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 January 9th, 2024. 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. Thank you again for continuing your interview. I appreciate it.

When we ended last time, we were almost up to the launch of Lucy. I think I'd like to start there, and talk about the launch, where you were, what your duties were during the launch and shortly after.

ANDREWS: Sure, thanks, good morning. I didn't have any official duties at the launch. I wasn't on console. I was over in the VIP area with part of the Southwest [Research Institute] contingent. We got to see the launch from an elevated position, and I can't remember the name of that building. But we hosted people from NASA Headquarters and our own respective institutional leadership, so it was more of a be available to answer questions about Lucy to the VIPs that were there. It was a spectacular launch, on time to the second that we said it was going to be years before when we wrote the original Phase A proposal, the concept study report, so that's one of the other things that made Lucy so successful.

Sun wasn't up yet, it was black, dark, and then the launch was great. Then it went up through a cloud deck and you couldn't see the rocket for a few minutes, but the exhaust plume lit up the entire cloud deck. Then it cleared the cloud deck and it arced over and went downrange.

There are some truly magnificent photographs of that launch and some of the time delay ones have the whole arc of the rocket going up through the clouds. It's really really pretty, so if people go online and look at those it's spectacular.

Then a few minutes after launch I cleared that area and went over to the blockhouse, the control center, to watch things happen. Within an hour we certainly knew that we had a problem with the solar array, so all our exuberance about a successful launch quickly turned into concern that we didn't have a perfectly healthy spacecraft.

JOHNSON: You were still there in the control center when you found out?

ANDREWS: By the time I got to the control center we had just started to begin to deploy the arrays, and we saw the one array fully open, latch, and get the latch signal, but we never got that on the other array that ultimately failed to completely latch. You're in this mixed mode because you're going from exuberance about oh, wow, it launched, and the most stressful thing happened and it went off, and then within an hour you're realizing you have a likely very severe problem with your spacecraft. Everybody went into troubleshooting mode.

Everybody plans for success, so parties are arranged and stuff like that, and by the time you get to the parties, and not everybody was informed yet of what had happened. People had seen the launch, they go to the party, they're all happy. But other people show up to the party and it's like well, we know there's a problem. There's this very mixed set of feelings amongst the crowd until people learn more. Not many people could know because there's information control, who can know, how we do a press release and release it to the media. You just don't stand up and tell everybody that there was an anomaly at that point.

Then the next several days were spent trying to diagnose the problem and then set up the evaluation in tiger teams that would work for well over a year to remediate the problem and do analysis and figure out what exactly was wrong to begin with. As you likely know, after, oh my gosh, probably well over a year of study and analysis and whatnot, we came to the "use as is" conclusion, that everything indicates that unless something changes on the spacecraft, we're in an adequately healthy state that we can successfully fly the mission. I think we demonstrated that in part with the successful Dinkinesh [asteroid] encounter on November 1st. However, that encounter was much closer to the Sun than we'll be when we do the Trojan asteroid flybys.

JOHNSON: When everyone was first aware of that anomaly, and as you said you had these teams that were formed, were you involved in any of that in your position or involved in oversight?

ANDREWS: No, because my role is the management of the science and in development I managed, and still do, the science payload. But this was a spacecraft proper issue. The management and oversight lay with Goddard [Space Flight Center, Greenbelt, Maryland] who's the overall mission managing institution, and then resources at Lockheed Martin. My position as just a manager was to advise the PI [principal investigator] as I could and then sit in on meetings and be aware. But the solar array and its nuances are not in my bailiwick.

JOHNSON: In our last interview you talked a lot about communication and how the team felt like a family and the way everyone was able to disagree and still work together. You felt like Lucy was unusual because of that. How much do you think that affected the response to this type of anomaly?

ANDREWS: Certainly that mindset that we're all one big team working together to achieve one big thing, that stayed on in Phase E post launch as we worked to assess and troubleshoot the solar array. I'm not aware at any point where it then got to finger-pointing or anything like that. The folks that developed the solar array, Lockheed Martin that acquired and integrated the solar array, Goddard and Southwest that oversaw and supported all this, were all supportive. There was no finger-pointing. There might be deep down inside some technical lessons learned about how to or not to fly this type of solar array technology on a mission like Lucy. But the team worked very hard and continues to work very hard to assess, analyze the situation, and monitor it as we continue through flight. Again, I think the culture and the community that we established during the development of the mission continues during the operations of the mission.

JOHNSON: You mentioned that it was a mixed mode after that launch and then the spacecraft had an issue so those teams had to be formed. But at the same time there were instruments that needed to be brought online and checked out. Let's talk about that, what that was like and what you were doing.

