NASA Johnson Space Center Oral History Project
Edited Oral History Transcript

Eugene R. Schwanbeck
Interviewed by Jennifer Ross-Nazzal
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Ross-Nazzal: Today is July 6th, 2021. This interview with Eugene Schwanbeck is being conducted for the JSC Oral History Project in Houston, Texas. The interviewer is Jennifer Ross-Nazzal, assisted by Sandra Johnson. Thanks again for coming by. We appreciate it.

Schwanbeck: Thank you very much for having me.

Ross-Nazzal: I wanted to ask you. How did you come to be the Project Manager for the ISS [International Space Station] Li-Ion [Lithium-Ion] Battery Project?

Schwanbeck: It's something that I guess I just fell into. Believe it or not, I was picking up my children at the JSC day care one day, and I ran into the ISS Program Manager, who was also picking up his children at the same time, and he said, "Hey, I just started a new office. It's called the Development Project Office. You need to go talk to this manager of that office. I think you'll be a good fit." I didn't know what he was talking about at the time, but I did. I ended up talking to the new manager of the new office that he had just created, and they were looking for somebody to manage this Lithium-Ion Battery Project, and the rest is history. That's literally how I fell into it, was picking up my kids at day care.

Ross-Nazzal: Oh, that's funny. This was around 2012?

SCHWANBECK: Yes. The project had started already doing some preliminary testing, and I guess you could call it maybe selection of potential candidate products to use inside the battery. That started as early as 2009, where—what do they call it—the preliminary risk and feasibility studies. That had gone on for a little while and then I joined as the NASA Project Manager around 2012.

ROSS-NAZZAL: How did you get up to speed on what was happening with the project?

SCHWANBECK: There was a lot of data that had already existed at the time. Most of it was already online on internal NASA servers. The individual who was fulfilling the project manager role had left abruptly, but he left behind buckets and buckets of data, and there were regularly scheduled meetings that I was able to attend and get to know the team and just jump right in. You learn by doing. It didn't take too long, maybe four to six months, before I thought I could really be productive.

But in the beginning because of the scale, the value, and the visibility of the project there were many sleepless nights. I didn't understand how NASA could trust me with hundreds of millions of dollars to make something that had to function in space unassisted for 10 years at a time. Getting to know the team and the people involved, specifically the Boeing project management and technical team as well as NASA and their subcontractors too—Boeing even had a few subcontractors that were extremely key and valuable in making this project successful. Once I knew the people that were involved, I could trust them; I knew that they were the best at what they did, I could start sleeping again.

ROSS-NAZZAL: How long did that take, you said four to six months?

SCHWANBECK: It was a couple months, yes, initially. It took a while. Because I needed to put my arms around the project and understand what it is we had to do, when we had to do it. As soon as we got that figured out and had a plan to do that, the ISS Program came back to us and said, "Hey, you know those things you're working on? We actually need those earlier. Everything you just sorted out, do it again, but deliver it here." And we did. Spoiler alert. We delivered early and saved the program a lot of money in the process by being able to close out the project early. But that wasn't just because of our fancy schedules, it was again because of the people involved that made it happen, specifically the Boeing team.

ROSS-NAZZAL: I wanted to ask. Those batteries that were on Station at that point, the nickel-hydrogen batteries, were really nearing the end of their life span at that point. Did you have a sense of urgency when you took over, like boy, we really have to get this thing up and running, and things have got to run smoothly?

SCHWANBECK: It's a great question, thank you for asking that. There were predicts that the cells in these original nickel-hydrogen batteries would last for approximately six years. But that was a very conservative estimate, because as history has shown, they worked for a lot longer than six years.

