Lindy Elkins-Tanton

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Erik M. Conway,
Interviewer

Q: My name's Erik Conway. I'm talking to Lindy Elkins-Tanton again for our second interview. It's July 7th in 2023, and we're on opposite ends of the country again and doing this by the glories of Webex.

So, Lindy, what risks did you foresee as your mission had been selected during development? This is kind of a question from memory. What did you think would happen, and then we'll talk about what actually did.

Elkins-Tanton: When we were selected in 2017, we were first selected for launch in 2023, and then right after selection, NASA said, "Well, could you save us money by launching in 2022? Is there a shorter trajectory, some other option?" We had this *beautiful* trajectory in 2022, and so after that study, we got reselected for that. At the same time, JPL decided that it was going to change its core flight software and that Europa Clipper was going to be the first to use it so they were going to write the new core flight software. We were going to benefit from that and run on that core flight software. So those were two big changes that took up a lot of time.

Actually, in 2017 we did a complete reschedule and rebudget of the entire project, and that's how we started. So it's only become clear to me in retrospect how kind of strange that was, actually, to spend the first six months after selection not actually working on it, but rebudgeting and rescheduling the whole thing.

The flight software change definitely felt like a big risk right from the beginning. That was a huge concern for the team, and we pushed back and we could not get traction. It would have taken going to the top of NASA to try to argue with JPL about not making that decision, and that's not the path that we decided to take. I wonder, in retrospect, if that would have been a smart thing to do [laughs], but it was early to put absolutely every card on the table and fight to the death, and there's a lot of trust involved.

So off we went with the new flight software plan and a new trajectory and one year less in development, but we felt fine with that because we'd actually originally pitched a launch in 2021, which now we realize that would have been super hard to do.

And then working with Maxar or what was then Loral, Space Systems Loral—their name has morphed over the years—really great partner right from the beginning, brought their A-Team, 100 percent engaged, transparent, helpful, all of that stuff that is so important, and that remained throughout, but the challenges of—as the project proceeds, there's always a new team getting involved. Now it's time for the composites team or now it's time for the ATLO team, whatever the different teams are. They're all new people, so having to reunite the JPL and Maxar teams constantly through the process to make sure everybody's speaking the same language and has the same expectations. We knew from the beginning that was a risk and something that we just worked on really actively. So those are two of the things that were on my mind at the time.

Then another thing that was on my mind at the time was a bunch of changes to the gamma ray and neutron spectrometer instrument that had not been in the proposal, but things that that team really wanted us to do. I forget what they were—David will remember the number—sixteen major changes that they convinced us were actually necessary. And in a sense—and this is something I'm sure you've heard over and over again, that there's not really any such thing as

heritage. You can never actually build exactly the same thing again. You have lessons learned that it's really clear you should not build that thing, and you have to make a change or the part isn't just made anymore or whatever it is. But this was a little bit more of a departure from heritage than we'd been hoping. So in 2017, those, I'm pretty sure, were the top things on my mind.

Q: First off, I want to talk a little bit about the flight software thing. I got a lecture from Janis Chodas about that as well. [laughter]

Elkins-Tanton: Yeah. I was wondering what she had to say. That's really interesting.

Q: So I was interviewing her because she's just retired, you know.

Elkins-Tanton: Yeah.

Q: So I'm kind of doing an exit interview. It was about the switch to the space-time architecture—

Elkins-Tanton: Exactly.

Q: —and how that ultimately impacted Clipper, which had much more money and time and resources than you would have.

Elkins-Tanton: Right.

Q: So clearly the plan at JPL's level was for you to ride along with that.

Elkins-Tanton: Right, and it's, of course, not how it happened.

Q: Yeah. As it turns out, you're going first, so you wound up being the developer. But tell me, did that affect you in terms of personnel? Because I know one of the things that ultimately winds up happening to you is you wind up with understaffing.

Elkins-Tanton: Yeah. Yeah, that was a part of it, but we were understaffed—just cards on the table, telling the transparent truth of my experience, and especially easier for me because I'm not a JPL employee—we were understaffed by 10 to 15 percent from day one of selection.

The thing I didn't talk about was DSOC [Deep Space Optical Communications.] I'll come back to the software. But DSOC, first of all, I want to make it super clear how much I support the idea of tech demos and how important it is to do this, how happy we are to be flying this, all absolutely true. Also true, it was super hard. These things are always supposed to be kind of plug-and-play, which is also a myth, like heritage, only that was *really* a myth for DSOC because it just wasn't developed at all. It wasn't a thing yet, and there was no plan, really, for like—there was no enclosed object that was going to be delivered. I started keeping track, and in the leadership meetings, every leadership meeting, at least 50 percent of the time was spent talking about DSOC, and so I started really pushing on JPL, "This is going to kill us, because

we're 10 to 15 percent understaffed, and the brains of our leadership are 50 percent on DSOC. They're going to miss stuff. Stuff is going to slip. We're going to have problems."