ANDREWS: After launch there was already a well-structured plan for spacecraft commissioning and then instrument and payload commissioning. Because what ultimately happens or appears to have happened is the solar array is almost completely open and from the standpoint of power generation, we don't see much difference in the amount of power the solar arrays are able to generate, which is part of the thing that gives us confidence it's almost completely open.

But what it is not, is latched. The overall stiffness of that solar array structurally is not what it should be, which compounds some difficulties in the spacecraft pointing system to meet the pointing requirements. But analysis and then subsequent tests, and now proven by flying the Dinkinesh encounter, in its current state the spacecraft works just fine. Although we did tailor—Lockheed tailored, they did a lot of work. I'm not going to trivialize that—a lot of the control algorithms, the spacecraft works just fine. Lucy can with margin still go do what it's supposed to do, again provided that solar array state doesn't change much from what it is now.

Again the analysis we've all done is that solar array should stay in the position it is now. We do have an upcoming test of that when we do a deep space maneuver at the end of January and early February of this year, which will be the first time we fire the main engines since launch. We're optimistic that the impulse delivered to the spacecraft from that main engine firing won't negatively affect the solar array state.

JOHNSON: One of the first things was the Earth flyby. That was one of the first times that Lucy was tested as far as the instruments?

ANDREWS: Yes. We launched in October of '21. Exactly one year later we came back around and we did an Earth flyby at a pretty low altitude. As we approached Earth, we did collect some very cool images of the Earth-Moon system. We did images of the Moon, we did images of the Earth, demonstrating all the instruments work out.

I believe it was Lucy that did the image of the solar eclipse at that time as we approached Earth. It was the first time a satellite beyond Earth had taken an image of the Earth-Moon system during a solar eclipse, and John Spencer put together a pretty cool little time-lapse video

of that data as the spacecraft approached Earth. You can see the Moon get eclipsed by the shadow of the Earth and then it reappears.

But all that worked well. All the instruments worked. Again the instruments, the spacecraft, the ground system, everything works on Lucy extremely well. We just had that solar array glitch that we're doing workarounds with. We're making it work with what we have.

JOHNSON: As far as what you're doing with your current position, you're still involved with Lucy with all of these because of the instruments?

ANDREWS: And the overall science program. In development Southwest is responsible for overseeing the instrument developments which were done again at Arizona State, APL [Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland], and Goddard and Southwest. And then I also manage the PI contract and I continue to manage the PI contract, so in Phase E the PI contract is the Southwest scientists, all of our subcontract scientists, the Science Operations Center, the payload oversight office, and the payload instruments themselves.

JOHNSON: Let's talk about that first encounter with Dinkinesh that we just had in November. It was an interesting fall for NASA. There were a lot of different things happening as far as getting things back and asteroid encounters and launches. This was a big one.

ANDREWS: Yes. A couple things about Dinkinesh that are amazing and a credit to the team. When we launched, we didn't know we were going to do Dinkinesh. When we launched

Dinkinesh wasn't even called Dinkinesh. I don't know if you've gone back and interviewed let's say Hal [Harold F. Levison] since the Dinkinesh encounter.

JOHNSON: No, I haven't. That would be interesting.

ANDREWS: He can fill you in on Dinkinesh. I want to be careful about what I do and don't say because while I sit in on a bunch of the science discussions where they're now looking at the data, I think a lot of it is still embargoed until they do further press releases and issue their paper.

What I can say, what I do know that's out in the general public, when we launched, we didn't even know we were going to fly Dinkinesh. It wasn't even called Dinkinesh. Then sometime after launch, not too long after launch, a scientist that had spent time at Southwest and was close to the Lucy team, but not a true member of the Lucy team, sent some email or made some comments that said, "You guys realize on your trajectory you're going to fly within 65,000 kilometers of this little tiny asteroid in the main belt." People said, "No, we didn't know that." Then somebody I think at Lockheed probably suggested for only an extremely modest amount of fuel, 3 meters per second or something, we could probably encounter. We could do an actual flyby of that target.

Then that thing got momentum of its own. People worked to actually give it a name, calling it Dinkinesh, which is the native Ethiopian word for the Lucy fossil, so we worked and we planned it. There are actually good reasons to do it. We didn't ask for more money to do it. We started the planning of it while we were still troubleshooting and assessing the solar array. But I'm a big advocate of the fail faster philosophy, which if something's going to go wrong, push the system so it goes wrong sooner so you have more time to fix it than defer it. So by

finding out how the spacecraft would perform earlier, the Dinkinesh opportunity was too much to pass up.

