus from its clouds down to the planet's surface—the first mission to study Venus using both flybys and a descent probe—to determine whether the inhospitable surface of the planet could once have been a twin of Earth, a habitable world with liquid water oceans.

In terms of working on these projects, there's the continuity that we have within Goddard, and we've been fortunate not only to have that from OSIRIS-REx to Lucy, but then also from Lucy to DAVINCI, as well, where it's a lot of the same staff members, on the Goddard side, working with Lockheed Martin as our primary technical partner, and there's been a lot of continuity on their side, as well, on the Lockheed side over the years. Some of the folks at Lockheed have actually worked two, three, or four of these missions themselves, in addition to other Discovery missions like GRAIL [Gravity Recovery and Interior Laboratory].[5] I'm sure you're talking to folks about GRAIL, as well. There's a thread of a really excellent working environment between the Lockheed engineers and the Goddard engineers. I'm sure they do the same with JPL [Jet Propulsion Laboratory, Pasadena, California], but I'll just speak for ourselves.

It's very synergistic of how we've worked together with these groups. In the big picture, one of the commonalities we've had across the board has always been this really strong partnership with Lockheed Martin, who does the spacecraft bus for all these missions; that's the main spacecraft itself. We typically have other groups who build the instruments, the instrumentation, coming from either other NASA centers or APL [Johns Hopkins University Applied Physics Laboratory] or universities, but those all then deliver for final integration at Lockheed Martin, and then Lockheed is the lead organization through launch, and they also do the uplink/downlink command operations, as well.

The first part of your note, I think, is that one of the really important threads here is that Goddard and Lockheed now, through four consecutive missions, all of which have had overlap and continuity, we've had a lot of continuity in the Lockheed side with the engineers. The

[5] GRAIL flew twin spacecraft – Ebb and Flow – in tandem around the Moon to map variations in the lunar gravitational field.

managers at Lockheed—it's been a different manager every mission. It turns out that successful developments of these missions that launch on time and under budget tend to get their managers promoted, and so there's been a real success story of the Lockheed engineers being promoted up that chain. But a lot of the engineers are so committed to working planetary missions that they will stay in that arena, working those kind of missions, rather than accept promotion possibilities onto other missions. In addition to GRAIL, there's also the Juno New Frontiers mission, as well, that they've done.[6] There's a lot of folks there who are very proud of their career just staying within that planetary world, being cross trained within the other missions from operations and just doing that work.

They've had sort of a natural succession plan. I know this is Lucy, but turns out the OSIRIS-REx lead system engineer is now the project manager on the DAVINCI project. The project manager for Lucy graduated basically to working Orion and now leads the Orion program. We have a lot of engineers that worked OSIRIS-REx that just moved over to Lucy, and they had a very strong background there. That's the first part.

The second part is on the Goddard side, when I mentioned the continuity that we had, one part that was interesting is that continuity was more on the management and financials side. The entire business team, all aspects of it from project planning to earned value to budget to resources, financial managers, all of those just moved over—configuration management—just all as a group, from OSIRIS-REx to Lucy under the Deputy Project Manager for Resources, Vince [Vincent E.] Elliott, who's really, really extraordinary in his field. We're so lucky we were able to retain him. Vince comes to mind because, just like the Lockheed folks, he's so committed to

[6] The Juno spacecraft has been probing beneath the dense clouds of Jupiter since 2016, the first orbiter to peer so closely to the planet. It seeks answers to questions about the origin and evolution of Jupiter, our solar system, and giant planets across the cosmos.

the planetary missions that he turns down repeated promotion opportunities to stay in this planetary world. That team came over intact from OSIRIS-REx to Lucy, and actually continues on at DAVINCI.

From an engineering standpoint, some of our system engineering leadership, some of them promoted up. Our Goddard Spacecraft System Engineer, Colby [S.] Goodloe, came from a more junior role on OSIRIS-REx, and so he moved up to take that next role. The system engineers for OSIRIS-REx themselves got promoted out to head up the system engineering branch at Goddard. Dave [David F.] Everett was his name on OSIRIS-REx. We had two new system engineers that came in in the leadership role, Jessica [A.] Lounsbury—she was Thompson at the time, but it's now Lounsbury—and Mike [Michael] Sekerak, and they put together a technical team at Goddard to work with the Lockheed folks that included some members, holdovers from OSIRIS-REx, and some new bloods, so we want to make sure we don't get stale, so we do make sure that we're always getting new blood in, and younger engineers along the way.