That ended up being a fight all the way to Headquarters. That was a very big deal. It took us a couple of years to get that fight done, and it included things like there was no agreement on, for example, an enclosure for DSOC. Was that the Psyche team's problem or was that DSOC's problem? It was that level of just, like it hadn't been planned. We actually had to redesign the major panels of the spacecraft chassis to accommodate DSOC. DSOC is more mass than all of our science instruments combined, more power than all of our science instruments combined. It's a very big lift for a Discovery-class mission, very big lift, and we were not supported in anywhere near the amount that would be needed to make that up. So that was a big distraction that I actually forgot about when you first asked me this question.

So we were understaffed, working on flight software along with the Clipper team. Finally had the argument all the way to Headquarters, and signed a new contract saying that JPL promised to keep Psyche fully staffed or else DSOC would be descoped. So that was the point, about two years in, when we finally became fully staffed, and that only lasted really until DSOC was delivered, and then we again went into deficit staffing. I know that JPL has a lot of staffing challenges, and I don't know what decisions I would have made were I in leadership. I mean, that's not an easy thing to figure out, to try to balance it, and I know that everybody was doing their best. Like, how do we make sure the right people are in the right places?

So, flight software. We had this idea that there was a central part of the core flight software that was needed both for Clipper and for Psyche, and I'm sure Jan talked about this. That part was being done, and I was tracking. We would get these progress reports, and the flight software was always behind. Then they would just reschedule so that their behindness was then

the schedule, and then they would fall behind *that* schedule. We realized that this was happening and that they were just having staffing problems, so then again we had to really focus attention and get a meeting about it and really make people change their practice. They brought in a new manager, and then better progress started happening, so that was really good.

But in the end, you'll get different stories from different people on the team about how much of a burden the flight software was, and David Oh, I think, has a very strong opinion about it, and Luke Dubord has kind of the opposite opinion about it, which is really interesting. From my point of view, I heard a lot of conversations about how the instrument teams had to change the way they operated their instruments and had to change the way their commanding happened in order to accommodate the flight software, and there were a whole bunch of things that we thought were going to be off-the-shelf because they were going to run the way the core flight software ran on the Mars rovers for the imagers, for example, and then when the flight software's completely changed, they had to do a bunch of work to change how the cameras would be operated that they weren't expecting. So there definitely were things for parts of the team where a lot of extra work was added. Then, of course, just the challenge of getting it done.

In the end, not to totally leap ahead, but one of the proximate causes of our launch slip was the guidance, navigation, and control software not being done. I had a conversation with Rob Manning. One of the issues was not just understaffing, but also not sufficient experience, but it's been a little while, I think, since JPL wrote a new core flight software. So I asked Rob, "Who are the top experts on the Lab about guidance, navigation, and control software who didn't look at our schedule and say, 'This will never work,' who never looked at the team and said, 'These people aren't experienced enough'?"

And he thought about it and he said, "Well, there's only a couple, and they're on Mars. They're on Mars projects. So they never looked at your thing and nobody with the knowledge, the requisite knowledge, could say, 'This isn't going to work.'"

So, to me, this is not—I don't mean this as—what's the word I'm looking for—just as some kind of condemnation. What it points out to me is the number of super specialists you need to do robotic space exploration is extreme, and I think we've got the highest concentration of them in the world at JPL, and there still aren't always enough, because it turns out that even if you think you're going to be able to figure it out, it really, really helps to have somebody who's done it before to point to you the things that you don't know yet. So that's a couple places where we had challenges.

Q: I remember someone saying that Goddard basically has one team to do anything and Ames has half of one. Usually at JPL there's three or four, but we have more projects than that now.

Elkins-Tanton: That's it. That's exactly it, and that's what we experienced. Frankly, I used to go and talk to Mike Watkins about staffing problems a lot, and he would push back and mainly he would say, "Yours is a small project and you don't deserve the A-Team." [laughs] And there weren't enough A-Teams to go around. I know that wasn't a nice thing to have him say to me, but I think he was doing his best under very tough circumstances. But isn't it a weird world where a billion-dollar project is a small project? It's just a weird world.

Q: Discovery didn't start that way. They started at 150 million. [laughs]

Elkins-Tanton: I know. Isn't that amazing? I know. And inflation doesn't make up that difference, does it.

Q: No, no, a lot of it is—I've written pretty extensively and will write more about all the additional rigor put into things after the Mars losses and so forth.

Elkins-Tanton: That's it.

Q: That's a big part of it.