The sense of urgency for us to complete and launch the lithium-ion batteries wasn't driven so much by the aging nickel-hydrogen but more so by our ride to space. When the

Japanese were going to launch the HTV, the H-II Transfer Vehicle, when that mission was scheduled to happen, we were the cargo, so we needed to be ready to get on that ride to space, which happened sooner than the nickel-hydrogen batteries were actually going to be nonfunctional essentially. Every year they do what they call a capacity check on all the batteries on all the channels, and we were monitoring it very closely year after year, as we were getting closer through our development process and our build process and our launch, which channels are aging the most, which ones would benefit from the replacement first versus last, and we came up with the remove and replace sequence, what we call R&R, to address the oldest. Obviously, you would say replace the oldest ones first.

But those weren't the most heavily loaded channels. Some of the more heavily loaded channels were degrading faster because of the way they were being used. They babied the nickel-hydrogen batteries I think the last couple years of their life, whereas the first few years they just use them, it's a battery, it charges in the Sun, discharges at night, nothing to it. But towards the end of their life they got a lot more conservative in what they would do to them to try to eke out every last drop of performance. We replaced every one of them before they were done. They could have gone on. That again wasn't driving the development, it was more the ride to space.

ROSS-NAZZAL: How did you get to know the team once you came on board as project manager? You have folks at Glenn [Research Center, [Cleveland, Ohio], you have folks at Boeing and other places as well. How'd you get to know all those people?

SCHWANBECK: All over. Yes. We had a weekly cadence of reviews and meetings. Very shortly after I joined the project my Boeing counterpart Tom [Thomas H.] Franssen, who you may talk to soon, him and I set up daily conversations. We would talk once a day every day of the week, sometimes on weekends, and when we'd travel, we'd have to hang out with each other. We were joined at the hip. I had my NASA technical lead out at Glenn you mentioned, Penni [J.] Dalton, who hopefully you'll get to talk to soon. Even though she was at Glenn, she was virtually with us all the time. Every time there was a meeting, she'd be online. Every time there was a review she would travel. She got more frequent flier miles than anybody I know, I'm sure.

But the team was fairly spread out around the country. Most of the technical expertise was from Aerojet Rocketdyne, which was located in Canoga Park, California. Everybody's on a different time zone. You got your west coast folks, you got your Central folks, you got your Ohio folks. Then any time you were talking launch or hardware storage you had KSC [Kennedy Space Center, Florida] involved, because those were the people that would ship our hardware around the country, around the world. We had to be mindful of the different time zones. But we had a really good, diverse team, and a lot of large reviews.

For the battery system in itself SRR [System Requirements Review], PDR, CDR, the Preliminary Design Review, Critical Design Review, things like that. But then each component of the battery system, we had reviews for that as well. So that gave us a lot of opportunities to get people together and share knowledge and get to know each other. You trust the people that you work with after you spend every waking moment of the day with them.

ROSS-NAZZAL: It's amazing spending days with people and talking to them every day.

SCHWANBECK: Our audits, we'll talk about that later. We'll talk about the trips to Japan.

ROSS-NAZZAL: Yes. I've got that on there.

SCHWANBECK: Our days, nights, and weekends we all had to spend together because we were the only ones who spoke English.

ROSS-NAZZAL: That definitely builds teamwork for sure.

SCHWANBECK: Yes, it does.

ROSS-NAZZAL: You look forward to spending time with someone you can actually communicate with.

SCHWANBECK: Yes, absolutely.

ROSS-NAZZAL: I was curious. There were other lithium-ion batteries that were being used in space. There was a Li-Ion pistol grip tool. There was an EVA [extravehicular activity] battery. There were some other uses of lithium-ion on board Station. Did that influence the battery that you guys were going to send up at that point?

SCHWANBECK: It may have influenced it from a technology perspective, but it was somewhat of a struggle to overcome to convince people that the batteries that you had mentioned used a small format cell, what they call an 18650, both of those tools. Our battery used a large format lithium-ion cell, the LSE134-101, made by GS Yuasa [Corporation]. The world at that time was hesitant to accept a large format lithium-ion cell. Even though they agreed the technology couldn't be beat for the size of the battery, the weight of it, and how much energy it can store, there were concerns about safety, and if there was a hazard if it would be propagated, if a battery of this size could contain a failure. Those were uncharted waters so to speak, whereas the 18650 which was used in the PGT [pistol grip tool] and the SAFER [Simplified Aid For EVA Rescue] and other EMU [extravehicular mobility unit] applications had been more proven. So yes, an influence, but also a struggle to do something that had never been done before.