The new dynamic for us to learn about was the Goddard folks were very used to working with Lockheed Martin. What was new to the Lucy team was working with the Southwest Research folks, from Hal's organization. As I'm sure Hal told you, there are two large groups at Southwest research that do space work, the San Antonio [Texas] group and the Boulder, Colorado group. It's not this simple, but predominantly the science leadership and analysis is at Boulder, and then the hardware that Southwest produces for other missions is largely out of San Antonio, although they have a strong science section, too.

At Goddard, we've worked before with Southwest, San Antonio—I know I certainly had, because they produced one of the instruments on LRO; they had the LAMP [Lyman-Alpha

Mapping Project] instrument on LRO. They've also successfully developed instruments, mostly, for a lot of other Goddard missions. They supply the entire payload suite of over 30 instruments to a mission we head here called MMS [Magnetospheric Multiscale].[7] We were very used to—at Goddard—working with Southwest San Antonio, but we hadn't had much chance to work with Southwest Boulder in the past, and so getting a chance to learn how to work with them too.

So we had a spacecraft team that knew each other. We had a lot of continuity, with some new faces on the Goddard technical side. The important part, though, was learning how to work with Southwest, and to embrace their values, as well, because it was the first time our organizations had worked at this level, where they were a PI institution. And very critically, the way that they broke up the roles and responsibilities, Southwest Research was responsible for delivering all of the payload instruments. For instance, I had a contract that I held as the government core with Southwest for the delivery of all the science instruments, which got a little more complicated because one of those instruments was a Goddard in-house-built instrument, and we don't do things contractually the same way as some of the other groups do. It was a really strong senior leadership team that they had, not just Hal and John Andrews. I'm sure you've come across the name Cathy [Catherine B.] Olkin, who was Hal's deputy, who had a real strong instrumentation and operations background; and a payload system engineer named Michael Vincent, who's also very extraordinary.

The functions that were provided by Goddard in terms of payload oversight management, overseeing those instruments and ensuring they all get delivered to Lockheed Martin, had been a Goddard responsibility on MAVEN, OSIRIS-REx, and LRO, certainly, and it is still on DAVINCI. But for Lucy we had this more unusual organization structure where there were

[7] MMS investigates how the Sun's and Earth's magnetic fields connect and disconnect, explosively transferring energy from one to the other. This process occurs throughout the universe and is known as magnetic reconnection.

actually three deputy managers instead of the normal two, so I was one. John Andrews, from Southwest, who was responsible for delivering the instruments, was also designated as a deputy project manager, and, of course, so was Vince. So Donya had three deputies when most missions only have two. But the Southwest folks are a real delight to work with. They come from a very science-focused background, and sort of an operations-centric perspective, so they're always very good about—you hear the management phrase "begin with the end in mind," but they were very good at that.

It was the first time—I'm sure Hal told you—that he'd actually been involved in a hardware development before, and so he relied a lot on Cathy and John, who had been through development efforts in the past, and, of course, the work that we've done, as well. But Hal was a real delightful person to work with. You've already come across the diversity in approach of all the PIs on the Discovery missions, I'm sure, and Hal's a great example of that. He really was a delight to work for because he was comfortable in saying the things that were new to him, where he wanted us to either help him understand more deeply or trust us that we knew what we were doing.

He had a real knack for doing some of the operations planning of the observations, to make sure that we would—it's not just enough to fly by these asteroids—I'm sure at some point your folks talk about what the mission is itself—but we can't just fly by the asteroids. It's important to know what the lighting angle from the Sun's going to be as we fly by, how closely we're going to fly by, what angles and directions. It's far more complicated than folks might think to just fly by these asteroids, and Hal was sort of a genius at mapping out those observations with software that he's written to plan them. It is part of the character of what makes Lucy interesting, too. And again, it shows the breadth of Discovery missions, and the

ones we've talked about before were ones that were either very close by, like the Moon, you get to in four days, or when we talked about MESSENGER [Mercury Surface, Space Environment, Geochemistry and Ranging] going towards the Sun. But here where there were breakthroughs in flight dynamics analyses that rely on gravitational assists of the Earth to sort of slingshot you out into the outer solar system enabled a whole new generation of these sort of outer solar system missions.

