DISCOVERY AND NEW FRONTIERS ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

JOHN P. ANDREWS
INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is September 29, 2023. This interview with John Andrews is being conducted for the Discovery and New Frontiers Oral History Project. The interviewer is Sandra Johnson, and Mr. Andrews is in Boulder, Colorado, and talking to me today over Microsoft Teams.

I appreciate you joining me and taking time out of your schedule for this project. I want to start by talking about your background, your education, and how you became interested in working on space exploration missions and started working for Southwest Research Institute.

ANDREWS: Okay, thanks, Sandra, good morning, and thanks for having me. While I'm not a native of Colorado, I spent a huge, huge majority of my life in Colorado. Ever since a little kid, I probably had dreams of being an astronaut, and I was certainly very interested in space. As time went on through high school and early in college, I knew that the path to being an astronaut wasn't going to happen, but you can still work in space. Colorado has a very vibrant space economy.

I went to the University of Colorado for my undergraduate where I got a degree in engineering physics and then when I graduated in 1986, I took a job at Southwest Research Institute in San Antonio, [Texas], and I worked there on some space missions, mostly a large spacecraft called the Upper Atmosphere Research Satellite.[1] I did that for five years, then my

[1] Upper Atmosphere Research Satellite (UARS) was an orbital observatory and part of NASA's Mission to Planet Earth, which studied Earth's upper atmosphere of Earth and natural and human effects on the protective ozone layer.

wife and I wanted to get back to Colorado because we missed it so much. I moved back to Colorado, then I actually took a job at the University of Colorado at the Center for Astrophysics and Space Astronomy where I did two big missions, the Far Ultraviolet Spectroscopic Explorer, which led us to do an instrument for the Hubble Space Telescope called the Cosmic Origins Spectrograph, and that was in collaboration between the University of Colorado, Ball Aerospace, Cal Berkeley [University of California], and Goddard [Space Flight Center, Greenbelt, Maryland]. I had been doing a lot of work with Ball Aerospace at that time, which then led me to go back to Southwest Research Institute because they had opened an office in Boulder about a year after I moved back to Boulder.

So in 2003, I went back to Southwest Research Institute when I started working on New Horizons with the PI [principal investigator] Alan Stern, and I held a whole different variety of positions on New Horizons. But early on up through launch, I was involved as an assistant manager to help get the Ralph instrument [visible/infrared imager] developed, and then we launched. I worked on operations for New Horizons and have supported it through both the Pluto encounter and then the Arrokoth[2] encounter, but while I did that, I did other missions. Then while I was an employee at the University of Colorado, I went and got my master's in aerospace, which is my last degree.

Today, I'm the executive director in Boulder in Division 19. I'm the executive director of this Space Mission Directorate in our Solar System Science & Exploration Division, and that's my background. My day jobs are always project management, and I haven't done actual engineering in a long time.

[2] The small Kuiper Belt object officially known as Arrokoth (original designation (486958) 2014 MU69) is the most distant and most primitive object ever explored by a spacecraft. It was discovered in 2014 by NASA's New Horizons science team, using the Hubble Space Telescope.

JOHNSON: Yes, sometimes that management takes over, doesn't it?

ANDREWS: Yes, yes.

JOHNSON: Well, let's talk about 2003 when you went back to Southwest Research Institute and you joined the New Horizons team. I think you mentioned that it was after it moved to Phase B.

ANDREWS: Yes, I came on board, they needed help with a variety of things. Actually, working for Southwest, I love Southwest Research, but I left because we wanted to be back in Colorado, and then, lo and behold over time, they opened an office in Boulder. I came back in 2003, 2004. New Horizons was in Phase B, the preliminary design phase, and then I just continued to work on New Horizons up until its launch in January 2006. Then after it launched, I was the Southwest Research project manager for New Horizons, not to be confused with the New Horizons Project Manager who was at the [Johns Hopkins University] Applied Physics Lab [(APL) Laurel, Maryland], but I managed the Southwest effort. Then it was in space for a long time, so I went away for a while. I worked on an instrument that's now on the surface of Mars. I did other things but was managing the Southwest activity for the Pluto encounter.

JOHNSON: Talk about some of those team members that you were working with on New Horizons. You mentioned Alan Stern, I know he was the PI, but talk about the team that you worked with and where it was when you joined. You worked with your Southwest Research

group and your team was working with NASA and the company that was building the spacecraft. Talk about that and how that all worked together.

ANDREWS: Yes, we had a really outstanding team with good people that are still all very close today, and I hate to do math in public, but it's been 17 years since launch, and everybody is still pretty close and tight knit. I think the most important relationship I came out of New Horizons with is with Cathy [Catherine B.] Olkin, who's just a fantastic person and a good friend. Cathy became one of the project scientists for New Horizons, and she would actually propose Lucy in its first incarnation to the 2010 Discovery call. While that proposal was not accepted by NASA at that time, it did so well, we knew we had to propose it again, and I'll come back to that in a few minutes.

But New Horizons was in space for on the order of nine years before the Pluto encounter. To show how good that team was and the bond, the turnover was almost nonexistent. The people who worked the mission to get it to launch and then operated for those nine years, they're all still around, both then and now actually. That says a lot about the people. I mean we're all older and grayer, but there's a lot of love and passion for that mission. Those people stuck around, do, and see great things, which paid huge rewards when we were in the room when the data came down for the Pluto encounter and then for the Arrokoth encounter, that's impressive. The people at APL worked well with people at Southwest Research Institute. We had involvement with Goddard and coinvestigators all over the country, multiple universities, observatories, etc., it's a very good team, yes.

JOHNSON: You mentioned that you were the assistant manager for the instrument Ralph.

ANDREWS: I was Southwest deputy project manager for Ralph.

JOHNSON: Deputy project manager for Ralph. Talk about the Ralph instrument. I know two of those instruments ended up on Lucy also, and Ralph was one of them, but had Ralph been used before New Horizons?

ANDREWS: No, as I understand it—now, I have to go back to history before my time on New Horizons—Alan Stern had used Southwest internal study money to architect some instruments that were very small and compact and affordable so that the New Horizons spacecraft, which had to be quite small, could carry out its investigation. One of the principal science objectives or the instrumentation needs was imaging infrared spectroscopy, which is in a channel we call LEISA [Linear Etalon Imaging Spectral Array]. Then we needed a color-imaging optical channel, the wavelength of light that the human eye actually can see, and then we wanted an ultraviolet [UV] capability.

I think there was a time when there was an instrument concept which integrated those three optical channels into one instrument, but in time, they devolved. There was a UV spectrometer, called Alice, which is on New Horizons and many other spacecraft in the solar system, but it is not on Lucy. I can get into the details of why that is later. Then Ralph, which is an integrated-type camera, so it has a single optical train, but two different detector assemblies. Ralph is capable of seeing optical light, visible light like the human eye, and then near-infrared light, which we can't see, it's just outside the grasp of the human visual range. Ralph has two channels, and the electronics was supposed to be built by Southwest, and the optical system by

Ball Aerospace, and then some folks at Goddard were involved with the infrared detector focal plane. Ralph was a consortium of those three groups to build that instrument.

Now some people will object to this; Ralph is really the flagship instrument for New Horizons because it's really that infrared spectroscopy plus the colored camera that yields so much science data about the surface composition, texture, makeup, etc. While the LORRI [Long Range Reconnaissance Imager] camera, which we haven't mentioned, which is on both New Horizons and Lucy, was built by the Applied Physics Lab, APL. That camera is very sensitive and can detect objects at great range and take very high-resolution images, but it doesn't do color. So when you see ultra-crisp, color images of Pluto or Arrokoth, it's because we've used color data from the MVIC [Multispectral Visible Imaging Camera] channel in Ralph to add the color to the LORRI instrument images, so that's the nature of that.