We didn't levy science requirements or anything on it. We just wanted to test the engineering systems and the pointing and the payload and see how everything would work out. Had we not done Dinkinesh we wouldn't know any of this until we do the Donaldjohanson asteroid flyby in April of 2025, which was part of our core plan almost all along to do that flyby.

November 1st comes along last year, 2023, we do the flyby, and it's just monumentally successful. I was in the science room in Boulder [Colorado] with the science team when the data came through; some of the data was first seen at Lockheed a few minutes before. But Dinkinesh proves to be an extraordinarily interesting and exciting science target. It has a small moon which people weren't expecting, and then on top of that the small moon is a contact binary. It's two little tiny asteroids barely in contact touching each other. There's a whole bunch about the system that's also fascinating scientifically. I can't go into that for two reasons. I'm not a scientist, and the other is a lot of it is embargoed while they work on their papers.

But it is amazing how that little target, which we didn't know about when we launched, that we did just as an engineering study, validated and showed everything works really really well, and it returns what's going to be some really exciting and interesting science about asteroids in the main belt that we had no idea about before. Lucy just gave us a great gift early. The fact that it still works even after the solar array is another great gift as well right now.

JOHNSON: When planning the mission and choosing the asteroids, that whole story was pretty interesting on how they did that and how the asteroids were chosen. But do you want to talk about some of those targets and just mention some of that planning?

ANDREWS: Okay. When we started out on Lucy, we spent a lot of time in a very small group discussing what the mission should do. You got to keep in mind that back in 2014 the Decadal Survey[1] they were operating under at that time encouraged a New Frontiers proposal, not Discovery but New Frontiers, that would do a Trojan asteroid tour and rendezvous. It would fly by at least one Trojan and then with luck it would ultimately rendezvous and loiter and stay at a Trojan and study it in great detail. Much like Dawn did at Ceres in the Discovery Program[2].

But the PI and his scientists came along with the fact that we know so little about the Trojans and there are so many of them. How do you even pick out which one you would go loiter at? I'm going to guess that Hal talked to you about this and he's the best person to do this, but the Trojans come in different flavors in size and their spectroscopic color and where they are L4 or L5 swarm. As they worked with the trajectory people at Lockheed, who have access to a database of the ephemerides for the known Trojans, other scientists looked at possible size, brightness, spin rate, color, color code, so that we could do our best to try to visit as many of the different flavors as possible.

The idea behind Lucy was we should probably do a reconnaissance survey and know more about the Trojans before someone picked out one where you would do arrival and rendezvous and loiter because that is a very difficult mission to do. You might need electric propulsion with our current technology to do it. It would take longer because you have to be slow enough when you arrive that you can then fully slow down and loiter with a low-mass

[1] 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.

[2] Dawn was NASA's first truly interplanetary spaceship. The mission featured extended stays at two very different extraterrestrial bodies: giant asteroid Vesta and dwarf planet Ceres. Both small worlds reside in the debris-strewn main asteroid belt between Mars and Jupiter.

body, etc. The idea of a survey is really what Lucy was all about, and we felt that we could meet the vast majority of the Decadal Survey New Frontiers recommended science for a Trojan mission if we did it within Discovery, and also save NASA a whole bunch of money because it would be a much lower-cost mission. That was the genesis of the Lucy science attempt.

Furthermore, because by that time New Horizons[3] had launched, and while we were working on the Lucy Step 1 proposal, many of us were also working to support the New Horizons Pluto flyby that would happen a year later. We already knew that the instrument suite we pretty much wanted to fly to the Trojans was much of the same suite that was on New Horizons that we were all very familiar with. That's why the Lucy LORRI [Long Range Reconnaissance Imager] instrument and the Lucy Ralph instrument are on Lucy just like the Pluto Ralph instrument and the Pluto LORRI instrument are on New Horizons. We even had debates, people suggested we change the instrument names and I said, "No no no no. Don't do that."

We had this little theme going on to make it sound—and I don't speak French and I apologize to people who do. But we put the little L apostrophe in front of the instrument names so it would be L'LORRI and L'Ralph. Then the other instrument is TES [Tropospheric Emission Spectrometer], L'TES. TES came from OSIRIS-REx [Origins, Spectral Interpretation, Resource Identification, and Security – Regolith Explorer][4] which was in development at that time.