I'm sure Hal would have mentioned this to you but one of the really interesting things about the Lucy mission—maybe the most interesting thing to some folks—is the actual orbital trajectory that was selected that allows us to fly by so many asteroids. We actually fly by more bodies—the solar system bodies—on Lucy than any other mission ever, because the location of these asteroids pockets that we're going to, these swarms they call them, that are gravitationally bound in an orbit that either proceeds or follows Jupiter means that if you're very clever with the architecture of how you fly the spacecraft, you're able to actually find a navigational course that will take you right by many of them. In our case, we had seven, but I think we even found another one this fall, that they opportunistically found they were coming close by.

Those breakthroughs in analysis that allow you to create new trajectories to get to new destinations opened up the outer solar system to the Discovery program for these swarms of Trojan asteroids—that's what Lucy's mission is, the Trojans—that proceed and follow Jupiter. Lucy never actually goes to Jupiter. That's a common misnomer in the press because these asteroid swarms in front of and behind Jupiter are at roughly that distance from the Sun, and so there's a common misnomer that folks have, that they think that Lucy actually goes to Jupiter when we're actually slingshotting behind it and in front of it. It's a beautiful trajectory—looks sort of like a clover leaf—that was set up that allowed us to get to the first swarm, to hit four of

the asteroids, plus a small orbiting one. Then we come back, slingshot back out to the other swarm, and that's when we go to the target that our PI finds most interesting. It's a binary one. I'm sure he talked about the PM [Patroclus-Menoetius] binary. That's his favorite.

It shows though the breadth of type of missions. The sort of scientist who is comfortable with these deep outer solar system missions have to be very patient. When we get to that PM binary, it's 2033. I mean, we're still ten years away from the biggest scientific payoff of that mission. The mission that I'm on now, DAVINCI, will already have gotten to the Venus surface by the time Lucy gets to its outer planets, so the sort of PIs that are successful in those deep solar system missions have a legacy of patience.

From a continuity standpoint, I would say one thing we must stress—and I'm sure Hal did, as well—is how much of the Southwest folks had previously worked the New Horizons Pluto mission. Cathy had been, I think, the Deputy PI of that mission, as well. John Andrews delivered instruments there. So the Southwest folks were not new at this. They were new at working with Goddard, they were new at having the sort of lead management role as a PI-managed mission, but they still had a good experience base to draw from for the work that they had done on the Pluto mission.

I was working on OSIRIS-REx, again, in operations, while this whole team was forming, but we are all friends, we all work back and forth with each other, and I was taken by how quickly the Lucy team came together at all levels, from management and science down to the engineers, and how quickly that team bonded together, and it was marked by maybe the most genial relationships between groups that I'd ever seen. It was very much a partnership from the beginning. Teams like this, when you take them from across the country, different organizations with different philosophies or organizational cultures, it usually takes a while for those teams to

mold together. But there was one particular engineering peer review that I actually chaired about Lucy while I was an OSIRIS-REx person, and one of the things that immediately struck me was how cohesive that team was early on, which I think actually was required for it to be successful later on when we got to COVID, and I'm sure we'll talk about that quite a bit.

Because this team formed so quickly, they were already working together as a very constructive group at the time that I came in. A lot of that has to be attributed to the folks who, like I say, have retired, but as Donya them moved into the PM position, I slotted into the DPM position, at that point there wasn't anything to fix, it was just to continue to keep it going. So we actually thought things were going to be, in terms of deep space or a planetary mission, about as simple as it could get until COVID came and threw a massive monkey wrench in the works. But if we hadn't already been used to working together so well as a team and working from a distance already with virtual tools like this, it probably wouldn't have gone well. But it's a real testament to the PI team, to the Lockheed folks, and to the Goddard folks that everything came together so quickly.

JOHNSON: Well, let's talk about that, March 2020. I think we were all watching it from January, February, and all the predictions that it was going to hit, but then being told go home, everyone, the Center's closed down, and luckily [Microsoft] Teams, some of the technology was coming in at the same time that that happened, and I think NASA was very lucky because of that.

BARTELS: I agree.

JOHNSON: Talk about that period, and as part of the management job on this mission, how do you prepare for something that unexpected, and then transition this mission to working so remotely?