Elkins-Tanton: That's really it. And, you know, Erik, you know this even better than I do, but I was watching the—there's videos that are available on YouTube about JPL and about those losses. One of them covers those Mars losses, and Mike Watkins and other people who I'm working with today are interviewed on there. A bunch of the things that were listed as lessons learned were exactly the same problems that we had on Psyche mission: not enough transparent communication, too much blame. This was my own personal thing that I thought I could bring, and bought to some extent, that I think we talked about before, was transparent communications and the welcoming of bad news, and especially making sure the junior people who know what's going on could speak up. Those are also Mars lessons learned. So 70 percent of the team absorbing that culture, it turns out, isn't enough. You need 100 percent of the team to feel that way.

Q: Yeah, I helped make those documentaries. We've been doing it a long time. When I watched the press conference for the IRB up in Tahoe via, again, the glories of universal Webex, I was kind of horrified that there was so much similarity.

Elkins-Tanton: So much similarity, wasn't there? Wasn't there so much similarity? And also it's not just that we've learned them before, but they're common sense. So a thing that I think about is one of the challenges I think that Laurie Leshin has at JPL right now is to try to lessen, to calm down the kind of cowboy hero culture, where you've got a bunch of A-Teams, but you've got your A+-Team, so basically all the projects are left a little hungry and suffering until they end up in their final tragic crisis, and then the A+ team comes in and saves the day.

   Part of what goes along with that kind of ethos is, I think, wanting to make things look good, but if you always want to make things look good, you'll never know the truth of it as you're traveling down the road before you're in crisis. So trying to make it so that people feel free to say, "Well, here are the places we're really struggling and we'd love your advice" before it becomes a crisis is so important.

Q: And very hard to sustain, it appears, because it requires leadership at all levels to believe in that.

Elkins-Tanton: Yes.

Q: Well, it's not clear to me that everyone in the line management is that way.

Elkins-Tanton: I think that's correct, and that's so well said, leadership at all levels, because I was very blessed, am very blessed, with the Psyche top leadership really believing in this cultural thing that I was trying to do, and most of our kind of middle leadership on the team has also really bought into that, but the part of the team where the GNC software team was silenced when they were complaining and shouting and worried, that part of the middle leadership hadn't really—it's not that they were against it, it's that I don't think they'd really absorbed what it means to listen carefully to everyone's voice and to carry the messages with high fidelity. So you're so right, what you just said. It has to be at all levels.

Q: So your GNC team, if I understood both the Psyche IRB and talking to David Oh correctly, had to have been kind of split between JPL and Maxar, because your attitude control system and GNC is a split system, right? It's partly built by Maxar and partly by JPL.

Elkins-Tanton: Yeah.

Q: So talk about where and on whose side, really, the failures in communications happened, because it's an interesting silence in the IRB study. It doesn't give me a timeline of how that happened and then finally became obvious to management.

Elkins-Tanton: Yes. Okay. I have got a timeline, if I can find it, a timeline that I made. So the specificity of on which side, I'm sure that you heard from David Oh on that, and that's important to listen to his story there. I mean, of course it is, but also because I really only know it from the JPL side, so if there were also Maxar people with high concern, I did not hear it.

Stand by for one second while I just look for this timeline, because our first big warning, I think, was in April of last year. It's just going to take me a second. I have it in a PowerPoint, and I'm not sure which PowerPoints, though. Hang on one sec.

Okay, that's not the ultimate one. I can find a more definitive timeline later on if that's interesting to you. Wait. I know one other place. It's a quick look. I'm just trying not to waste a lot of time, but I'm going to take one more quick look, because I think I know how to find it. Let's see.

So we had asked for a relatively small budget upper, and we were having our DPNC in Washington, D.C. on April 26th of 2022 for a little cost review. I forget what it was, some numbers of millions of dollars.

On the previous Friday, on April 22nd of 2022, was the day that I got a text message from Henry saying, "Can you talk?" Did we talk about this last time? I can't remember.

Q: No.

Elkins-Tanton: So when he texts me and says, "Can we talk?" it's never good news. He's not telling me about his new puppy. It's a bad thing. So I always call him up right away.

Our previous worst problem was we had this what could have been mission-ending issue at APL, where they were lifting the flight instrument into their thermal-vac, which is a vertical cylinder thermal-vac with the bottom that comes up. You know that kind? And they had built like a little corral of welded steel bars so that they could lay wires and pieces and clamp the instrument to it, and they had bars lying across the top of it, too, and they didn't check that the bars were pushed into the center of the disc when they were lifting it up. They didn't actually just

walk around it and make sure everything was going to fit in. They just started lifting it up. Some of the bars were leaning over and they hit the side of the cylinder and got pushed upward by the hydraulic until they broke, and there was this very, very loud bang, and then they stopped everything, so absolutely could have broken the flight instrument and the mission would have been over.

It turned out everything was fine, but we didn't know everything was fine when Henry sent me "Can we talk?" that time, and all he said to me when I got him on the phone was, "Are you sitting down?" which I knew was bad.