ROSS-NAZZAL: Would you talk about the impact of the lithium-ion battery fire on the [Boeing] 787 and what impact that had on your project?

SCHWANBECK: Oh boy. Yes. That was I guess unfortunate but timely because it allowed—well, actually it created a lot more attention than we had expected. Lithium-ion wasn't new by any means back in the early 2010s, people had been using it for 10, 15, 20 years prior. But the amount of media coverage that that Boeing 787 fire received, it grounded the whole fleet for many months, was very unexpected.

The Boeing Company, who had worked on that battery—and I know you're going to talk to some folks at Boeing who were involved in that or have already—they were wearing two hats. One day they're working on our new design and the next day they're flying to Seattle [Washington] to go do an investigation for a battery that just failed. How fortunate were we to have the experience of people that were so close to solving a problem that we hadn't had, but as a result were making the product that we were developing that much better?

We had after the Boeing 787 fire two independent audits of the ISS Lithium-Ion Battery Project, one commissioned by Boeing, the prime contractor for the development, and one commissioned by NASA. We used the Aerospace Company to go through and look at all of our documentation, everything that we had created to date, everything we were planning to make, to see if for some reason we had missed something. Likewise, the Boeing investigation team did the same thing with all the new knowledge that they had just gained from going through the failure scenario and making modifications to their battery to make sure it didn't happen again on another airplane.

As a result, we did have one notable design change, the insertion of some radiant barriers between cells. It was something that was thought to be necessary. Only at a high state of charge would a cell have the potential to, if it failed, propagate to its neighboring cell or cell pack. By inserting these radiant barriers between the groupings of the cells, it made the design that much more robust, that much more tolerant to maybe a self-sustaining thermal event known as thermal runaway in the business.

ROSS-NAZZAL: Those are pretty scary. We've been out to White Sands [Test Facility, New Mexico] and seen what happens just to a little laptop, they've got all those out there.

SCHWANBECK: We took our cells initially in that risk mitigation period out to White Sands and shot them multiple times with large projectiles to see what would happen, different angles, top-down, side, oblique, whatever, and we put them in groups and single and tried to determine what do we need to do to make sure this doesn't happen on orbit, because we can't afford to have one of these batteries, number one, not function, but number two, cause a problem for another system on the Space Station. That was a fun experience.

ROSS-NAZZAL: Yes, I bet. Were you out there for some of the tests?

SCHWANBECK: Yes, I actually was. In the beginning of the project, like I mentioned, we did individual cell testing to help us determine which parameters we needed to control in the design of the battery so that we would never approach them or exceed them to get into uncharted territory. Then later at the end of the project the NESC, the NASA Engineering and Safety Center, did a full-scale battery test, not populated with all lithium-ion cells, mostly mass simulators, but a good grouping of real lithium-ion cells, and they attempted to trigger a thermal runaway event to see if the design was robust enough to prevent that. It did. It didn't go up in flames. The cell that was triggered obviously did, but it didn't propagate throughout the rest of the box, which was very comforting that we had a pretty good design.

ROSS-NAZZAL: Yes, I think Tim [Timothy R. North] said that the guys were pretty disappointed. They wanted to see fireworks.

SCHWANBECK: They did, it was very anticlimactic. I was down there with them in the bunker. When they set this thing off, we all had to go underground in this concrete-reinforced room just because we didn't know what was going to happen. A little bit of the electrolyte leaked out the side, and that was pretty much it.

ROSS-NAZZAL: You must have been relieved though.