[3] The first spacecraft to explore Pluto up close, flying by the dwarf planet and its moons in 2015. After a nine-year journey, New Horizons also passed its second major science target, reaching the Kuiper Belt object Arrokoth in 2019, the most distant object ever explored up close.
[4] OSIRIS-REx is the first U.S. mission to collect a sample from an asteroid. It returned to Earth on September 24, 2023, to drop off material from asteroid Bennu. The spacecraft didn't land, but continued on to a new mission, OSIRIS-APEX, to explore asteroid Apophis.

But the whole idea was we knew our proposal would be reviewed. At the same time people were picking up the *New York Times* and looking at Pluto pictures on the front page. It's like no no no, we want people to read our proposal and read about LORRI and then read the newspaper and read about that picture on the front page of the *New York Times* was taken by LORRI. It was an awesome PR [public relations] campaign to help sell the proposal, and I really pushed to make sure we kept the names the same, don't change them. Somebody came up with the idea of putting a little L apostrophe in front of them, and that still sticks to this day because in any given meeting, because a lot of us work on multiple projects, if you just talk about LORRI, it might take a few minutes to figure out which LORRI somebody is referring to.

It was going back to that idea that we're going to do a survey, and then Hal working with the trajectory people at Lockheed and other scientists came up with this orbit that yielded us a family of Trojans that we could visit that met spectral classification, spin rate, color type, size, etc. Most of our encounters are in the L4 swarm that we get to first. That's the swarm that leads Jupiter in its orbit by about 60 degrees. We can do that in several many years. We launched in '21. We'll get to L4 and fly through it in '27 and '28. That would have been a six-, seven-year mission, which everybody thought oh, that's fine, we'll sell it that way. Seven years is in family for a Discovery mission. But Hal really wanted the Menoetius, the binary system that is the creme de la creme of the mission, and that's in L5. To do that the spacecraft has to come back from L4 and then go back out to L5. It adds like another five or six years to the whole mission.

We spent a lot of time strategizing do we put L5 in the baseline mission, is it an SEO [Science Enhancement Option], how do we convince reviewers that the spacecraft will live that long. We just said that the prize is too great. We have to put L5 in the baseline mission. Lucy was designed for a 12-year mission life, longer actually, so that we could get to L5.

I can't say from a reviewer standpoint if that was the linchpin for selection but it certainly was yet another gift that kept on giving for Lucy that we could do both L4 and L5. Now we met all the metrics of curiosity in spectral class, size, spin rate, etc. But then we're also visiting L4 and L5, two separate distinct bodies. While I won't promise anything, by the time we start to approach L5, and if we were to talk about extended missions, it's conceivable that we'll find or be able to visit another target in L5. But that's something we'll figure out in 2031 or something like that.

JOHNSON: It seems like it's a long ways away but really, it's not that long.

ANDREWS: Yes. As you know when you talk to people like Alan [Stern], I worked on New Horizons starting in I don't know, 2003, and when we started working on it and think well, we've got years till launch and then 10 years to get there, and then here I am today all those years later looking back and unfortunately time flies by.

JOHNSON: Yes, it does, sometimes quicker than we want it to, that's for sure. Speaking of time, as you said it's designed to last a lot longer. I think Hal probably mentioned that when they were first doing those trajectories, I think he said it was Brian Sutter at Lockheed Martin.

ANDREWS: Brian Sutter. Yes. If it wasn't for Brian Sutter, we wouldn't have a Lucy because he did some trajectory work after the Step 1 proposal which was able to get us to go from a big rocket to a tiny rocket, which through the rules of the AO [announcement of opportunity]

allowed us to save $30 million. That made a big difference in our cost strategy. Brian is a superstar.

JOHNSON: But Lucy could last a lot longer.

ANDREWS: What I hear from Hal is—and Hal is a planetary dynamicist, so his career and living is studying the solar system over 4.5 billion years and knowing where objects move and predicting where they will move. I think when he gives a talk nowadays, he's pretty confident that at least for 2 million years Lucy will just keep doing what it's doing, which is cycle back and forth from L4 to L5 to the Earth, L4, L5 to the Earth. It'll do that without human interference.

Unlike let's say Voyager which will go on forever, it left the solar system; New Horizons will leave the solar system; Lucy will be out there almost forever but it's going to be cycling around. If you talked to Hal, you probably know the story about the plaque that's on Lucy in case our great-great-great-great-great-great-great-great-great—whatever—grandchildren one day, or an alien species or whatever it is, or the cockroaches that inherit the Earth and develop intelligence, find it out there. There's like on Voyager, Pioneer, and New Horizons, a plaque and information to the future or to aliens about who we are and where we came from.

JOHNSON: The plaque and the people that they quoted on the plaque was pretty interesting and tying it in again with "Lucy in the Sky with Diamonds."