BARTELS: No, that's a really good question, and we think about that a lot in looking back at it, as well, as preparation for the next time, because the next time we will be prepared. I would say that for COVID—maybe I'll speak for myself, and maybe not everyone would say this—I don't think that any of us were prepared for COVID; I think we were just reacting to it as quickly as we could. Like you say, these sort of collaboration tools, like Teams, we had literally just started using them broadly within the engineering team within the week or two prior to this. Of course, it's easy to look back now and say why didn't we know that it was going to be a multiyear situation, but I think a lot of us felt that it would just be a short-term situation, and we had to break apart the team really quickly to understand those who could support remotely from those who did have to come into work.

One of the things that building and testing a spacecraft, because now we were six months past CDR and so we were into full-blown hardware across the board with all groups, is that there's a large amount of the work that technicians do and that I&T [integration and testing] engineers do on the floor that must be done in person; it cannot be done remotely. But there is a lot of work that can be done remotely. We can talk about how efficient that is, but everyone got adept at these tools as quickly as they possibly could, and because we had been working together very well.

There was already a transition that some folks had to giving some liberalism on being able to telework if they could do their jobs from telework anyway. And so it was jarring, but not

completely jarring. But we had to break into two different approaches right away. I actually never stopped coming in during the entire pandemic, because I mentioned that one of the instruments that flies, the Ralph spectrometer, is one that is built here by Goddard personnel in-house. So we immediately had to implement the safest policies that people knew to employ at the time.

Some of them now, maybe, looking back weren't as effective as they seemed at the time. Once we said we don't know how long this pandemic's going to be, once we realized it was going to not just be over in a couple of weeks, we set up at Goddard, at Lockheed, and at the Applied Physics Lab and Arizona State [University, Tempe], the other places that were primarily producing the hardware, to make sure that people could still work safely, and to work forward. There were some very innovative things that the Lockheed ATLO team did that we'll talk about, I'm sure, later, although Hal and Keith, I'm sure, brought them up, as well.

Goddard was very, very focused on safety at the time, because this was just such an unknown that no one knew how to deal with. They were very proscriptive on this side about the work that would be allowed to be done. I don't remember the actual number but I think we had a limit of only 15 percent or, at most, maybe 20 percent of the overall Goddard workforce was allowed onsite, and every work location onsite had to be certified to be as safe as we could, social distancing in particular, and it was a real challenge. Part of the story of Lucy, I'd be remiss if I didn't mention that the Goddard in-house instrument called Ralph—which was not an acronym, just a name they gave it—that that team went to basically a seven-day-a-week work schedule with two different crews that overlapped, and those who could support things did. That includes things like even monitoring of tests remotely. We changed so many things, it's not just working like this, like we're working now, but mission assurance inspectors who formerly

always physically went to a location to look at things through an eye loop now started doing things with photographs and with real-time camerawork. There were some things we did, even with Lockheed, over FaceTime, just because you couldn't be there in person.

Here, that Ralph instrument team—and I did all the paperwork to push through to center management—any activity that had to be performed onsite needed to be approved at the associate center director's level, and there was a whole set of requirements that had to be met. You had to identify exactly how many people would be in what location, at what time, what the PPE—the personal protective equipment—that they would be provided with, down to the number of wipes that people needed. And only when you could demonstrate that you had thought through everything that could be thought through—and also Plexiglas barriers between people sitting in the same room, and there was a whole set of criteria that we had to follow—and only then were we allowed to do work onsite. And so while most of the Goddard project level people who work at sort of the spacecraft level, or in management, or working with the other outside groups, were working remotely, we had a good-sized crew of I would say probably around 30 to 35 people who were reporting to Goddard every day to go to work in the labs to complete the integration and test of this Ralph instrument so that it could be delivered to Lockheed.

And each other institution had their own variant of that. The Applied Physics Lab, and the L'LORRI [Lucy Long Range Reconnaissance Imager] instrument—that's the name of their instrument that they produced—had similar rules that they had set in place. Every institution was focused primarily first on the safety of their personnel, and then we were willing to accept inefficiencies in the work, but we weren't willing to accept a launch slip. That was one of the important things, because as we got into the first and second months of the pandemic, and so

many other projects were already slipping their schedule, one of the things that we said was, "We're doing pretty well from a budget standpoint. We can afford to surge support some folks here." The biggest sin on planetary missions is to miss your launch period and to miss your opportunity, especially with these missions. I mentioned the complex trajectories it takes to get to these asteroids; if you miss your launch period, it becomes a little more complicated. We were lucky on Lucy. Had we missed our launch period, there was one a year later that would have allowed us to recover almost all the science, and so that would have been okay, but at a tremendous additional cost hit. There's another Discovery mission right now named Psyche that had missed their period, and it's easy to compare and contrast the two where they happened.[8]