SCHWANBECK: Yes, I was. I wasn't that surprised. They were proving something that we had designed into it and thought we knew, although we never tested it ourselves at that scale. I think the disappointment in that test team ultimately made them conclude that their test conditions might not have been right, so that they reserved the opportunity to test again at a future date, which they haven't done to my knowledge. But it is what it is.

ROSS-NAZZAL: What impact did these reviews and this decision to insert those radiant barriers have on your schedule and then also your budget? As program manager I'm guessing you didn't have unlimited funds, so what happened?

SCHWANBECK: We were again fortunate enough to have a great team. The Boeing team had some expertise in thermal blanket material for engine bell housings from some of the work they do out in California. Once it was decided that we needed to do something, the design solution was a flexible fabric-like material that had some special layers inside of it which I can't describe in detail.

ROSS-NAZZAL: That's okay.

SCHWANBECK: But suffice it to say they did the job because it was a proven method of preventing radiant heat from being transmitted because of its original intent on rocket engines.

Boeing had a design solution relatively quickly so there wasn't much of a schedule hit for that. They identified a manufacturer near Minneapolis, Minnesota, if I remember correctly that made similar material for the military, and they were able to get a contract in place and have them manufacture all the radiant barriers that we would need for all of our batteries in record time.

The only question then was how much is this going to cost. The ISS Program has a certain amount of flexibility for the unknown and we wrote a change request describing what we wanted to do, the cost impact, which was, in my opinion, relatively low for what we were going to get, more peace of mind, a more robust design, more assurance that there wouldn't be a failure on orbit, and they approved it. So we got the additional funding.

As I mentioned earlier, by finishing the project early we saved the program a lot of money by closing out the contract sooner than we expected. If I recall correctly the savings was seven times the cost of this modification.

ROSS-NAZZAL: Wow. That's huge.

SCHWANBECK: Yes. It was a good investment.

ROSS-NAZZAL: What did Mike [Michael T.] Suffredini think of what was happening? Do you recall any discussions that you had with the [ISS] Program Manager? Were there any debates about the decision to move forward with this new radiant barrier amongst other subsystem managers and other folks?

SCHWANBECK: No. For whatever reason he, the guy who handpicked me to lead the project, trusted our judgment. When we came to him with a recommendation there wasn't a lot of back-and-forth. He knew what we were trying to do, make this product better, make it so that there wouldn't be any issues. There was never a question of not funding that change request. It was almost, "Is that all you need? What else can you do?"

We thought this was enough. For whatever reason, either good design principles or dumb luck, we had a really good robust design to begin with. The lithium-ion battery was constrained to fit in the same footprint of the nickel-hydrogen battery. It physically had to plug into the exact same spot, the same dimensions. The volume inside the box, for lack of a better word, what we call the orbital replacement unit, the ORU, was fairly full with the nickel-hydrogen cells. But because the lithium-ion technology is a little bit more energy-dense, there was more real estate inside to play with, and so that allowed us to position the cells in such a way that there was spacing between them. That proved to be one of the most important things you can do for resistance to propagating a failure, is having physical distance, space between the cells and the cell packs and the cell groups. We had 3 groups of 10, so 30 cells total inside the battery, and they weren't all touching each other, there was space in between them, and that was probably the best thing we could have ever done. It was naturally that way from the beginning for thermal reasons to keep them cooked and cooled at the same rate, but also because we had the real estate to do that. The nickel-hydrogen design, they didn't have that. Everything was pretty well packed in there.

ROSS-NAZZAL: I've read that you briefed congressional staffers and center directors and a whole variety of folks.

SCHWANBECK: Oh boy.

ROSS-NAZZAL: I wonder if you would talk about that and what some of the issues were that you were briefing these high-level folks on.

SCHWANBECK: I was on vacation in Disney World in Orlando, [Florida] and I got a call from a congressional staffer one time, kind of unexpected. I shouldn't answer my cell phone on vacation, right?

ROSS-NAZZAL: Right.