And then Ralph was also a little complicated because that infrared focal plane has to be very cold. For purposes of the mission to be as long as it was, it's cooled passively, which means we only use a radiator to dump heat to deep cold space. We don't have a refrigerator or a cryocooler or anything active on the spacecraft that cools Ralph. It's kept cold by pointing to the deepest, coldest parts of space. In other words, we don't want sunlight on the radiator or even sunlight when the spacecraft is as far away as Pluto.

JOHNSON: I read that it was important for the instruments not to have moving parts.

ANDREWS: Yes, so everything about New Horizons—and it's funny, it wasn't until I was working more on Lucy that I began to truly appreciate the beauty and aesthetic of the New Horizons design for deep space exploration. For starters, it has radioisotope thermoelectric

generators, RTG, for the power source and not solar arrays because beyond Jupiter, which is not where Lucy goes but it goes to the distance, Lucy has demonstrated that solar arrays are a real challenge. Without solar arrays, New Horizons has sufficient power to do what it needs to do, but I think more importantly, it doesn't have a pointing constraint on the spacecraft. New Horizons can slew and point wherever it wants to for the most part without worrying about putting enough power or putting enough sunlight onto the solar arrays.

And then when we got to working on Lucy, which is one of the very few and the early spacecraft with solar power, to be going to this distance, you really begin to appreciate the challenges of having to carry the solar arrays and point compared to New Horizons and how compact and agile it is to do its observations and flybys.

So New Horizons is a tremendously elegant, ultra, ultra-deep space spacecraft. It's just the way it's designed and the instrumentation and the way it operates and its features are really optimized to do what it did and is still doing.

JOHNSON: Yes, and like you said, it was nine and a half years after launch—

ANDREWS: Yes, we launched in January 2006, and the encounter was on Bastille Day in 2015.

JOHNSON: Yes, that's a long time to wait to see what you worked on.

ANDREWS: It was. So have you done New Horizons interviews with people?

JOHNSON: I'm just starting that, yes.

ANDREWS: So New Horizons is really quite fascinating because in the launch period, which was, I don't know, two or three weeks-wide, we wanted to launch early because we wanted to get the Jupiter gravity assist, which is very cool, which we did. Because we launched, you know, right on time, and we were able to fly by Jupiter. Had we missed that Jupiter flyby and that Jupiter gravity assist, the flight times to Pluto could've gone up incredibly long. When we rolled out to the launchpad, we didn't yet know if it was going to be 9 1/2 years to Pluto or 12 or 13 or 15 years.

And I remember pretty clearly looking at various graphs at meetings and reviews that had if you launch on this day, and if you miss Jupiter, it gets longer and longer and longer to get out there. Well, there's a lot of luck in everything we do, but there's a lot of good engineering talent and management and whatnot, but you know, New Horizons was ready to launch at the right time and did its Jupiter flyby, which was really important, and we shaved off many years on the time it took to get to Pluto.

Lucy ultimately would also launch to the second, to the day that we said it was going to launch when we wrote the proposal, so that too was impressive. I'll come back to this probably many times, but then again, we did Lucy during the pandemic, which is probably the most impressive thing, yes.

JOHNSON: It was, and the stories about that are great, and I do want to talk to you about that. Once New Horizons launched, did the instruments come online to check them? I know that the spacecraft hibernated.

ANDREWS: Yes, so the way NASA structures their projects, you do launch and then you commission the spacecraft to make sure that the spacecraft itself is working properly. Then once you know the spacecraft is safe and healthy, you can turn your attention to the instruments, and you start to do your instrument commissioning. We frequently refer to launch +30 where those 30 days right after a launch are very intensive to both commission the spacecraft and then get instrument checkout completed. NASA projects are done by phases, Phase A, Phase B, phase C/D is usually combined, so they refer to it as Phase C/D, then Phase E is the operations phase, which technically doesn't actually start until actually you have launched and you've commissioned and you know that you have a healthy, working vehicle and system. So in the case of Lucy, I was on the development team, but I'm also on the operations team. But the folks like Donya [Douglas-Bradshaw] and Arlin [Bartels], and Jessica [Lounsbury], they've done their job after 30 days or so, and they can go away because the keys to the car have passed to a new group of people to operate in phase E.

So New Horizons commissioned the instruments and then off we went, and New Horizons for a deep space mission was very fortunate because of the Jupiter flyby. We were at Jupiter, oh, I don't know, I think 12 ½ or 13 months later, so we only had about a year because we were screaming. Most missions, Juno[3], JUICE [Jupiter Icy Moons Explorer],[4] Europa [Clipper][5], Galileo,[6] they take a much longer time period to get to Jupiter because when they get there, they need to be moving slow enough that they can still stop and enter orbit. That wasn't

[3] Juno launched in 2011 and is studying the interior and origins of Jupiter for the first time. It has been orbiting Jupiter since it arrived in 2016.
[4] Launched by the European Space Agency in April 2023, Juice is expected to arrive at Jupiter in July 2031 and enter orbit around Ganymede for its mission.
[5] NASA's Europa Clipper is schedule for launch in October 2024 and will conduct detailed reconnaissance of Jupiter's moon Europa and investigate whether the icy moon could have conditions suitable for life.
[6] Launched into Earth orbit from the Space Shuttle Atlantis in 1989, the spacecraft arrived at Jupiter July 7, 1995, the mission orbited Jupiter 34 times before being sent into the atmosphere of Jupiter to end the mission.

the case for New Horizons, we wanted to be going as fast as possible, so we got to Jupiter in about 12 months. So within 12 or 13 months from launch, we had to do our first flyby. There are some very memorable images from that flyby where we caught one of the volcanoes on [Jupiter's moon] Io erupting, and it's a beautiful image. So we had a nice Jupiter encounter.

It was active the first year and then we entered a period of boredom, so to speak, for eight years on the cruise to Pluto, but once or twice year, we would wake up the instruments, check them out, do practice runs of what the flyby was like. In hindsight, it always seemed with New Horizon it was always busy for a mission that was just out there in space going and going and going. Then, of course, in the year or so before the Pluto encounter, it was extremely busy, very, very busy.

JOHNSON: Yes, we'll talk about some of that. You told me that part of what you were doing was managing the Science Operation Center [SOC].

ANDREWS: I was the Science Operation Center manager for a period of time up through and after launch. Then when I started doing other things besides New Horizons, I was just managing New Horizons for Southwest, and I wasn't the day-to-day SOC manager. We passed that off to some other people.

JOHNSON: Okay, well talk about when you said that it got really busy that last period of time right before the encounter with Pluto.

ANDREWS: Sure. By that time, you're doing the extraordinarily detailed minutia, second-to-second planning, the choreography is the best way to describe it of where and how the spacecraft will point and when. When it's pointing, what instruments will be turned on and taking what data. A spacecraft operates with very limited resources, so you only get so much data rate, data storage, power, propellant. Every time you do something, you make sure that the system as a whole is being operated safely and within the limitations you have. Because Pluto is so far away, the whole encounter itself, some 24-hour time period, is done on autopilot, right? There's no person in the loop. If something goes wrong, you don't wait for New Horizons to phone home and somebody to think about how to fix it, then call it back and say, "Go do this instead." It's all automated, it does its thing.

So part of your planning is to be really focused on what could go wrong so that you're designing into your timeline and your sequences. Sequences are the series of commands you want to execute on the spacecraft in the instrument. You really want to understand what could go wrong, so you can anticipate and build into your thing, oh, this might go wrong, therefore, I either need to know if it does, in which case I would do this or collect extra data for redundancy. To choreograph all of that is incredibly complicated. Tens, maybe hundreds of people at that stage worked on it, incredibly complicated, and as you can see from the data, extraordinarily successful.