ANDREWS: We've had a lot of great tie-ins. If you haven't talked to Hal in a while, other things that have happened is Ringo Starr was in Denver. He gave a concert late last year, I can't

remember the exact date, but Hal arranged finally to go meet him and give Ringo a copy of the plaque. There's a video that Ringo did for us before launch which is funny. You see Ringo Starr on YouTube talking about Lucy. He ends it with his peace sign. Peace and love. It's just go Lucy, peace, and love. That was pretty cool.

But to me the bigger tie-in has been, because he's been a hero of mine since I was literally a little kid, Donald Johanson, who led the team that found the Lucy fossil in the early '70s. No offense, you're like me, old enough to remember. Back when we had only about three or four different television channels. You watched PBS as a young person. They would show the *National Geographic Specials*. I remember the *National Geographic Special*, the film with Donald Johanson about finding Lucy and our human ancestors and between anthropology, archeology, paleontology, and space, those were and tend to still be the STEM [Science, Technology, Engineering, Math] subjects that drive children to be interested in things.

Even today most children, their early interest in anything science-related is dinosaurs or it's space. Then maybe that might evolve into biology, computer programming, and other things. But it certainly starts with space and biology. Donald Johanson, huge hero of mine. Finally to meet him and have him at events because of the whole Lucy theme and the fossil theme is phenomenal. Got to talk to him quite a bit at the launch. Then he was in Denver back in November at the Denver Museum of Nature & Science event that we had and he gave a talk. Just a remarkable human being, extraordinarily nice gentleman, very interesting. He just ate up and loved what we're doing with Lucy, just like we love what he does with the origins and evolutions of humankind. That was really cool.

JOHNSON: As you mentioned that event, education, outreach, all those things are important to NASA and have been because like you said that's how we get the kids interested, that's how we have people that want to work for NASA and the companies that help with these missions. Talk about that event after Dinkinesh and just what it was, what your participation was, and how that went.

ANDREWS: Again, after launch and whatnot, I am mostly in a role of management of the activities at Southwest, the science team, and the payload operations and science operations. I'm not much involved in the day-to-day operations and activities. That's what our staff works on. We have a lot of excellent outstanding people that do that. Many of them have been involved with Lucy from day one. They also had worked on New Horizons.

On a day-to-day basis I do much less Lucy than I did during development. But as I described earlier, I was there when we all met in Boulder on the 1st of November for when we got the data. What made that even cooler was that Lori [S.] Glaze, the head of the Planetary Science Division, had been with the team down at Lockheed that morning, and then she was with the team that afternoon in Boulder when the data came through. It's a great pleasure to have the head of the planetary program in the room with you when you can show off that hey, we made it all work, we took the taxpayer and NASA's money and we delivered. We did a great thing. That's very exciting.

But again had we just seen a dot on the camera and the camera pointed we probably would have walked away very happy. But the fact that what we saw at Dinkinesh was so phenomenal, that just blew everything away. Now the scientists are off way earlier than

originally planned, looking at data and doing things. We're formulating assessments to how well the payload worked. That all worked great.

Then within a couple weeks—well, before the Dinkinesh encounter—we had planned to do a museum event, which is kind of risky because had things not gone right and we'd lined up all these talks and everything that may not have been so pleasant. But right now the universe's good graces are shining down on us. Hal gave a talk at the museum and Simone [Marchi] gave a talk at the museum. Simone is deputy PI. Donald Johanson gave a talk and it was just fantastic. The IMAX theater was full. A fraction of it was Lucy people but a lot of it was just people from the Colorado Front Range that were interested in the subject. That's reassuring.

Then it was in the media, the press. There's a *Scientific American* highlights of space thread going around someone just sent me the other day. The Lucy images from Dinkinesh are in the top 10, which is impressive, considering it's competing with all the JWST [James Webb Space Telescope] images which are truly phenomenal. It's just very exciting.

As far as education and public outreach, after selection Thomas [Zurbuchen] encouraged Hal to have a student effort, and we thought about what it was going to be because we didn't think we wanted to fly a student-built instrument, which we did do for New Horizons and it was very successful. But there were different mindsets on whether that should be done for Lucy or not. We instead came up—working with Sheri [Klug] Boonstra at ASU [Arizona State University] going back to the whole L apostrophe thing—the L'SPACE [Lucy Student Pipeline Accelerator and Competency Enabler] Academy. I don't know who you've talked to about the L'SPACE Academy but it is an internship program and an educational program where literally by now, I don't even know the numbers but Sheri does, many many thousands of college

students across the country have participated in this academy to learn how to do and develop space missions.