We were really lucky when COVID hit, if anybody can be lucky, in that the supply chain work that we had of all the people who were supplying things at lower levels that we assemble into us, a lot of that work was complete, or near complete, and so we were at the point where Lucy's job was basically some assembly required. It was to put everything together and test it. We still had to finish the major instruments, but a lot of the spacecraft components were ready to deliver, or just about to, or just had delivered to the Lockheed folks. The Psyche mission, just that year later that they were behind us meant all the difference in the COVID world, where all of those COVID impacts of the supply chain folks being able to deliver hardware really hit Psyche hard.

We were so blessed that we already had most of our hardware in house. If we hadn't had that, and we were able to actually secure a defense rating as well, contractually to help keep that work going, we would probably have been dead right at the start. But Hal specifically pulled us

[8] The Psyche spacecraft is traveling to a unique metal-rich asteroid with the same name, orbiting the Sun between Mars and Jupiter. By August 2029 the spacecraft will begin exploring the asteroid that scientists think – because of its high metal content – may be the partial core of a planetesimal, a building block of an early planet.

all together and said, "Can we do this safely?" He met with myself and Donya and John and Vince, and we looked at this and said, "We think we can. It's too early to say we can't do this. It's going to take all the money we have." And so we might have been able to save Hal some money he could've used in phase E—operations—to augment his science team, but we made the decision that as long as we can safely proceed, we are going to, to try to hit that October 15th, 2021, launch date.

Each group put in their own rules and restrictions, maximizing telework where they could but acknowledging that a big chunk of the hardware work has to be done in the clean room, on the floor. Finding ways to support that safely was where we focused. Again, your short question, my long answer, was how did we prepare. We didn't prepare because no one knew how long this was going to be. But once it became clear that this was indefinite, and we didn't know how long it was going to be, we had to move as quickly as we possibly could to implement the protocols that would allow safe work to continue while we still kept moving to the launch date.

The thing that I think most of the team is the most proud of is the fact that—there's a lot of luck involved, as well as the timing, as well as just really hard work from folks, but that's the real story of Lucy, to me, is how that team was able to maintain their development, and maintain the relationships they had forged when we moved into the hardware part of the mission, and a big chunk of folks we're now supporting remotely.

There were restrictions on travel, as well. I stayed traveling back and forth with Lockheed Martin at the time, and so I was going back quite a bit through empty airports and very strange environments at the time, and strange restrictions at all transportation areas. At the hotels the rules had all changed. Everything had changed. Everything about the world was

different, but everything about the spacecraft was the same. It was the world that we were used to. The one thing that did not was the actual nature of the work. The methods we employed to allow it to be performed all were new to us, but at least the work itself, it provided some surety in a very unsure time to have a very clear idea of what the goal was to complete the spacecraft assembly and testing, get the instruments installed, get it launched. That clarity of focus allowed people to get past the uncertainties. And, of course, everyone had people to take care of in their personal lives. Everything was harder. Everyone with kids suddenly had to find out childcare from home and all of this.

JOHNSON: How do you keep a team of people with those kinds of concerns—basically, they didn't know if they were risking their life by coming to work, or the lives of people at home that were more susceptible to COVID—and how do you keep them focused when you're looking at something like that? I know everyone at NASA, especially with these missions, they're focused people anyway, but how do you keep those teams cohesive and together during a really scary time?

BARTELS: Yes, it's really hard. We were working on the proposal for the DAVINCI mission at the same time, and there were a lot of those folks who never even got to know each other during that whole proposal phase. With Lucy, because the team already was really tight and working together well, there was actually almost a comfort of at least seeing everybody's faces at home. You'd see them in their kitchen, see them in their bedroom, some had their offices in the garage, and you got to know all their dogs and all their cats and everything, too. There was some comfort, actually, in being able to at least still keep in communication with the folks. In a

strange way, working together over these collaborative tools helped keep us together personally, as much as the work.

And, of course, I should be careful, too, to say, like you mentioned, there were some people who just were not comfortable coming onsite, even if their job would expect them to do so, and we made things as safe as we could. But one of the rules was if anyone does feel they're unsafe, either for themselves or taking something home to their family, we would either find other roles that they could do remotely or we would help them find other work here at Goddard that would allow them to commute from home, because we clearly were not going to put anybody at risk.