I'll put it this way, and Lucy is similar and we can get to that. Lucy will do an originally unplanned flyby on November 1st, we're going to get data in about five weeks of a small asteroid, but flybys are unforgiving, you don't get to do it again. If you take a mission that goes to the orbit of Mars or orbits Jupiter, and if you're there and you're successful and maybe you failed to target a moon to take a picture, the odds are you're going to be able to come back and

do that. But when you do deep space flyby, you know, the vast majority of the time, it's a one-time only. Your mission's not going to be able to come back and get that data set again, so you want that robustness, resiliency, paranoia of making sure it's going to work built into the system.

JOHNSON: Were there simulations? You're talking about being prepared; let's talk about that.

ANDREWS: Oh yes, so yes, yes, there were models. A replica spacecraft of both New Horizons and Lucy and most spacecraft is built and kept on the ground so that when there are problems, you can troubleshoot something that's in the lab. While it doesn't physically look like the spacecraft, right, electronically, it's a replica of the spacecraft, so you would expect it to behave very similarly when you send the command or a command fails to send. Or something doesn't work the way you thought it should, you can troubleshoot and figure that out while you're sitting in the laboratory. Then the only thing you can really do is alter a command structure and send a revised command to the spacecraft that will hopefully fix your problem. But again, as I said a few minutes ago, during an actual encounter that doesn't work because it's got to all be automated.

JOHNSON: Yes, so all of that had to be planned ahead of time thinking of every possible event—anything that could happen and plan for that.

ANDREWS: Yes, and again we—people—that planning started—well, it first started with the original proposal, people worked on it while the spacecraft was being built. But in earnest, those plans are done after the spacecraft launches. Then part of that reason is—and Lucy will be a

good example—until the spacecraft launches and you see how it's working in space, you're not 100 percent sure of what you have, how it's going to behave, and whatnot. I'm sure others have mentioned, and we might talk about the solar array anomaly on Lucy, okay, which has caused us a great deal of angst since launch. If we had no way to slightly alter the mission under the presumption that the solar array was going to be exactly like we thought it was going to be, then we would have problems. But you always have to be adaptive and be able to wait to see how the vehicle performs once you launch it to then say, okay, if it's doing this, we have to do that, if it's doing that or if it's doing exactly whatever we thought it was going to do based on its initial design, then the plans you had are probably mature and good enough. I think it was [Dwight D.] Eisenhower, plans are worthless but planning is essential, right?

JOHNSON: Yes, exactly.

ANDREWS: So that applies to a lot of things, but certainly in spacecraft operations, you got to launch and find out that you indeed have what you thought you were going to have or something slightly different or massively different and then figure out what you can do.

JOHNSON: Talk about the encounter with Pluto. Of course, it went worldwide because it was that first look and then the colors that we saw.

ANDREWS: Yes, I was in the auditorium at APL when they first started the data, and they've been a long internally—you know scientists, are interesting, but these bets and worries, there is the possibility that Pluto could be just this white cue ball in space with, other than maybe some

craters or something, no surface differentiation or it really wouldn't be very exciting. That was a concern, right? And, oh my gosh, lo and behold, Pluto is one of the most interesting surfaces that we've seen so far in the solar system. Then when you look at those images and you realize those are various mountains of different types of ice rising, what is it, 12 or 13,000 feet, plateaus, all the different, what we would call, geology and typology if we were looking at Earth or Mars, but it's, in fact, all ice. It's just unbelievable.

First of all, the first thing you might think about is, oh, my God, this is so weird and it's so cool, but then you say in the back of your head, this so blows away any form of expectations just because of what it was. Then it wasn't this big, white cue ball in space, and then when you image the other moons, they, in their own right, were not quite what people could've expected, it was amazing. There's nothing in life like having your expectations not just exceeded but blown away.

JOHNSON: Were you surprised by the interest in the public for seeing those images?

ANDREWS: You know what, I was actually because you could can never tell what the public may or may not be interested in. So by that time, MSL [Mars Science Laboratory], Curiosity [rover] had landed. I mentioned earlier that after, I don't know, New Horizons launched, I went off and did some other projects. Well, one of which was I managed an instrument, a small radiation detector that's on Curiosity. You know the hype with Curiosity, the fact that Curiosity worked, the landing, which I personally consider one of the probably three greatest achievements of NASA, and that set the stage I think for what the public and the excitement, and people appreciated what NASA could do.

And I wasn't expecting, I guess, Pluto to be quite as exciting as it was, and part of it was give due credit to Alan. Alan's ability to instill enthusiasm on a global scale is quite spectacular, and he had the people and the public fired up and the press set up to do this. I don't know if people have said this to you before, but when we're planning a mission, and we're talking about is it so cool, is it so sexy that this is what people want, and they're going to—this is the mission we really want. The question you ask is will that first data, will that first image be in the *New York Times*, but more importantly, will it be on the front page, above the fold? I don't know if people have ever said that to you. You always want to be, for good reasons not bad, on the *New York Times*, front page, above the fold. Pluto did that, I think most recently. Those first James Webb [Space Telescope] images last year, which were amazing, unfortunately, Hubble [Space Telescope] did it, but for the wrong reasons the first time, but after the fix. I'm hopeful that Lucy one day, maybe not when we do the little asteroid flyby in November, but certainly when we flyby our Trojan[7] targets, we're going to be on the front page of the *New York Times* above the fold, yes.

JOHNSON: Yes, that's always exciting to see NASA get that kind attention. I know Pluto is one of those things that people have very strong opinions about because when it was demoted.

ANDREWS: Yes, exactly. I was just an observer of that. Some people call it a fight or discussion, and it doesn't change the fact—you can call it whatever you want to call it, you can call it a Slush Ball, you can even call it a comet, which it's not, don't care. It doesn't change the fact that

[7] The Jupiter Trojans are outer solar system asteroids that orbit the Sun in front of and behind Jupiter and at the same distance from the Sun as Jupiter. Because of the combined gravitational influences of the Sun and Jupiter, these Trojan asteroids have been trapped on stable orbits around the Lagrange Points for billions of years and provide a unique sample of the remnants of our early solar system.

it's one of the most fascinating objects that we have yet experienced in the solar system. I will just leave it at that.

JOHNSON: Were you were involved with Lucy, when in 2010 they were responding to the AO [announcement of opportunity]?

ANDREWS: Oh yes, yes, it was interesting, I won't forget this. By that time, Cathy had been working in Southwest, mostly on New Horizons for I—if I had to guess, about six years, and she wanted to propose to Discovery. I had participated in Discovery proposals before, going back all the way to the first call. I think you just said that we're celebrating the 30th anniversary of Discovery?

JOHNSON: Correct, yes.

ANDREWS: Yes, I did work on the very first Discovery AO in the early '90s with a bunch of great scientists at LASP [Laboratory for Atmospheric and Space Physics] at CU [University of Colorado, Boulder], and what was then Martin Marietta. I don't think it was Lockheed Martin yet. I tried my hands in Discovery for a long time before it was totally successful. I walked into a meeting, Cathy was just chatting with Alan about something in his office, and the fact that she was writing a proposal came up, and I love to do proposals. She had this problem, and I said, "Well, you just need to go do this, this, and this, and bring in these people." She didn't know that those options existed, so I jumped on her proposal and helped her work on it. I'm not going to get into the names of the partners at the time, but the science was in Discovery to do Trojan

flybys, and in that particular call, NASA was providing the use of the Stirling isotope nuclear power sources [Advanced Stirling Radioisotope Generator], which were still in development. So a whole bunch of people proposed and latched on to using those, and within a few years, that project would be canceled, so they never would have been available anyhow.