Additionally large numbers of interns, and I don't know the numbers, but by now it's many hundreds have been staffed out typically in the summer to Goddard, Southwest, APL, ASU, Lockheed to do and learn various things funded through the L'SPACE Academy. That has seemed to be and been deemed a very successful effort. It continues now for several more years in Phase E.

Additionally probably every scientist, some of the engineers on the project, are giving talks at high schools and schools. We have multiple web pages. I think one of the coolest, and I apologize if I can't remember who developed it, there's a web page: Where Is Lucy? If you google it and go to it it'll give you up-to-date and instantaneous locations of where Lucy is in the solar system, and then it shows its trajectory path so you can see where it's going to go and when. Just before Dinkinesh a new feature was added that allows you to predict where and when Lucy will be looking at the targets and stuff like that. It's very cool. We do what we can to have a very large substantial presence.

Hal unlike let's say Alan is, from what I've seen, not a Twitter user. He's not always on Twitter or X, whereas I know Alan does. But Lucy has a good social media presence and a lot of people out there working on E/PO [Education and Public Outreach]. Again obviously the biggest thing you can do is do a successful encounter and get those photos and images out in the media and you clearly get a lot of excitement which we did and will do.

JOHNSON: I know they did those films, the cartoon films to get kids of all ages.

ANDREWS: That's Katherine Kretke, our E/PO outreach. I don't think you can actually E/PO anymore. I think it's public outreach. Her and her group came up with the idea of that little Lucy cartoon. I'm just not right-brained enough to think about those things and I find them a little corny but they work. I think that's great.

JOHNSON: Yes, I think it's good for younger kids because it gets them excited and it's something they can relate to. Then the posters that they've done with very much throwing it back to the '60s.

ANDREWS: Hal and I go back and forth on this quite a bit. I'm not a big tie-dye psychedelic person. Hal is way into it. I love a lot of—I'm just going to call them the more traditional conservative Lucy posters I just love. But I have to admit there's now a psychedelic decal poster for each encounter and they're collectibles. I don't think I have one here in my home office. But I do have them in my office at work.

JOHNSON: The ideas that came out with Lucy have been pretty interesting. I notice Psyche now too; they're trying to do some with that mission. I've been seeing those coming online. It's interesting how it does capture the public's imagination more.

Let's talk about since your experience working with NASA and you've done this more than once on different missions, but with the Lucy mission itself, what do you think some of the lessons learned from this mission are.

ANDREWS: Oh my goodness. As I and others have talked about, what really makes Lucy unique is the team and the camaraderie and the communications. It has a huge amount to do with it. I've worked on a lot of projects and I'm not badmouthing the other projects but I've never worked on a project like Lucy where everybody's a friend. I can't even think of times or meetings where there was real friction or animosity. That's actually unfortunately—it's uncommon to be that way versus have some other things.

Now there's a couple reasons for that. The people that do this and the people I've always worked with are extremely impassioned about space and we're very success oriented. People should remember that to even get a space mission is a competitive enterprise. They just don't fall in your lap. If they did, well, then you're working in a different environment.

The people, the PIs, the project managers, the engineers, the financial people, the administrators, and then the people that do the selection process, it's a competition. The types of human beings that compete are competitors. They want to win. They want to succeed. Those types of people can also—I'm one of them—it can be difficult to operate at that level and succeed. Along the way you're going to probably find friction and you might annoy some people, to be polite about it. But there was almost none of that on Lucy. It was always whenever there was an issue or problem across multiple organizations it's well, let's just get it fixed, and let's just get it moved on. That stayed through the pandemic as well. A lot of it was early on we established pretty much a badgeless community. It didn't matter if you were at Goddard, didn't matter if you were at Lockheed or Southwest or ASU, APL, or whatever. It was let's just work together and get the job done. That worked very well.

It's also established by the tone and Hal is extremely laid-back and establishes a communicative open friendly environment. Which is not the MO [modus operandi] for a lot of PIs or project managers. More than anything it was that.

Whether we got lucky or by design we had extremely good people at every place in the organization that mattered. We had people that all came to Lucy with a lot of experience. I don't think there was really anybody on Lucy, certainly in higher positions of engineering or management, that was learning something new every day. They had done it before. That experience matters as well. It's those combinations of things that come together and that make big differences.

I think the other thing that Lucy did, and I know because I was very much involved with it from day one, was we knew exactly what we wanted to do. We knew the requirements. We knew how we wanted to do it. We didn't have to get into development and do a lot of rework of requirements or exploration of how something was going to work. We knew what we wanted to do. That helps a lot.