I think the other thing that people realized is because of the inefficiencies you get by doing everything more telework, that it was going to put our schedule under a lot of compression. One of the things we had to convince people—I'd say two things—the first was that that job was still doable, and it was still very possible for us to hit our launch date, but to do so would require us to work in a different way, and to work with more compartmentalized teams literally seven days a week, six or seven days a week. But we weren't going to ask any individuals to work those kind of hours, because that kind of stress of additional overwork, on top of worrying about their health, would have been the easiest way to lose people's faith and trust in the group.

I won't say there weren't people that put in an extraordinary number of hours that really should not—no one should have to ask them, and we didn't ask some of them. But some of them were just so passionate about their work, especially at Arizona State and at Goddard and at APL, but we tried really hard to make sure the workloads were manageable. When we went to a seven-day-a-week schedule, like I mentioned, we had basically two four-day crews who worked

four long days, with one day of overlap, but still at least make sure that each of them had a weekend day off. One group had Saturdays off; the other had Sundays off. That's the only way to sustain that sort of work, because, in retrospect, if we had known that those sort of protocols would still be in place a year and a half later when we launched, I don't know how realistic it would have seemed upfront that we could maintain a cohesive crew that long.

What was interesting was as the work continued, and the team continued to meet all of its delivery milestones along the way, even people who were skeptical initially that we would be able to do this, on our own team, actually started to realize that this actually could be done. Especially at Lockheed, because all of the elements eventually deliver their hardware to Lockheed for integration, just like with OSIRIS-REx and MAVEN. They put in very, very good protocols there. We call that phase ATLO, assembly test and launch operations. Some of the groups just call it integration and test, but in the deep space they always call it ATLO.

The ATLO lead at Lockheed is a very extraordinary individual named Chris McCaa that is really the unsung star of this work. But he'd been through this before. He was the OSIRIS-REx I&T lead, as well, so he is a master at figuring out how to reorder work, and find fill-in work, and just keep things moving. Under his leadership, no matter what was going on in terms of maybe one group was later than they thought, or one group couldn't support, or one group wasn't willing to travel or something, he found something just to keep that team going seven days a week, every day advancing as they go.

From a staffing standpoint, we augmented the test team quite a bit with the Lockheed personnel, so that there could be two full crews who could actually work separate from each other, and Lockheed broke up the experience of those teams between the two to make sure that it wasn't an A team and a B team; I think we were orange and blue or something. There was a real

effort of saying it's not here's the prime team and a backup, as sometimes happens when there's two groups. It was certainly two even teams that were able to just work and hand off to each other each four days and keep going. They'd put in protocols there like we had all sorts of little slogans around us, like 6-15—you couldn't be within six feet of someone for more than 15 minutes per day—and there was real adherence to that at Lockheed, just like we had here at Goddard.

It was interesting enough. It's easy how quickly we forget what the world was like. Our instrument that was built in Arizona State, things were a little looser in the state of Arizona than they were in some of the rest of the country, and COVID protocols, and some of the commercial test facilities that that team would go to actually made them feel unsafe. So we had the Arizona State instrument called L'TES [Lucy Thermal Emission Spectrometer] delivered to Lockheed early, and finished up its test program there, because we could prove to the Arizona State folks that their personnel were safe. They were safer in Denver working with the Lockheed folks than they were being in Tempe with some of the commercial labs outside of the university. Every person has some story like that during that time period.

The Lockheed folks worked very hard to implement policies that can be demonstrated to be safe. Maybe one of the biggest ones for someone like me is that when we got into the integration and test daily power spacecraft operations within ATLO, on most missions there's a control room that's like a hive and a buzz of activity, and for me it's actually the most enjoyable part of the mission. All of these groups that had been working together separately all come into one place, wherever the spacecraft is—so we're in Denver in this case—and you're basically, for that last nine months or so prior to going to the launch site, you're all living on the road together in this one communal test environment, where everyone's talking to each other, and it's normally

20, 25 people. That's the first thing that had to go under COVID. And so a lot of folks like me, that are used to having a console too and following the telemetry in a leadership role, just to make sure we understand what's happening, or mission assurance, or discipline engineering leads, Lockheed could only allow a very minimal absolute number of people to be together like that in the control room. So we had to decide how do we take what's normally 20, 25 people all working together communally and get that down to I think it was eight that were allowed to be in that area.