While the proposal was not selected, mainly because of weaknesses of the—well it could be mainly for a couple reasons, but the principal criticism was the use and the combination of the nuclear power sources, which were fictitious. Anyways, the proposal got very good science marks. Right, when you get a proposal that's done well but not selected, it's kind of silly not to propose it again. As the AO, the announcement of opportunity, for the next Discovery round was approaching, we started to crank up studies and people to figure out would we propose Lucy again.

At that time, Cathy was so busy with New Horizons, she couldn't PI another Lucy proposal, and so I was very, very active in recruiting Hal [Harold F. Levison]. I actually like to say I'm the one that hired Hal for Lucy, and I can go on at great lengths about how that happened, but I don't think I'm going to tell that story. Ultimately, we convinced Hal to PI Lucy, and Cathy would be the deputy PI for which she would have the time even while she was still working on New Horizons. I think that the world of Cathy Olkin. She is a phenomenal person and scientist and is hugely responsible for Lucy being a success. The big trick in life is timing, and Cathy did tremendous things on New Horizons as well and Lucy.

So Hal took over as PI, and as we re-concocted the mission. I think we knew early that there were no nuclear power options being expected for the 2014 Discovery announcement of opportunity, so we started to explore doing it with solar power. By that time, Juno had been selected and was in development. I'm trying to think between Juno and ESA's [European Space

Agency] comet mission called Rosetta, they both path found or pioneered solar arrays way out in the deep solar system. Well, Lockheed ultimately became our partner for Lucy, and they had experience obviously with Juno with super large, special solar arrays, which work well. The 2010 Lucy morphed into the 2014 Lucy, so now we had solar arrays, and I think we switched to one instrument between 2010 and 2014.

So we knew we were going to fly Ralph, we knew we were going to fly LORRI, and my memory is the 2010 version had the ultraviolet spectrometer on it from New Horizons and other things. As we did our studies, we didn't think it would return the science we wanted in just a flyby mission, so we switched it out for what became the L'TES [Lucy's Thermal Emission Spectrometer] instrument, the thermal emission spectrometer from Arizona State [University] that flew on Lucy. I'm one of, I think, only two people that was on Lucy 2010 with Cathy and then was on Lucy when we did it again in 2014.

JOHNSON: The Planetary Science and Astrobiology Decadal Surveys[8] affect how these missions are proposed, and another one had come out between the first and the second proposal, so did that affect, obviously the power like you were talking about, but also the mission objectives?

ANDREWS: Yes, it did. I can talk about the Decadal and its importance for a second.

JOHNSON: Yes.

[8] Decadal surveys provide detailed insights into the strategic priorities and mission directives set for the next decade across key scientific domains including Astrophysics, Planetary Science, Earth Science, Heliophysics and Biological and Physical Sciences. These surveys play a crucial role in shaping NASA's future endeavors, reflecting a broad consensus within the scientific community on the most pressing and promising areas of research.

ANDREWS: Time goes by, we just got in the last two years a brand-new Decadal, and it will drive, and I don't want to use dictate, but encourage how things will be done. In New Frontiers—and we talk about New Horizons being the first New Frontiers. In New Frontiers, NASA tells you the themes that you can propose for. Like you can go sample a comet, you can bring samples back from the moon. When you write a New Frontiers proposal, you actually are limited in your creativity and your science because you just—if Mercury, as an example, is not in the New Frontiers AO, then there's no point in writing a Mercury proposal. The amazing thing about Discovery it's just a free-for-all, and you can propose whatever you want to within planetary science, and then NASA, the review, the community will separate the wheat from the chaff, and ultimately decide through a very lengthy, rigorous, competitive process what they're going to do.

Now the Decadal, at that time, advocated for a Trojan mission that included maybe a flyby of one but then they rendezvous, i.e., you arrive and stay at a Trojan and study it. Because it would've been a New Frontiers, you would've had more money than we had in Discovery. If you're going to stay and loiter at the asteroid, there's other science instruments and things you would do that you can't do if you're just doing a flyby because with a flyby you go by so fast. Certain instruments like a neutron gamma-ray spectrometer can't collect data fast enough or long enough in a flyby to be of use.

So as we were pondering Lucy the second time, Hal Levison concocted the vision where we really know so little about Trojans, and they are extremely interesting and important to resolving and confirming various theories about the solar system's origins and evolutions that we don't actually know which one to go to. It's true we could go to one, but it would be sampling only one of what's likely a very large and diverse population, and what you would take away

from that is probably not much. Other than that it would tell you, oh, we might need to go see other Trojans to learn even more. Furthermore in Discovery, it would be very difficult technology-wise for the money to arrive and rendezvous, stay with a Trojan, very difficult. But during a flyby, it's not difficult, and we had these marvelous astrodynamics people early on at Lockheed that put together our trajectory. I don't think I'm being recorded visually, but we have beautiful posters of the Lucy trajectory.

What we found was, well, we can do a tour, we can see several Trojans, and as others said, or I can explain here, the Trojans are at Lagrange points around Jupiter, the L4 and the L5 Lagrange points, which trail and lead Jupiter by about 60 degrees at about the same distance Jupiter is from the Sun. The funny thing about, they call them Jupiter Trojans, and we talk about this all the time, but we never go near Jupiter. The closest Lucy ever gets to Jupiter is the day we launched, isn't that interesting? The spacecraft will fly out to the distance that Jupiter orbits the Sun because that's where the L4 swarm is and then the L5 swarm, but one swarm is 60 degrees ahead of Jupiter in its orbit, and the other swarm is 60 degrees behind. It still takes a long time to get out there.

I don't say we undercut Decadal, but we pitched a different story, which was very well received, so Hal gets huge credit for concocting it this way. The thing to do is go visit a bunch of Trojans of different types, different flavors, see what they are, see what they're made up of. Then maybe after Lucy, you'll have said, well okay, now we know something and we know a certain type of Trojan we should then go to. That's a mission well past my retirement date, but that was the way to do it. We're going to do a tour, we're going survey, we're going to first do a coastal survey, right. If I compare it to explorations of the Pacific Northwest in the 1770s, we're going to do a coastal survey. We're going to figure out what's there first and figure out what's

really most interesting and appetizing, and then somebody will go back later on and colonize or exploit or do whatever they're going to do.

And so this time, the idea behind Lucy is to sample these things through flybys, which is not what the Decadal called for, but we got a lot of traction. It's like, oh, this, this is right. In a way, we scooped what was supposed to be a New Frontiers proposal by proposing Lucy and winning, and I don't know if others have mentioned it, there's a little funny story. The AO for Lucy was in 2014, and it's a long process. We write the proposal, then you get selected, then you have to do Phase A, which takes about a year to then do the final round of competition. As that final round of competition was winding down, the AO for New Frontiers was coming out, and the team started to talk about, well, you know, what happens if we don't win Lucy? We should retool and write a proposal for New Frontiers. It's like, yes, okay, that's a lot of work. It's very, very hard to lose these things because you just put so much effort into them, and I can't even begin to tell you how ecstatic and exciting it is to win these things.

So we were winding down Phase A for Lucy, waiting to find out if we're going to be selected. At the same time, we had to start work on a slightly different proposal for New Frontiers, and I'll never forget this. I don't know if Hal mentioned this, but the morning that Thomas [Zurbuchen] called Hal to tell us we were selected after Phase A. This is the big kahuna. That morning, we were supposed to have a big proposal meeting for our New Frontiers proposal, and Hal received a phone call from Thomas about 8:00 a.m. Mountain time on January 4, 2016. It was cold and snowy, and the first thing Hal did was walk into my office to tell me we were selected, and we were jumping for joy. We looked at each other, what are going to do? You got to get ready to make a press release, and so on.