If I can plug a book which is not my own but I read it over the Christmas break, there's a book that came out called *How Big Things Get Done* [*The Surprising Factors That Determine the Fate of Every Project, from Home Renovations to Space Exploration and Everything In Between,* by Bent Flyvbjerg and Dan Gardner]. As I'm reading or actually listening to that book and the professor who wrote it, he's saying a lot of things about what makes a big project successful, and over and over again I resonate, yes, that was Lucy, that was Lucy, that was Lucy. A lot of it is about a lot of intense preparation early. Establishing good requirements. Knowing what you want to do. Getting a good team to go do it. Having a vision, then going to do it. That's what we did.

JOHNSON: Since you have been involved in the AO, the announcement of opportunity, the proposals, and the process to answer that, with Discovery and also with New Frontiers, talk about the difference. They wanted a New Frontiers mission that would go out and do some of the things that Lucy is doing. But it was something that was then proposed to be done in the Discovery Program. You mentioned that during Lucy, because you weren't sure if it was going to be chosen or not, the group had already started working on one for New Frontiers. What would be the differences between working on those proposals?

ANDREWS: When there's a New Frontiers call—and of course there haven't been many. There have probably been more than a factor of three more Discovery calls than there have ever been New Frontiers calls. But New Frontiers is structured. The Agency limits the science themes that you can pursue.

When a New Frontiers call comes out the Agency will say, "All right. We want New Frontiers proposals, but you can only go do the following." The following is a list that's generated by response to the Decadal Survey that's done. Obviously, all the missions that have been selected, OSIRIS-REx, Juno[5], Dragonfly[6], they were all proposed because the specific science was requested in that call. For an example, I'm not intimate with every New Frontiers call but my memory would be there's never been a New Frontiers call yet that asked for, as an example, a dedicated Mercury mission. Mercury was something that was done with

[5] Since it arrived at Jupiter in 2016, NASA's Juno spacecraft has been probing beneath the dense clouds encircling the planet – the first orbiter to peer so closely. It seeks answers to questions about the origin and evolution of Jupiter, our solar system, and giant planets across the cosmos.
[6] Dragonfly is a rotorcraft lander mission designed to take advantage of Titan's environment to sample materials and determine surface composition in different geologic settings.

MESSENGER [Mercury Surface, Space Environment, Geochemistry and Ranging][7] under Discovery.

The last few New Frontiers missions have included south pole lunar sample return. A Lunar Geophysical Network. I think there was a large Venus mission called for. I can come back to that in a minute. There probably was a Titan mission called for. Then Dragonfly would have fulfilled that.

A lot of us have been gearing up and prepared to work on New Frontiers by the end of last year actually and then current funding restraints with the Agency have slipped that out perhaps quite a bit. The nature of missions, we're still South Pole-Aitken Basin, Lunar Geophysical Network, Saturn atmosphere sampler, and Enceladus flyby mission, etc. New Frontiers really defines what you can and can't do.

Discovery is a free-for-all. Other than you can only get so much money, so much time within Discovery you can propose whatever science you want. Then it's up to the community and the reviewers to go through what was proposed and then figure out the recommendations, and then the selecting official makes the decision of what they want to pick in Discovery. In the last few rounds, as an example, when we submitted Lucy to do a Trojan mission, as I described earlier, we knew the Trojans were being called for in New Frontiers. But in a slightly different type of mission with a slightly different science payload. The same is true for Venus was being called for.

Then I would think going back in both the case of Lucy and then ultimately DAVINCI[8] those are two missions that kind of—I don't want to use the word usurp but looked at the

[7] The first spacecraft to visit Mercury in 30 years, and the first ever to orbit, MESSENGER mapped the entire planet, discovered abundant water ice in shadows at the poles, and unlocked knowledge about Mercury's geology and magnetic field.

Decadal and said, "We can get you much of what's being asked for on a Discovery budget rather than having to be a New Frontiers." I would argue that both DAVINCI and Lucy have demonstrated that that paradigm is successful if you just look at different new and clever ways to do it and if the community is prepared to not have absolutely all of the science that might be defined in the Decadal for a New Frontiers mission.

But when we were doing Lucy, we knew all this and there had actually been prior Trojan mission proposals in New Frontiers and in Discovery because Cathy Olkin had taken the original Lucy to Discovery in 2010. But we sat down with the Decadal; we sat down with the description of a New Frontiers mission. We realized well, we're not going to do this. We're not going to do this. We're not going to do this. We're not going to do this. But this is what we are going to do.