But this time at that April date in 2022, he just said—and it was Friday, remember—he said, "I'm setting up a Webex for 7:00 o'clock tonight for you and me and Bob Mase."

And I said, "Henry, this sounds bad."

And he just said, "It's bad. I'll talk to you then."

So we got on the Webex that evening at 7:00, and it turned out that was the day that Swati Mohan had reported back to Henry, after working with the GNC team, with the news that she saw no way that we would be ready for launch in 2022, in August of 2022. Because Henry has the right attitude about this kind of problem, he brought in all the experts immediately that same day, that same Friday morning and afternoon, and they talked all through all of her reasons for thinking this and the data that she had and the schedule that they had, and he agreed at that point that it was looking very, very unlikely that we were going to make it.

So Swati, of course, is a huge genuine hero in this story. She is the expert who came in and knew enough to know how to help that team understand where they really were, because they were never able to put together metrics that convinced their leadership that they were in as much trouble as they instinctually felt that they were. So we were able to look at them kind of

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falling behind their metrics and we kept hearing, "But they think they're going to catch up. We think it's okay." But it was not at all okay.

It turns out in the end that the GNC experts say you have to have a fully working testbed twelve months before launch. Twelve months ahead, almost literally, Henry and David Oh and I were in the offices of Maxar in Palo Alto trying to explain to them how urgent it was for them to finish the testbed for us. [laughs] So the new vice president didn't really understand that a planetary launch can't slip, and they had only one person who could do it, so it was a very brittle staffing plan. Twelve months ahead, not only did we not have a testbed that was working, we didn't even have a testbed yet, so none of us knew that that was basically right there, that it wasn't going to work, but Swati's the expert who came in and explained, "This is what you would have needed. You don't have it. We're really in trouble."

So that was Friday the 22nd, and two days later, flying to Washington, D.C. for the DPMC, thinking we were going in with this really good story, well, all we need is this relatively small upper and we're good to go, and suddenly we can't say that anymore. Suddenly we have this death threat. So over the weekend, we put together a tiger team and got everybody really on it to see if there was anything we'd be able to say more definitively by Tuesday, which there wasn't. So we went in and just said, "Look, there's a new threat," and that's all we could say. So that was the beginning of the timeline of understanding that we were going to have to slip.

It was really not until June that we had completely convinced ourselves within the team and convinced NASA Headquarters that we could not launch in 2022, and I'm sure that you have experienced this over and over, but for me, it was the first time understanding that when you have hundreds and hundreds and hundreds of people working as hard as they can, and, of course, through the pandemic with existential threat and missing their kids' soccer games because

they're going to launch in August, no matter how hard it's been to get through COVID and the hundreds of crises that we've already overcome and solved correctly and finished, actually taking that momentum and determination and saying, "Okay, now we have to admit we're not going to. We have to back off," that's huge emotionally and in terms of momentum management.

Then also, of course, in July that's when we got our Internal Review Board, chaired by Tom Young, in July, so just a year ago from when we're speaking, and then the message to the team is, "We're not stopping. We're supposed to keep going doing what we're doing, but we might be canceled." [laughs] So how do you handle that emotionally? Emotionally that's so hard on people, because they thought they were going to spend their last drop of blood and get us to the launchpad in August and then be done, go on to a new project, have a giant vacation, whatever it is. Now it's, "No, no, no, best case, you're going to keep doing the same thing you're doing, high stress for another year. Worst case, we're canceled." So that's a very difficult emotional roller coaster to take people on. So that's the timeline that we had last summer and what we were going through.

Then we had our continuation-termination review in October. I have to say I do think that the review board did an excellent job, and I think that their report was exactly right on, so that's a huge relief, because if I had felt like they were doing a bad job, the stress would have been really unmanageable. So it was good to feel like we're all on the same side trying to figure out the truth and how to fix it.

Q: What was your role during the review board process?

Elkins-Tanton: I had a bunch of different roles. So during the review board process, which started a year ago in July and just ended quite recently, as you know, with their final final report out at Headquarters, after their final checkup, after their final report out [laughs], so there were sort of three jobs through that whole process. One was work with the board, which I'll say more about what I was doing on that, another one was support the team to completely rebudget and reschedule the entire project with a new trajectory, new launch date that we had to find and then use for scheduling and budgeting. Normally the scheduling and budgeting process takes six months, and we were given six weeks to do the whole thing *and* keep the team working on the project so that we continue to make forward progress.

So it became three full-time jobs at once, and it was very hard on the leadership team at JPL. Matt Wallace came in, as you know, and I just don't have enough good things about Bob Mase and Henry Stone and Matt Wallace and, of course, the rest of the leadership team, but especially those three, because they had to—I mean, how do I even articulate this? They had to keep their internal stress internal, they had to swallow their pride and to be on their best behavior at all times in order to blend into a new seamless leadership team of three people, where there could have been a lot of hard feelings between them and a lot of nasty words and a lot of swallowed nasty words. And as far as I can tell, none of those things happened. I mean, they were consummate professionals, and because of that, we succeeded. I mean, it's amazing what they did. I'm very, very, very impressed by what they did.