But the first thing we had to do was cancel our proposal meeting for the New Frontiers, and of course when you're selected and you're told, there's an embargo, you're not supposed to tell many people about it. But we had like 30 people waiting on a proposal meeting, and we had to call them and tell them, we're not going to have this meeting today. Everybody knew the principal reason why you wouldn't have that meeting is because you don't have to have that meeting because there's no point in writing a Trojan New Frontiers mission when Lucy was just selected. It was a great morning, and so in a way, the way the information came out for some people was, oh, they're canceling this meeting, and we didn't tell them why, we just don't want to have this meeting today. Then within a few hours, they figured it out, they knew for sure that they have clearly understood why we didn't have that meeting.

So this long conversation got started with the Decadal, and it structured things because Discovery is open. We gave NASA and the community most of what they wanted, maybe even more in a Discovery, and took the Trojan mission, an encounter, off the table for some time until we know more about Trojans. When I see the missions that are being proposed in Discovery relative to the Decadal, that happens more and more often. If you can get a lot of what's in a New Frontiers Decadal study in a Discovery, that's very good for you, clever, creative, go do that. That then frees up the competition in New Frontiers and other things for those missions that really truly have to be of that class and scope. For example, comet surface sample return is one of the New Frontiers themes. More power to you if you could do it in Discovery, but the costs and the availability, that'd be probably so way beyond what you can do in a Discovery mission. But Lucy was a sweet spot for the Trojans.

JOHNSON: Were you aware, or your team aware, that they were thinking of choosing two and then Psyche's proposal?

ANDREWS: We knew that the AO and the statements from [NASA] Headquarters made it clear they're going to select two. Our competition was Psyche, another asteroid mission, as you know, hence selected, soon to launch, and VERITAS [Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy], a Venus radar mission, and DAVINCI [Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging], a Venus atmospheric probe mission, and an asteroid [survey] that had been selected for study previously many times, and it's actually now in the planetary defense thing, and for the life of me, I cannot remember its name. It's a massive asteroid survey for planetary defense to forewarn us [Near Earth Object Camera (NEOCam)]. Those were the five that were put in the phase A, and I'm going to be honest, our team, once we were in Phase A—I think that call had 25 proposals in the 2014 AO—but we always just knew it was going to Lucy. And once were in Phase A, we really knew it was going to be Lucy because our strategy that was conceived before we even wrote the first words was how we were going to have the right cost reserves and the right partners. We're going to leverage the New Horizons instrumentation, the spacecraft wasn't, in the grand scheme of things, all that hard, we had the right teams because we had great win themes, we were confident. Never so confident that we just took it for granted, but we were pretty confident we were going to win, and we did.

And then when we got engagement, so you do the site visit then we actually get face time with the NASA reviewers, not the selecting official but the reviewers. You know when

something's a lovefest, it's a lovefest, and you know it's a good thing, and Lucy was a good thing, a great thing.

JOHNSON: Do you think that part of the reason it was selected, or how much do you think it influenced the selection that you were using instruments that were already proven?

ANDREWS: I think within Discovery because the Agency is, rightfully so, somewhat risk-averse, and yet they want new technology, that's a hard thing to balance. But I think in Discovery if you're trying to do an ambitious mission, which I think Lucy is, you want to do it with proven instruments. That helped a lot because where we wanted to put our money in development, we wanted to have a lot of reserves and demonstrate we could do it; we knew there would be some risks with the solar array. In the case of Lucy, it was the right story, absolute right story. Other missions might be able to structure something different because other parts of what they're trying to do may not have elements of risk, so you can absorb some risks in the development of the instrument.

You know, there's a mantra on Lucy that we used that came from our chief planner and schedule. The management team that we started with, they knew early when we started that they were going to retire, which is how we then got Donya and Arlin who—you spoke to both of them—but Donya and Arlin are not who we started with. We started with Mike [Michael] Donnelly and John Loiacono who had been the project management team that had just done OSIRIS-REx[9] with Lockheed Martin.

[9] The first U.S. mission to collect a sample from an asteroid. It returned to Earth orbit on Sept. 24, 2023, to drop off material from asteroid Bennu.

That was another huge win theme for us, extremely experienced leadership in the management area coupled with managing the industrial partner, Lockheed Martin that had just launched O-REx on time and under budget. That's funny too because O-REx was a success because they're down in Houston right now trying to weigh the samples to find out how much came back. That was just one of our other win themes that just built this tremendous confidence into us. Then it was also great when Donya came on and then Arlin came on, and Arlin also was on OSIRIS-Rex. As you talk to Arlin—I've never met anybody in my career with as much mission experience as Arlin, just the number of things he worked on, so he's great. Then Donya's beyond great, we can come back to that later, but we just knew we had the right people for our plans to—I can't remember what triggered this, what your question was that triggered this line of discussion, but I don't think I've answered your question.

Oh, you asked about the instruments, yes.

JOHNSON: Yes.

ANDREWS: So that was really important, yes, very important, yes. In fact, I'm going to be honest, I want to tell you a story that I'm beating my own drum, but I remember early on, I said, "You know guys—" to the whole team, Cathy and Hal and the others. I said, "Let's put this in context." We submitted in 2014, and the New Horizons encounter was in 2015, and I said multiple times, "We should realize that TMC [Technical, Management, and Cost] and the review panel will be looking at our proposal and reading about our instruments at the exact same time. If everything goes well, they're going to see data from these instruments as part of New Horizons."

And I think that too had to have been part of the big win theme. The whole world is looking at the New Horizon stuff and reading about LORRI and reading about Ralph, and then the people looking at our proposal go home at night, and they read about LORRI and Ralph. I think there's luck, there's synergy, there's proper planning, but the timing of the universe just came together perfectly at that time.

JOHNSON: Yes, and that team, as you mentioned, a proven team that works well. You mentioned in 2010 that you helped with the proposal because you enjoy doing proposals and you'd worked with that sort of thing before.

ANDREWS: Oh, I'll just say, part of my job responsibility is new business. When proposals come through, I'm going to be involved, but I'm also always—we have to fight to eat. I, like others, we work on our proposals obviously, so we have work to work on in the future, so we're still there to work on other proposals.

JOHNSON: Right, exactly, and as a proposal—one of the things Hal said that you were instrumental in getting that, in 2014, getting all of that together. I was just curious, and you can give an overview of, as a proposal manager for a Discovery mission, what does that entail? What would your normal, day-to-day job duties be when you're working on that proposal?

ANDREWS: Well, I was the business capture lead and the proposal manager. I managed Phase A pretty much also because our Goddard management team was still working on OSIRIS for Phase A. I'm very proud of this, very, very proud. I've orchestrated getting us through Phase A, and

as soon as we got selected, I stepped out into a deputy management role as the payload science lead, and then Mike Donnelly and then John Loiacono took over as management at Goddard.

But to answer your question, yes, it's fascinating. I love that part of the stage, the proposal management, business management, because everything is very formative and you're laying out a technical architecture, the science architecture. But you're also working on the marketing, the win themes, the sell themes, the strategy for how you're going to fit in the budget, and stuff like that. It's a management job, so it includes all the normal management things. You go schedule, there's a budget for a proposal, but you're not yet building anything, you're not managing acquisitions or hardware, you're managing graphics and ideas, and so it's got a very different flavor. I know a lot of people who are very good in the proposal management and then later on, they're expected to manage the project as well or something, and not everybody does both well. I know a lot of people who do some things great and the other side great, and that's what we need. But you have to be able to work with the scientists to catch their ideas.

One of the most important things you have to do in both step one and then the Phase A is convert what the scientists want to do into requirements. In the step one proposal, you have to have the science traceability matrix, which is probably the most important part of the whole step one proposal. Then in step two, you probably don't want to change your science traceability matrix, but now you need to create your mission traceability matrix in great detail and flow down requirements. We had Michael Vincent who works for me, he's at Southwest. We call him a requirements whisperer, just a genius at sitting down with the scientists and crafting, taking what it is they think they want and converting it into what they really need and then writing it down in the form of requirements that makes sense, that a reviewer can read and understand, and that one day can be verified and implemented.