Then what they started to do was really innovative things for the rest of us who were still following L'TES, but now remotely, because we were all badged by different colors, depending on our criticality and things. I was in the category of needs to know, wants to know, but is not directly doing the testing of the spacecraft, and so they would actually set up Zoom sessions just like this where instead of us seeing each other, I would see the telemetry screen of an operator, and I could hear them talking to each other. That novelty of these communications tools also then came in for integration and test, and even operations.

On the OSIRIS-REx mission, when you talk to them, the actual contact of the asteroid, and grabbing of the sample, and coming back, that was done remotely, as well, by teams that were calling in from home, and learning how to do all of this stuff over voice comm and over video that typically had always been a room of people sitting next to each other.

That sort of flexibility has now become the norm, though, because now that we've proved we can do it, out past the pandemic phase, there's a lot of folks that expect that, because it gives them a lot more flexibility with their home life and their family and things if they can do some work there instead of coming in to work like I have here. If you can do this job from home, why wouldn't you?

There's a whole different discussion we'd have about the efficiencies and inefficiencies that come from remote work, but the real story about Lucy is how that team quickly moved to implementing safe protocols that allowed us to surge the personnel some but still find safe and humane to the team ways, sustainable ways for the team to get them to hit their marks. And we still shipped to the launch site the date that was in the original proposal back in 2017 of when we were going to ship to Florida in 2021.

Of course, at Kennedy [Space Center, Florida], they also had protocols there, which meant that a lot of the same work—although things were loosening up just a little bit. They would tend to come and go in Florida, and so a lot of those same protocols we'd had to have established at all the other areas, we had to respect the protocols that Kennedy put in as well, to protect their personnel and the staff. Your original question was how did we prepare for it. We didn't prepare—I don't think anybody prepared—but we reacted as quickly as we could. We spent the first week or two hoping it would all go away in a month or so, and two or three weeks we realized, well, however long this is going to be, we need to put in a sustainable plan if this is just perpetuity.

JOHNSON: Right, and something that can go forward, because we don't know when or if it'll happen again.

BARTELS: Right.

JOHNSON: All the stuff you were talking about in the testing—I did find that document; it was about the ground readiness testing, the GRT testing that you were an author on, which I thought

was interesting. I was reading that, and you've gone over those also, as we've talked, but so many things have come out of that experience that, as you said, your team was at the right time, luckily, in that development and in that phase that you were able to keep moving, and then take those lessons learned to other missions now because of that experience.

BARTELS: Right, yes, they become the starting point now so that we know that we can actually build on that. And as the world gets more decentralized, and all things are moving this direction—there would have been a time where you would have flown me down to Houston to meet with you in person for a week.

JOHNSON: Well, yes, we used to travel to do interviews, and I haven't done it in over three years.

BARTELS: Oh, really?

JOHNSON: Yes. Yes.

BARTELS: And because people are finding it to be probably maybe not 100 percent the same experience but close enough to it that this is probably the way you'll be doing things a lot.

JOHNSON: I was wondering because, like I said, we haven't traveled, and it saves on our budget because there's no travel involved, but does it help with these types of missions that have a tight budget that people aren't traveling as much, or aren't having to do that? It seems like for something like a Discovery mission, that might be useful.

BARTELS: It's part of the tradeoff. Our travel budget, moving forward to the next mission from Lucy, the DAVINCI one I'm on now, we have a smaller travel budget than we would have had on previous missions, just because of that very thing. What would have been typically at this stage, on Lucy, a small group going out to Denver every month just to be in person to meet with the team has gone on to be almost more for special activities or special engineering discussions. I have to admit I'm a little torn, because from my perspective I think there's a real synergy that happens of engineering teams when they're face to face, shoulder to shoulder, working together, that no number of Zoom meetings or Teams meetings will replace.

I think that was just proven true in a recent meeting we had here in DAVINCI where we had a group go out to Denver to meet with the Lockheed folks, and we were able to make some agreements in real time that it was just harder to do over the previous few months. I think there's real value in face-to-face and side-to-side working, but it has to be balanced also, though, with knowing that it has to be value-added now and not just for continuity. It's a management truism that you need to be really working together with the people that you're leading and seeing management by walking around. All the management training that you'll see will always stress how important it is not to lose contact with your team and your folks, but we have to recognize that there's a balance, and I think we find that balance.