So my job, when the review board first convened, I also had to tell them my entire story of my experience what happened with the mission, and my main message that I was trying to get across to Tom and the board was this was not something that had just happened over the last six months with a staffing shortage in GNC, that this was a story that went back to selection because

of all of these pressures on the project and understaffing all along. It was more like death by a thousand cuts. At one point, Tom Young was frustrated and he said several times to different people on the board, but he also said to me, "Why won't you just tell me what went wrong?"

And I said, "Tom, if I had a broken leg, I would point to the broken leg and say this is what went wrong, but it's much more systemic and subtle than this, and if we had understood what was going around all along, we would have been working on it. We need to do this all together and figure out the many reasons and threads." I think the complexity of it was fairly well communicated. Like you said, these are lessons learned that we learned before, but when they all happen at once, I think on a mission this size that's kind of the thing that caused us to fail in the end.

But as Laurie Leshin said so beautifully the other day and somebody said it to her—I forget who she said said it to her—that a successful mission is dodging a thousand bullets and an unsuccessful mission is dodging 999. So that is really an important thing, I think, for every single team and probably every team you ever talk to, that there's so much amazing good work done and so many giant problems located, solved, and overcome, and it's important not to forget that, all the amazing things done.

So, talking to the review board, constantly cheering on the team, and this was actually a place where it was helpful not to be a JPL employee, because I could say to everybody, "You really can go and report to the board, individually and in groups, your authentic experience. It's very important that you do this, and I have the assurance up to the top of JPL that you are welcomed and wanted to do that, and there's going to be no retribution, no matter what. That's not on anybody's mind. We need to know what you each really experienced." And I think that that really happened. The board said that some of their meetings were among the most emotional

they'd ever had in their careers, like people really let fly with their own frustration, rage, impotent striving, in the cases where they weren't able to make it, and the board heard all that, which I think is good, to get that really heard.

Then I was running culture surveys and helping to plan events for the team and pushing the leadership to have biweekly all-team meetings where everything would be reported to everybody on the team, and now we're down to once a week for that. So those kinds of things I was doing all the time, and then participating in the budgeting and scheduling as appropriate.

Q: You mentioned Swati earlier. How did she get added to your team? Was she brought in because there were already suspicions of things going wrong?

Elkins-Tanton: Yeah, yeah, because the team was increasingly loudly asking for help, and then at first the message just wasn't propagating upward. You and I both know how this telephone game goes, like I'm your direct report and I come to you, Erik, and I say, "I'm so upset about this. I just don't think it's working and I'm trying and trying and trying, and I can't solve it and I'm not meeting my metrics, and I think we're in trouble."

Then you take that and you report up to the next person, and you say something like, "There's some concern that there's some things we have to overcome." And then it gets a little bit less emotional as it comes up. So that's what had been happening. We just hadn't been really understanding.

The immediate management of the team had been asking for more proof that they weren't going to make it, which is really hard to do, and so we weren't hearing about that in time. But then as the noise got louder, then we pressed harder on the JPL management to give us better

leadership, because mainly the answer we'd gotten back for five years was, "We don't have anyone else to give you. You have to just deal with it." But then as you become the next one to launch, you get greater leverage on getting more experienced people. So from my point of view, at least, that's what happened.

Q: Presumably people rolled off some other mission and became available too.

Elkins-Tanton: Yeah, or were stolen from temporarily or loaned or something, yeah. It's a constant, constant fight.

Q: We have only about twenty minutes left to talk about the pandemic, so what phase of the project were you in when JPL starts shutting down in the middle of March of 2020?

Elkins-Tanton: Oh, my gosh. It was right before our critical design review. [laughs] It was right as we were getting ready to start really building. So it shut down in March, critical design review in May, so that is the first virtual review that NASA's ever done, so we spent a lot of time to try to figure out how to have a successful virtual review. I think it actually was pretty successful, success as judged by locating things that we need to work more on or areas of concern, feeling like we're actually digging in and finding problems. How long was JPL shut down totally? Like three months or something, absolutely shut? I can't remember the number.

Q: Yeah, the classified people started coming back in two weeks. It took the Laboratory management, a little longer than that to start figuring out how to bring everyone else back. So it

may be that Psyche wasn't the priority when that happened—Clipper was—in 2020. Well, 2020 was the first priority, and then Clipper.

Elkins-Tanton: Yeah, that's right. We were lower down.

Q: You were lower down, so you may not have come back for three months, but I don't know because I don't have all the timelines. I just know what they did to have to re-plan everything.