And Cathy and Michael internally and externally won awards for the requirements capture and flow for Lucy, and that was one of our major, major strengths, both on the step one and the step two proposal. A huge amount of the proposal management is making sure those requirements are captured and then flow, and then getting the right organization of the proposal and the right words down, and then proving that everything fits, and then they're proving it, so we did a lot of cost models and whatnot. That part of the job is very different. Then once you've been selected and now all of a sudden, you begin to manage the design and the hardware acquisition and the integration and the test.

My whole career has been cradle to grave. I work out proposals, usually then work on that project, and then go work on more proposals. Probably only in the last few years that I've been promoted to my current position, I continue to do cradle to grave, but I also help people do a lot of the cradle stuff, so on stuff that I will never then work on in the future, but it's my job to help them bring the work into the organization. Southwest has been very successful in doing that. I know that's true because we have two New Frontiers PIs and one Discovery PI, and Southwest has now built and provided well over a hundred spaceflight instruments in the last forty years, and we have spaceflight instruments all over the solar system, all around Earth, etc. That's our business model, and that's what we do, and that's proposal management and how that works.

JOHNSON: As you mentioned, communication is important all the way through, from the very beginning during that proposal period but all the way through the mission too. Talk about that and the importance of that communication and those relationships, and as you mentioned, scientists and engineers don't speak the same language all the time.

ANDREWS: Yes, no, no, no.

JOHNSON: And so you're dealing with scientists, you're dealing with engineers, you're dealing with people that build stuff, you're dealing with people that do all the technology running those programs. You have all these different types of people working these different aspects of this mission, so talk about how important communication and maybe having someone like Michael Vincent who can do that communication effectively?

ANDREWS: Sure, yes, there's no doubt, communication is everything, and the people. Maybe we'll talk more about people later, but I have never worked on a project where the group of people that did it were as good and nice and knowledgeable and professional and masters of their craft as we had on Lucy. That was top-down from Hal. Hal is just the nicest guy in the world, and we're going to talk about how wonderful Cathy is, Donya, Arlin, if you go back to the prior management group, Mike Donnelly, John Loiacono, my group, Michael Vincent, and others.

One of the things that Lucy benefited from, even in the proposal stage, is for many of us, certainly on the science payload, we had all worked together on New Horizons, so we'd already known each other for a decade or more working and building and doing stuff. There's a lot of camaraderie. There were times where people could get a little hot tempered or frustrated. We have passions about this, and there are differences in the opinions, but on other projects, I've seen it where things explode, there can be shouting and these are high stress, these things happen.

I never saw any of that on Lucy. It was just always so civil and great. I'd say we're a family, but I get along with this team better than I and other people I know get along with their family, it's better than a family. Whether it was luck or as we established, formed bonds and formations early, we passed it along, so we just had great people. You put great people in a great environment, and you're going to do great things.

We haven't said it much, but I want to pass that along. Lockheed Martin as well, just absolutely phenomenal, and Lockheed's experience in deep space missions is—you'd say it's world-class but it's solar-system class. I just don't know of any other entity that can compare themselves to what Lockheed technically and everything that they have done. So we had the right partners at the right time, and it was just great, awesome. We communicate well. We were all friendly. The first few minutes of the meeting were friendly conversations, and part of that was Hal—you've talked to Hal. I think you know he's jubilant, outgoing, friendly, happy all the time, that's his nature, and I think that you see that across the whole team.

JOHNSON: You mentioned that you were instrumental in in hiring or recruiting Hal to work on it. Talk about what you think and with this type of mission that is PI led, it's different than some of the flagship missions that NASA has.

ANDREWS: Sure, yes.

JOHNSON: So it's a completely different way for NASA to get these missions up. But talk about what you think it takes for a good PI and what made Hal special in that position and why you thought he would be good in that position?

ANDREWS: So if you talk to Hal, maybe he said it or maybe he didn't, I can't even count the number of times Hal would say, "Well, I've never done this before, so you got to—" you know. The historical debate and discussion is indeed about what skill mix, talents, and experience a PI has to have, and I worked with a very broad spectrum of PIs over my career. Each one's different, they all have their strengths, they all have probably some problems. Hal's reluctance early on was, "Well, I've never—" Now Hal never even worked on a mission. Hal's a theorist, he spent his whole career, and he's world-class, I mean Hal's world famous for what he's done. So his, what I would call, scientific gravitas is not in question, okay, nobody doubts that Hal knows his science.

But then the question was well, you know you've never worked on a mission, you don't even know what a PDR [preliminary design review] is and a CDR [critical design review] and earned value management, just all these things that I could go on for an hour about what's entailed, about processes and design. It's funny, Hal's a car tinkerer, he rebuilds cars and stuff like that, so even though it's not a spacecraft and he never built a spacecraft or a science instrument before, Hal knows what it's like to take something apart, put it together, the challenges of the timing and the organization and the structure. It's just that you wouldn't put that on your CV [curriculum vitae], your resume to NASA, but in fact, it does have an applicability. I spent a lot of time almost twisting his arm, he'd probably even say that, to convince him to go do this. He was at a point in his life, he was ready to do something different anyhow, and he said, "You know, why not?"

I just had this conversation with Hal the other day, but one of the greatest attributes Hal had because he didn't have prior mission experience or flight instrument [experience], he didn't

come into it with preconceived notions or biases that his way was best because he didn't have it his way. He was open and receptive to anybody on the team putting forward ideas and suggestions, and that's communication, right? That's the kind of team we all want, people want to be heard, and that's Hal. Because he's not sitting in there listening to you and thinking, well, that's not the way I would do it, so don't do it that way. He's sitting here thinking, listening, "Oh, I've never done this before, so your idea might have some merit." He's very good at that. Without mentioning names, most PIs come to this table having done different things, and they come with a pretty strong bias about how things should be done. They're not the best communicators and that's the difference between working at a fun project and a not-fun project. Hal made it a very fun project.

And then there's Cathy, and Cathy did come to Lucy with tremendous experience and knowledge. Cathy's one of those scientists that started out as an engineer and then went into science, incredibly intelligent, capable, and in a way, in many ways, complemented Hal. The other thing that helps with your science leadership is if they're complementary, maybe not two of the same kind, and Cathy brought all the New Horizons encounter experience, so they're just a great team, an amazing team.

But I think the first thing we have to recognize is a PI job is not a science job. It is indeed a management job, it's a leadership job, so your ability to assemble, formulate, and lead a team is first and foremost the most important thing. I know people that have built instruments but don't know how to lead a team, so maybe they're not the ideal PI candidate. I don't know if NASA's done this—it'd be interesting to do some psychological survey of all of PIs, and pick New Frontiers and Discovery, or their PI programs in heliophysics and astrophysics, just see what type of data you'd cull from that about personality types and how did things go.

And it's never about any one person, this is true for every mission I've observed. A PI frequently gets a lot of credit and kudos, their name is the first name on the papers, though they're the ones out in front of the press, but again like I said earlier, they're standing on the shoulders of a lot of giants. There were tens, hundreds, and thousands of people who made that mission a success to the point that that PI could be out in front of that camera telling a good story for NASA instead of a not-good story. Hal also recognized that, he acknowledged everybody, we still do all the accomplishments of every person that goes down to that.