Because again, we're all very competitive and we want to succeed, we did not know that Lucy would be successful. At the same time by the time Lucy was in Phase A doing our concept study report, the next New Frontiers call was coming up so you had to stand up your team and prepare to do a New Frontiers proposal. Late in the Phase A for Lucy, Discovery Lucy, we started to work with pretty much the same team to do a New Frontiers proposal.

What was hard about that is you had just spent years and a lot of time and effort working on a Discovery proposal that you're hoping is going to win while you're working on a New Frontiers proposal because you're thinking you may not win. That's hard. That's really mixed emotions. Again to this day one of the greatest joys of my life outside of personal family events would be on the morning of January 4th, 2017. Thomas Zurbuchen called Hal that morning to tell him that Lucy was selected. Hal was coming into the office, the first person he told in person

[8] 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.

was me. He had called one or two people on the way from the bus stop to the office. But we literally danced for joy in our office.

That day we were supposed to have a bunch of meetings lined up to discuss the New Frontiers proposal. I almost immediately looked at Hal and said, "Oh my God, this means we can cancel all those meetings." But all the news was embargoed so we couldn't tell people why we were canceling the meetings but it didn't take a genius to figure it out. After Hal left to go start informing other people that we were selected for Lucy I had to start calling people and emailing people to tell them we're not going to have any New Frontiers meetings but I cannot tell them wink wink why we're not having New Frontiers meetings.

It was a great joy. While we could have gone on and we probably would have written a great New Frontiers proposal, when I look at the missions that were studied and were selected for the Phase A study, that would have been CAESAR [Comet Astrobiology Exploration Sample Return], the comet return mission, and then Dragonfly, just to fly on Titan. It's not clear to me that Lucy would have for the money and everything been as compelling. Then at the end of the day to pick something that's as clever and ambitious as Dragonfly I have no idea how Lucy would have competed with that.

But I like Discovery in a way just because it opens up the greatness of the American mind and style, which is competition and creativity and entrepreneurship. Let people throw out any idea, project, and see what the community wants, and go from there. Whereas New Frontiers is more money, more oversight and insight, but it's much more regimented because you can't just propose any big mission. It's got to be the subsets of the big missions that the National Academy and Headquarters have prioritized.

JOHNSON: I just have one more question that I like to ask people at the end. Thinking about your role in Lucy and that mission and also with New Horizons, what would you say you're most proud of?

ANDREWS: There's an old saying. I don't know who said it. If you don't beat your own drum, you leave it to others. You might as well do it. For me personally, not an ego statement, but I'm proud of all the legwork and the leadership that I contributed to Lucy in the definition and the proposal and the concept study report to lead it and pull it all together and then get it selected.

We did that with a very very small team of people that were extremely talented, very very dedicated. I think a lot of people from the outside didn't think we could pull it off. I think that part of the tremendous joy in the final selection and then getting to go do Lucy is both the reward and the accomplishment that says, "Hey, look, we did what is extremely difficult to do, and a lot of people didn't think we could do it." That's really the important part.

I guess at the time I felt like, still do, we're the Seabiscuit of mission development teams. A lot of missions get proposed multiple times before they're selected. It is true a prior Lucy concept had been proposed. It was vastly different than what we did. In many ways we took Lucy as a brand-new fresh idea for the very first time all the way through selection, development, on time and schedule. Let's not forget that. We did everything we said we were going to do for cost, for schedule, for performance so far. That's a monumental achievement. Not only that, relative to how unfortunately a lot of other missions turn out, that is a huge, monumental achievement. That I'm very very very proud of.

JOHNSON: Throughout a pandemic on top of that.

ANDREWS: Little things like that, yes.

JOHNSON: Is there anything we haven't talked about on either one of those missions that you wanted to bring up or make sure was in this?

ANDREWS: No. I got to be honest. When we talked before and I didn't go back and replay anything, I don't remember everything we talked about, but I don't know if I have much more to add. But it's been a great pleasure. First of all it's been an honor in many ways. Been an honor to be able to even work on Lucy and do the things. It's been an honor to have you reach out and talk to me. I hope that in the future there are people that hear everything from everybody that's worked on Discovery and New Frontiers which are just truly amazing accomplishments. These are the pyramid projects of our ages. They're motivational because they hopefully—it's like we talked about earlier. It's what people are looking and paying attention to and helping them motivate to go into any STEM field, whether it's medicine, engineering, climate change, etc. All the important things that we need to have done.

JOHNSON: Thank you for talking to me again.

[End of interview]