Elkins-Tanton: Unbelievable, unbelievable. Right. So whatever amount of time it was, I don't remember. Of course, we didn't have that in our schedule. Who did? And, of course, then I couldn't go either, and it was a long time before I could start coming back again, since it was absolutely critical people only.

The team was amazing. All the teams were amazing that managed to work through the pandemic, and we had a lot of problems. We had significant problems with all three of our science instruments, all three of them, and although the magnetometer, our significant problem with the magnetometer happened earlier when we had to step away from UCLA and find a new vendor.

By the way, two weeks ago I was in Copenhagen for the first time in my life, visiting them at their labs. I'd sort of met the team in the U.S. a bunch of times, but because of the pandemic, I never made it to Demark before just now, so that was nice.

So that magnetometer problem happened pre-COVID and then was really fixed. But both the gamma ray and neutron spectrometer and the imagers had very significant problems that required people to travel and work extra and have lots of extra meetings during the pandemic.

So, oh, man. Trying to help people who are working at home with kids, you know, trying to be flexible and all the things that JPL had to do, and then trying to keep all the subcontractors somehow feeling connected at a time when everyone's connections were gone, and a lot of our problems ended up being with contractors to the subcontractors, where they just didn't even feel the urgency. Like, they didn't see the vision. They didn't understand this was incredibly critical for them to keep going. They would have COVID shutdowns and then they would not respond or they would send in stuff that was subpar.

There were a *lot* of supply chain problems and problems where—something that I've become quite obsessed with is companies that lose the recipe. One example of this was General Dynamics with the SDSTs. They were having trouble building ours and Lucy's, to the point where we had to send a team in to meet with them in person right in the height of COVID when traveling was an unusual thing to do, but they were not doing it and we needed them to do it. Turned out there was just one person who really knew how to tune them, and she'd retired. So they had to somehow coax her out of retirement because she'd never managed to train anyone else in how to do this. Her name was Helen.

Then later we had the same problem at Lockheed. In the Bay Area, they were building a cryo cooler, and they just couldn't successfully build a cryo cooler, so we had set up a tiger team to basically teach them what was wrong with the cryo cooler, and it turned out their cryo cooler expert had retired and *her* name was Helen. So my son and husband and I developed this idea that there's a least reduceable unit of technological knowledge called the Helen, and that the complexity of your project can be measured in Helens, how many Helens is your project, how many individual people's super expertise is required to get this done.

So all these things are so expensive, as you well know, and the cost-plus contract where they didn't have the personnel who knew how to do it anymore and they couldn't build it right, so we have to pay them another million dollars to build it right, that just makes me crazy. I would say to the team, because, you know, they come from a different business background, "Shouldn't they eat some of these costs? Can't we get them to put a little skin in the game?"

And the team would say to me, "Lindy, you can have the ethical high ground or you can have a space mission. You choose." [laughter]

So that's COVID. That's kind of COVID in a nutshell.

Q: So a lot of your contracts were not fixed-price, then.

Elkins-Tanton: Just Maxar. There might have been some other ones, but the one I really know about that was fixed-price was Maxar. Amazing. Yeah, the big one.

Q: The big expensive one, about which you were incredibly lucky, it sounds like.

Elkins-Tanton: Yes. All of that success depends upon the willingness of the people involved to keep talking and negotiating, so what when we had a request that went beyond the contract, we could negotiate a contract out on and just do it professionally and keep marching forward. So that's worked out, and it did work out really well. There were definitely rough spots, but on the whole, I thought that was quite successful.

Q: Still in COVID era, and maybe this is an impressionistic question, but how did the work get reorganized in 2020 and 2021 to keep the project moving forward?

Elkins-Tanton: Wow. I don't have a crisp answer for that. There was a lot of conversation one-on-one and in small groups about who needs to be together and who needs to come in and how do we organize this so that the people who need to come in can come in. We discovered things like a lot of testbed stuff can happen from home just as well.

In fact, an interesting point that the testbed team has pointed out to us is that one of the things that needs to happen when teams are working together trying to problem-solve on the testbed is they need to be able to all look at the same monitor, and that's actually easier to do on Webex than it is in person, so they found actually that working from home was better for a lot of the testbed teams, more efficient, and more effective collaboration, which I thought was quite interesting.

Q: Fortunately, the testbeds are something you can mostly do remotely.

Elkins-Tanton: That's right.

Q: There still has to be someone present onsite to make sure they're running.