I talk often internally, there's a book that was popular some years ago, you might remember, it was called *Don't Sweat the Small Stuff*. I don't believe in that book in this enterprise because, in fact, it is the minutia that can kill us. I mean these systems are very complicated, and if something goes wrong at the lowest level of assembly and it's not caught or weeded out, it can kill a whole mission. I don't believe don't sweat the small stuff is the appropriate paradigm for what we do. I bring that up because this is part of the how you instill all the way down to a team member doing what might be considered one of the most smallest, trivial, or early things, that it is important. Having that team member involved and happy and communicating is important because one day, your success, Hal's success depends on how happy [they were], did they get it right early on and years ago.

When we launched, there are things that are built into that system that were done years before and had to have been done right years before, and that goes to teamwork, team enthusiasm, plus the processes and practices at each institution. But, yes, so there's no doubt, communication, happy people, good team, people who want to work together because in time—Lucy is especially good example that because of the pandemic—you're going to put in a lot of

long, long stressful days with people that I hope you like and communicate with. Otherwise that job is going to be very difficult.

JOHNSON: Yes, well, let's get to that, let's talk about the pandemic and when it started in March 2020 and how that affected everything. Because the NASA Centers closed down, and so a lot of people on the team were affected by that. Luckily around the same time, things like Microsoft Teams and the different ways of communicating long distance, which for a project or a mission like Lucy, you were probably doing some of that already because the teams are spread out.

ANDREWS: Sure.

JOHNSON: But talk about those first days especially, and as part of the management, that group that had to make those decisions, what was going on and what was going on at Southwest Research? What was going on with those teams at that point?

ANDREWS: Sure, I'm going to preface this by something I want NASA and Headquarters and others to know and understand. Lucy, rightfully, got huge kudos for what we did during the pandemic. We delivered Lucy on time, actually a little bit under cost, and it would've been more under cost if we didn't internally use all our reserves for pandemic costs to deal with the pandemic. A lot of people asked either how we did it or why other projects weren't successful, they couldn't do it, and there's a couple, I believe, reasons for that. But one of them is when the pandemic started, Lucy was probably just short of being right at the launch site. Lucy was in a pretty good spot to deal with the pandemic. Our team was mature, informed, and we'd all been

working together for quite some time, and so when we had to switch to going to all Zoom or Webex—and you're right, prior to that, we were still doing a lot of Zoom and Webex and Teams, we just did more of it once the pandemic started. We didn't have to on-ramp a bunch of people at the leadership level or anything. We just knew who we were dealing with. Other programs in NASA's portfolio that have come along after that, I'm going to say Psyche, we have a mission at Southwest called PUNCH [Polarimeter to Unify the Corona and Heliosphere], they weren't at that level of maturity yet when the pandemic hit. I think about this all the time, if we had to do what they had to do, there would've been different outcomes because of the pandemic and the fact that the doing it—these virtual meetings is an interference or a different experience in communication and team building than if you're face-to-face.

So with that said, I guess there's an element of luck and timing that Lucy had, but there is more than that because there is an element of, as we were talking about, just the nature of the people. When the pandemic started, one of the great graces of Donya is she has something that's rare amongst us engineers and scientists, a very high emotional quotient. She was really tuned and plugged into the emotions and worries and everything. We had had a lot of talk early on about with the whole pandemic story. We didn't want to get people sick, but more importantly because people were dying. We didn't want anybody to get sick because we kept them in a team or an organization or a group where the result would be really sick and/or death. We spent a lot of time for the early weeks figuring things out.

We also benefited from an incredibly amazing project manager. If you have not interviewed Matt Cox, you should. Because Matt really had his act together about how he and Lockheed were going to assemble and isolate two teams working in two shifts to keep our project moving forward, and they did exactly that. There was minimal, I'm not going to say zero

because it wasn't zero, there were minimal infections on that team, and everybody had an ethic where I'm working on Lucy, and I'm going to go in and work with my team in the clean room. Now it's funny, they're all masked and gowned because by that time, we're working in a clean room, so maybe working in the clean room during a pandemic is the best place to be. But people still traveled, we had to ship hardware and move some people around, they did that at risk, and again, we had minimal infections. But Matt was on top of virology and data and statistics and numbers. He was a genius, just again one of those other awesome, amazing people that Lucy had.

So Matt, Donya, we all set up a plan of how people are going to work in shifts, and we did it, and it was hard I mean. The other benefit Lucy had, going back to our initial formula strategy on money, we had a large war chest. So when the pandemic hit, at the time the pandemic started, our forecast is we probably would've launched Lucy and could've returned, I don't know, $30 to $50 million to NASA. That would've been the size of our Phase B, C/D underrun. We didn't do that because that money got put into shift work and crashing the schedule, doing everything we could to make sure we would be on time with the launch, which we were. Even with all that, we still struggled, there were technical problems and challenges that were still overcome, but again, that team was formed.

But the new people that came to Lucy in the first year of the pandemic were Lockheed people that were being brought on to do integration and test. They were experienced Lockheed people that had already done OSIRIS and InSight [Interior Exploration using Seismic Investigations, Geodesy and Heat Transport],[10] they just hadn't been on Lucy before because we weren't yet at that stage of our life cycle. It was fortunate that the people we had to bring on as a

[10] InSight was a NASA Discovery Program mission that placed a single geophysical lander on Mars to study its deep interior.

project were local Lockheed people that were already around and experienced. We didn't need to find a new Donya or a new me or a new Cathy, all that was stable, that was great. It was the people that had to do the day-to-day work in their clean room.

JOHNSON: You mentioned Donya and her ability and we talked about a good PI. What do you think makes that good project manager or that person to run a project like Lucy, especially through something like COVID?

ANDREWS: Yes, well again, something like COVID, the first thing is exceptional EQ, which Donya has. Project management is very difficult, so the first thing you better have is passion, and you better be prepared to be passionate 24-7 because you can get a phone call at any time. Project management is about communication and leadership, the ability to identify and groom and bring in the best people that you can. It's about knowing your craft, right, being able to ask good questions, and filter the answers so that you can really home in on where are the problems and the challenges, which are not always clear. And this isn't a negative thing on the people doing the work, but they're not always really articulate in what the real problem is. You have to pull that out from them, right, to really understand, and that can take time.

And then, you know, a project manager is also a referee. You got your scientists on one side, your PI, you got your spacecraft vendor, you're trying to get everybody to understand, and I guess most importantly, this I say all the time. One of the principal jobs of project management is to manage expectations because if the PI is thinking we're going to deliver a week early and the spacecraft manager is thinking we're going to deliver a week late, you have a difference of expectations. You ought to be able to balance that and align everybody's expectations. I got to

be honest, once you've aligned everybody's expectations, things are good, right. Most people are unhappy when, well, that didn't meet my expectations. Then we should better balance what people's expectations are so that what we get, it does in fact, meet people's expectations. I mean I can go on longer, but I think those are the key points.

I will say this—and none of them were, and none of them are—micromanagement is not a good solution to anything, so that's what makes a good manager a manager. They've already gone to identify good people and have them work. I'm a big, historical buff and a big fan of Theodore Roosevelt, but Theodore Roosevelt had some phrase, I'm going to paraphrase it. But the hallmark of a great executive is to hire the best people possible to do a job and then get the hell out of their way, so they can do that job, and I think there was a huge amount of that on Lucy.

JOHNSON: Yes, it sounds like it, and I agree. That's a great plan for a manager. We've got about 15 minutes or so left, let's talk about some of the instruments and any delays or any problems because of COVID with the instruments?

ANDREWS: We had very few problems with the instruments because of COVID other than COVID put limits at APL and at Goddard and at Arizona State where all three instruments were built. Southwest built the electronics for Ralph, but by the time the pandemic started, those electronics were pretty mature and about ready to be delivered. I have to go back and look at my notes to remind myself if they actually were delivered. If you limit in a clean room to maybe three or four people masked and gowned still trying to keep some physical space from one

another, you're going to slow the work down. Because if you needed normally 7 to 12 people and you're limited to three or four, things are going to slow down.