Like I say, there is a part of me that thinks there's only efficiencies to a point that you achieve remotely. What I notice is the biggest impact on the young engineers, and I see it now happening post-COVID here, young engineers just out of college—this isn't a great, perfect analogy, but it was almost sort of an apprenticeship program. All of the work that they did in college to get to that point to get their degree is necessary, but they only really start learning the

job when they work side-by-side with more experienced engineers, and pick their brains, and learn those things, all the things you don't learn in a classroom. That's been much more difficult for us, post-COVID, to find ways to get the young engineers really trained and embedded, and to give them a feeling and sense of belonging as well.

One of the first things that happens to young engineers when they join projects is you are joining a team, working together. There is a communal feel that you build that is harder to do when we're all remote. We can have virtual happy hours, and we were playing little virtual games, and we were learning all of these tricks that were coming in the media of how do you keep a team together during COVID, and we tried a lot of them, but they're not quite the same.

I will say, the one thing, though, that has changed forever is that every meeting now that we have, it seems like, is at least virtual, even though we have core days and core hours where a majority of the folks are here working together to have in-person meetings. Every meeting now has a video component because we will always have somebody who's calling in remotely. That's the nature of the work now is that you have to assume that there is a virtual component, even if there are some folks in-house. Those sort of tools that were developed quickly during COVID are now so standard, it's hard to imagine a world without them.

JOHNSON: Yes. I could see that. It is, even for our job. It's hard to imagine what it was like. To go back and remember the way we used to do things, it was quite different. We have just a few more minutes. I want to go back and ask a question. We talked about all the pros of having these teams that have worked together before on a mission, then get to move to another mission, and possibly the same people move through. You had mentioned that the business group—which makes a lot of sense—that they would be doing that. Are there any cons to that? Do you

think there's any downside to the same people working these competed missions over and over? I'm just thinking about bringing in newer people, or is there an effort to keep bringing the newer people in? What are your thoughts about that?

BARTELS: Yes, there definitely is. We think of it from a long-term succession plan. We're always basically bringing in engineers who ideally would be junior engineers on the first mission and would move into leadership roles on the next mission. I mentioned how the OSIRIS-REx and Lucy, actually, systems leadership both moved up to administrative roles at the center level from that experience, and in that wake the backfill comes from younger engineers, like the person who's the DAVINCI overall probe lead was responsible for the spacecraft on Lucy and was a verification engineer on OSIRIS-REx. So he's a good example of that pipeline that comes through. I myself have moved from being an instrument manager to a spacecraft manager to a DPM to a PM along the way, so it's important not to get stale.

I think one of the most important things is what we have to guard against—and we try—is when a topic comes up and we say, well, here's how we did it on this previous mission, that's not enough. The question was why was that the right answer on that mission and is it still the right answer on this mission. We spent a lot of time examining our heritage to make sure that we're not just blindly applying the heritage from one mission to doing the same thing the next time without examining whether it's still the right thing to do. With engineers in particular, we do want to make sure that we're getting new, fresh blood in. You don't want to become stale as a team. I think we've tried to find the right balance between having some continuity through the missions with always bringing in new blood.

Right now, we have a lot of young engineers who are bringing model-based system engineering, MBSE. That's a new technique in the industry that all the engineers under 30 know and none of the engineers over 50 do. So we're making sure that we're incorporating those aspects into the mission, and always looking for fresh approaches as well, while not losing what we know has worked in the past. It is something we guard against a lot, of making sure that we are not just blindly applying previous techniques or previous answers to questions. We may have the same question. It may be the same answer as it was before, but only if we understand why it's still the right answer now. We do spend a lot of time thinking about that.

We also want to make sure that we don't treat this as a closed environment here at Goddard of just that one group of people who stays together as a clique. We're always bringing in new folks, and as I'm hiring in my staff here on DAVINCI one of the things I'm really looking for are people who may actually be new to planetary missions, just because they haven't had the opportunity, and the people that I then would be grooming to be my successors someday in leadership roles on the next missions down the road.

We definitely try to look at succession plans, and a lot of the PI teams do that, too. Sometimes the experienced PI that helps them win the mission always intends to hand over to the deputy later on. That was always the intent on OSIRIS-REx, for instance, and it is the intent on DAVINCI, as well. It's a really good question. Otherwise, things can get stale, and making sure that we don't miss something by just assuming that what we did before is still the right thing ten years later is something we spend a lot of time to check, and review teams also check us on that. It's a good question.

JOHNSON: I think that's a good place to stop.

[End of interview]