Elkins-Tanton: Yes. Oh, my gosh, they told me great stories, that team. That was one of the teams that I would make sure to visit when I was allowed back on Lab. The minute I was allowed back on Lab, whenever that was, two years ago and plus, I started coming more or less

every other week, and it's only really this spring that I've taken little bit longer breaks from JPL, so it's been a tremendous amount of travel for me and patient support from my family while I was gone more or less every other week. So I'd make sure to stop in at testbeds from time to time, and they would tell me these great stories about problem-solving when there was almost nobody on Lab and they needed some piece of hardware that they didn't have and they didn't know where it was, and the person who knew where it was wasn't there, and the thing was locked and they had to make it up. They just would. They were, like, cooking by the seat of their pants, making it work, and I loved the way a couple of the young testbed people told me these stories with just big smiles on their faces, like they had loved having the autonomy and the responsibility and the ability to get stuff done. It was kind of beautiful.

Q: But an environment that didn't last. After all, they had a lot more freedom when there was no one there to watch them.

Elkins-Tanton: There was no one there to help them, yeah.

Q: And help them. That's another way of putting it. Exactly. It required more initiative on their part.

Elkins-Tanton: Yeah, that's right. That's right. And I think that's really what everybody wants in their job, and this is what studies say. People think that it's the money or the vacation, but it's the autonomy. People want the ability to make decisions for themselves.

Q: So how do you think—you'll probably want to give a quantitative answer, but can't—how do you think the pandemic affected Psyche's progress as opposed to the other issues we've already talked about, the understaffing, the flight software, etc.?

Elkins-Tanton: You know who's got the crisp answer for that is Bob Mase and Brian Johnson, our business manager, an amazing guy who has shifted to another project now, and we have another great guy, but Brian was incredible during this whole process. This is, I think, sort of an unsung hero a lot of times, is the business manager, super smart, innovative thinker, Brian is, and he thought of ways to look at our metrics and create a new matrix to help us understand better the change in the effectiveness of our workforce pre and post COVID. Part of what we used were the earned-value accounting metrics, which were helpful and they showed us the reduction in efficacy after COVID really hit, and that is quantifiable in terms of dollars and people and schedule. So we did quantify all of that. And there were more things that he did, which I can't accurately describe at this moment that helped us understand individual areas, where was COVID having the biggest effect. So we were actually able to come up with a number, like "This is the dollars that it cost us through this process," kind of separate, as we say, from the other challenges.

     I know that every project has challenges and it's interesting to me that I've heard different opinions from different experienced people at JPL about whether, for example, the problems we had with each of our science instruments was kind of out of family for a mission of our size or not. It seems like we did have more hardware problems than the average, so that didn't help us either.

Q: It sounds like because you were talking about, for example, the "Helen problem," that key people had retired. One of the things that happened early in COVID was a lot of people retired.

Elkins-Tanton: Yes, that's right.

Q: A lot of people decided they just weren't going to try to continue functioning in that environment.

Elkins-Tanton: Yes, exactly.

Q: So one point of curiosity is whether that was a significant influence that probably can never be discerned from the statistics that you've collected.

Elkins-Tanton: You know, that's interesting. It should be measurable, though, because we know someone has got team-turnover numbers, how many people left over time. That's something that the business office could find, if they don't have it already.

Q: Okay. Interesting. It sounds like I really should talk to your business manager.

Elkins-Tanton: Yes.

Q: I do have this outstanding interest in what the productivity impact of the pandemic was. I hope that someone in Lab management does, too, someone Leslie Livesay's office maybe, or maybe Dave's. I don't know which side it would be.

Elkins-Tanton: I definitely recommend Brian Johnson. Where did he move to? Was it Clipper or Mars? I don't know. He's very, very good, though, and obviously you can find him. He put a lot of thought into that.

Q: Okay. Since we're running out of time, next question, summarize for me what's been done to overcome your hurdles to get ready for your October launch date of 2023.

Elkins-Tanton: First of all, we really got fully staffed, which is awesome, and we got those ten to twelve significant leaders that the IRB had needed us to get. We got them almost right away. As you know, we were working with the IRB hand-in-hand, and they were talking to us about their conclusions day by day, so day by day we were reacting to and trying to take their advice and fix things, so we've got those leaders into the team almost immediately that the IRB said we needed them, like long before they made their report. So by the time they made their report, we had managed to react to the majority of their findings, because we really were able to get that head start, which is really great because that's what we needed. We weren't going to wait five months to hear their conclusions and then react to them. It doesn't make any sense. So that was very key. We got those people right away.

Then we did work really hard on changing our metrics, and this is something Bob Mase did a lot of work on, to try to have better real-time information, more accurate and more

complete, and divide the information. For example, the PFR burn-down, how many of them are actually taken care of, and how many of them are in signature, how many of them are held up by individual people or where are they by subsystem or by line organization, so that kind of data really helped us to push things along. Then having some kind of specialized experts come in and vet them all and see if there were special threats hidden in the pile, that kind of thing.

Then, of course, a big reorg got the team itself into this IPSO (Integrated Psyche Systems Organization) organization, and Jennifer Trosper coming in to lead that, and Jennifer Maxwell stepping up in systems engineering, that kind of reorg was really, really helpful to the team to make people better communicate to people exactly what the expectations and the metrics were.