Now when the pandemic started, our instruments were doing pretty well schedule-wise. The pandemic started in March of 2020, and the instruments were supposed to be delivered to Lockheed by the end of that calendar year, but we knew we had wiggle room for them to be late and still make our launch. All three teams APL, ASU, and Goddard implemented protocols where their doctors and surgeons at their respective institutions would allow them to work under certain conditions. Again, as I said earlier, we had very few cases of COVID, that's my memory at least, and work progressed.

And Ralph had had a lot of technical challenges just prior to the pandemic, and again, fortunately, we are able to retire. Fortunately, those were retired, that's the best way to put it, before the pandemic broke. Had the pandemic started three or four months earlier, we probably again would have had different outcomes. Ralph went through a long, challenging integration in part at Goddard because it had us go and do special chambers and get really cold for testing. APL had similar challenges, and at ASU, the issue came together, then all of a sudden, they had some problems they weren't expecting for a high heritage rebuild. Then they had difficulties getting out of house to go to test facilities that were impacted by the pandemic. No one made their original delivery date by the end of 2020, but everybody did make their dates within a few months on a timetable that had no impact to the overall project, which pandemic or not is extraordinarily rare for instrument development. Again, for all three of the instruments, they're high heritage, we benefited from that, but they're all three still difficult builds. Everybody, even with the pandemic, they made it to the party on time.

JOHNSON: I saw an article, and they even quoted you in it, but about the ATLO [Spacecraft Assembly, Test, and Launch Operations] had to be revised because of the schedule or delayed because of the pandemic, to have everything integrated.

ANDREWS: We did slow down, again the good news by the time the pandemic started, Lockheed had most, not all, but most of the stuff on the shelf they needed to begin the integration of the spacecraft. We had the gentleman at Lockheed [Chris McCaa], and he deserves a medal of honor. He had done a lot of integration and test lead, and he put together and ran a team that was amazing, clockwork. His name needs to go in the record.

Lockheed just did an amazing job there. Again, they are masters of their craft, and we had the A++ team to do Lucy. We had the support of Lockheed senior management, and that matters too, the buy-in of senior management. Yes, even with the pandemic, we're on constant Zoom calls listening and hearing things, but in hindsight, things went well. We had a couple of challenges. We had to change out reaction wheels because the delivered wheels proved to have a problem. Wow, I got to go back and think about my notes. There are other challenges, but we never had anything, and I've been on other missions that do, where something just doesn't show up and isn't going to show up for a long time. And again part of that was we started very early.

This is another part of the Lucy success story, how we structured our spend plan. We requested and got approval to buy a bunch of stuff in Phase B to retire schedule risk so that it was sitting on the shelf. Had we not done that, we could've waited, but we didn't, you may as well reduce risk where you can. We had that stuff there, so that was part of our plan, good on us. We didn't know a pandemic was coming, but we looked good afterwards because of the prep and planning that we had.

Early in our conversation, you mentioned how people sometimes wind up and they're rambling, and I'm thinking about our conversation, and I started to ramble. Early on, I was talking about schedules, but our mantra was schedule is king. Certainly for planetary mission, schedule is king, right, because the planet has got to be in the right place when you leave the Earth, or else you're going to have to wait until they are again next time. Making that launch date is everything, so schedule is king. The vast majority of discussions and decisions we made, when to buy things, when to do things is all driven by maintaining schedule. You can also only do that if you have a good war chest, so your reserves, and we had super large reserves both in going into the pandemic and over the mission's lifecycle by design. That was part of our business strategy when we started. Those are two imperative things, being totally focused on schedule and having the money to be able to do so.

JOHNSON: And, again, that goes back to management and being able to make those things available for when you needed them. Well, we just have a few minutes, but maybe we can talk about just some of the milestones, well, as far as the integration and testing, getting ready to launch, getting those instruments to Lockheed, getting it and things built. Was any of the testing delayed or were there any worries or any problems during that time period that you recall?

ANDREWS: Oh, yes, there were. I'm trying to piece things back together. Lucy left Denver in late July, like the 30th, of '21, and we were all excited, a bunch of us were going to fly on the big cargo ship from Denver. I was one of those, I really wanted to do that, but it turned out that was also the exact same time my daughter's college, she went to school in Vancouver, was reopening. They wanted the kids back on campus, so we drove her up there, and it was

challenging because while they wanted the kids up there, Canada hadn't yet opened their borders, so we had to do some timing. I missed the airplane ride, but I remember the date, which reminds me of when we shipped. We shipped pretty much on time at the end of July of 2021.

If you work backwards, once the instruments were on by late spring, Lockheed had and ran a very clean, environmental test campaign. Things worked really well. I'm just not sitting here thinking about, holy cow, we had this or we had to repeat a test. Things went well, which means we designed a good system, Lockheed gets huge kudos, the instrument teams get kudos, they delivered, the instruments went right on. Little, trivial things but no showstoppers or anything that ate up days of repair or rework. Again, I could say we were lucky, but I could also say we worked hard and did a good design up front that empowered everybody to make it go through that way.

We kept a lot of people remote during AI&T [Advanced Integration and Testing]. Traditionally maybe a whole bunch of people from different instrument teams would go to Lockheed to watch, observe, and participate. We didn't do that, people looked at telemetry and data from tests remotely so that we minimize this probability and statistics that people might get contaminated and that panned out. Goddard very much wanted to have boots on the ground at Lockheed, but again when people fly and you potentially bring in infection, we wanted to preclude that. Southwest, our office are at Boulder, and Lockheed, where we did integration, for those who don't know, it's down in Littleton, may be 40, 45 miles part. Southwest rented some office space down by Lockheed, and we created a little Lucy management office where the Goddard people could come and the Southwest people could come. We can be close to Lockheed and maybe go in all masked and have a one-hour meeting and then get out of there and then go back to our little local Southwest Lucy office, and that worked really well.

We have people shuttling in and out of there, we had very tight masking and cleaning requirements. I remember as soon as you opened the door in that space and you walked in, the first thing you thought was you're in a janitorial supply shop because of all the cleaning agents and everything that's just sitting there. But that helped because that allowed Hal to meet face—mask-to-mask with Donya or Arlin, etc. That was a good tool, a good thing that we did there to help out.

JOHNSON: Yes, and it is important to have those meetings and in reading about this, not just this mission, but other things that were going on at NASA, people miss that time in the hallway, that five-minute conversation that you can't necessarily have.

ANDREWS: So this is—and I'm still waiting for the shoe to drop. I'm a big believer in face-to-face, and I'm harping on my people even now because I—even before—but even now, we've developed some bad habits. People need to pick up the phone more often, and people need to see each other more often, and the communication will improve. But relying on an email to go back 20 times back and forth in hopes that something is going to be resolved is very wasteful. But more importantly, it's the number of ideas that are created at the water cooler or the coffee machine or at lunch, those are important things. I'm waiting to see over time, if through studies, will there be fewer patents filed, will there be fewer new things on the market?

I know we've had a terrible impact on the education of our young people. The pandemic, while it might be hard for an adult, the fallout pain of the pandemic on our young people, anybody that was 2 years old to 25 years old during that time period who lost socialization skills and opportunities, etc., etc. It's going to be devastating, and as a society, and I mean a planetary

society, I don't think we've realized, and we may not realize, the impact of that for years to come. But I do believe underlying the fabric of our civilization are problems that are going to come from that experience.

JOHNSON: Yes, I agree with you, and I'm sure there'll be a lot of studies about that before it's over with or they're already doing it. But that might be a good place to stop because we're getting up to time for launch and then all the things that happened after launch. If you don't mind, I'm going to go ahead and just stop the recording, but I appreciate you talking today to me.

ANDREWS: You're welcome.

[End of interview]