Then the next step for us has been I guess what's traditionally a little bit of a stumble or a challenge, is the development-to-operations transfer. So we've been working that really hard. I appreciate the fact that that transfer has also required us to work more on team culture, because an awful lot of effectiveness of humans is feeling like you're supported and valued and respected, and that takes certain behavioral attributes [laughs], the ways that you don't say things or ways that you do say things. So working on all of that and helping people really feel valued and coaching people when they needed coaching.

All of those things, they tend to be undervalued in tech organizations. It's something that I witnessed a lot at MIT also. I find that the further the distance intellectually between culture and behavior, like cultural norms, and the actual work that you're doing, the harder it is to get people to value cultural norms. If you're doing something like theatre, where cultural norms are very closely related to actual acting practice, then people are much more receptive to cultural norms. But when it's far away, like, "No, I'm building an imager. I don't actually care about how people say things," unfortunately, it does really matter, though. So being able to bring a little bit

more of that to the table in the dev-to-ops transition has helped us. Even though it's quite time-consuming, it's proven to be critical.

Q: You mentioned IPSO. What is that?

Elkins-Tanton: So it's the new integrated development organization that they put together to remove some of the silos that had existed in the team. It's an acronym that Matt Wallace made up and it stands for Integrated Psyche Systems Organization.

Q: I see. Okay. Something Matt knows. All right. The siloing of the pandemic was one of the things that I think the IRB hinted at or maybe said outright.

Elkins-Tanton: Yeah.

Q: And was part of, I suspect, your troubles, as it was for Clipper and others.

Elkins-Tanton: I think very parallel between Clipper and ourselves. Tracy Drain is a particular friend of mine, and she and I get together for long philosophical chats about teams and things like that, and I think the challenges that the two projects have had have been parallel in a lot of places.

Q: Since we're almost out of time, my last question is usually what haven't we talked about but should have, which is another way of saying what didn't I ask because I didn't know to ask about it?

Elkins-Tanton: Let's see. So I think I've wrapped into my answers to you most of the things that I thought we were very important and maybe either highly resonant with other experiences or maybe a little bit different, so therefore interesting. One thing that I can't remember—sorry, I can't remember if we talked about this last time, our student collaborations projects.

Q: You mentioned it, and I wanted to follow up on it, so go ahead.

Elkins-Tanton: Just that this was one of the things that Thomas [Zurbuchen] had asked us to do, was re-propose them, and we had a much more audacious plan, something that was much more what we wanted to do anyway, and so it's kind of unusually broad. We have a nice paper we published about it, and if you're interested in more, maybe talking to Cassie Bowman, who leads our student collaborations, might be good, just because there's nice ideas in there that other projects might appreciate also.

Other than that, just to say I'm really grateful to how honestly and hard JPL is working to make up for the deficits that have existed on this project, and I know that it's hard on Leslie and hard on Laurie and it's hard on all of us, but it's really important to get it right, and I'm really, really glad for the communications and the transparency and the big effort. I think it's wholehearted, and that's good to say out loud.

Q: Thank you for that. There's a period of drift in 2021 and 2022 that I need to investigate at our leadership level, but I feel like must have impacted you, too, but it started—

Elkins-Tanton: Unbelievable.

Q: It started to feel at JPL like there would never be a return, and yet it was obvious that something had to happen.

Elkins-Tanton: That's right.

Q: I don't understand any of that, but I have to talk to people about it. As I said, I think it affected all the projects.

Elkins-Tanton: Yes.

Q: What, from your perspective, was happening, or was the problem that nothing was?

Elkins-Tanton: I felt like nothing was happening, and I had, in general, a really difficult time with Mike Watkins' leadership. Alas, I'm not the only one there. But I think that was a time that in particular called for very active, visual, optimistic, constant leadership more than ever, and I think that JPL and other places did not have that during the pandemic. It takes a special kind of leader to step up at those moments.

Q: Nothing seemed to change until Laurie was chosen as Mike's successor.

Elkins-Tanton: That's right.

Q: That surprised me a bit, not because I—I assumed things would change, but that it took that—I don't know.

Elkins-Tanton: Yeah, I know. [laughter] I wish you luck in digging through that, because I think that's a very, very interesting problem. You know, Mark Simons, I think, has interesting things to say about that.

Q: Okay. He would be interesting to talk to too.

Elkins-Tanton: Yeah.

Q: Fantastic. I'm out of time.

Elkins-Tanton: Thank you, Erik.

Q: Thank you for your time. You'll see this transcript in a couple of weeks. I'll send it off today.

Elkins-Tanton: Thank you very, very much and for all the work that you do. Take care.

Q: Thanks and good luck with your launch in just a few months now.

Elkins-Tanton: Fingers crossed!

[End of interview]