SCHWANBECK: But apparently early on in the project when we had 8 to 10 different providers of lithium-ion cell technologies, everybody was happy because they thought they might get a piece of the final contract. But as we tested and downselected and narrowed down which product would be the best for our particular application, looking at the qualification data from the manufacturer and some of the testing that we did ourselves, one company in California, my opinion, thought that they were guaranteed the work because of their connections maybe, I don't know. It turns out though that there was another product that we were able to acquire from Georgia—the state Georgia—that seemed to be a better fit for what we were doing.

We got a lot more information from that provider in the testing that they had done internally in their company to develop the product, the lithium-ion cell is what I'm talking about, and they compared very favorably with the testing that we were able to do here at Johnson Space

Center, also out at White Sands. But with this other company in California there were some gaps in our knowledge of the product and the history. The data just never materialized.

When we didn't pick that company, they approached their congressperson and that person just happened to be the Speaker of the House Nancy Pelosi, and she reached out to the NASA Administrator and basically said, "What are you guys doing? Why are you not picking this company in my district to build the next lithium-ion battery for the International Space Station?" The way Penni describes it is better than I do but she always says these are the largest lithium-ion batteries ever utilized for a human-rated spacecraft. That's true. When NASA got the call for why you picked this company over that company, I got the call from a congressional staffer saying, "Why didn't you?" It all rolls downhill.

Through the cell selection process, we were able to show very clearly why one product fit our application better than another product. The actual down select was not something that NASA did, it was not something that Boeing did, it was something that Boeing's subcontractor did, Aerojet Rocketdyne in California, with both NASA and Boeing oversight. It was very thoroughly documented why that decision was made. We sent a huge data packet up to [NASA] Headquarters [Washington, DC] and they shared it with Congress and nobody ever said a thing after that. Done.

ROSS-NAZZAL: Oh. Right?

SCHWANBECK: Yes. It was all scary for a minute there. But at the end being thorough and the documentation that the team had put together all along the way. It's not that they had to go generate this, they just had to go get it off the shelf, because they knew somebody might question why we're making the decisions we're making today, and so they took all the necessary steps through the process. It was fairly easy to fight that off. But it was my first experience with a congressional inquiry.

ROSS-NAZZAL: Kind of a big one too, being the Speaker of the House.

SCHWANBECK: I guess now she's back in the House. This was before. The first time Nancy was Speaker of the House.

ROSS-NAZZAL: Oh, that's right, yes.

SCHWANBECK: Then she went away for a little while and now she's back. Yes.

ROSS-NAZZAL: Very interesting. Too bad you didn't get a chance to go up and talk to her in person.

SCHWANBECK: Yes, that would have been fun. It would have been an experience.

ROSS-NAZZAL: Might be a little nerve-racking. We talked about the tests out at White Sands, and you talked about the test for the down select of these various vendors that you had to choose from. Do you have any interesting anecdotes or memories of those times? Or were you back here at JSC just keeping an eye on things when that was happening?

SCHWANBECK: One of the tests in particular I recall. I think this wasn't our cell test but more the NESC ORU test. The schedule wasn't going according to plan. I had showed up several days after the team, the people who do all the work. I come in at the end, I watch the show, and then I go home. But I showed up several days after they were there to get everything set up for the big show, and they still weren't ready. One problem after another. I'm sure Tim has told you some experiences about this. But the thing that I remember was jumping in the thermal chamber with one of the technicians and physically wiring up sensors on the cells just to get the work done.

I know I wear the project manager hat. But I'm not immune to physical labor or helping out anybody who needs help. It's one thing I've always told my team, is that I'm never going to ask you to do something I'm not willing to do myself. Which unfortunately for them is not a lot.

I jumped in the chamber and I'm wiring stuff up and we're checking out signals on the outside, and somebody's telling us that the resistance is still too high, these sensors shouldn't have that much resistance in the lines. We know they have to feed through a port in the vacuum chamber to go from the inside to the outside, and everybody's focusing on those connections to make the transition, and every one of them checks out just fine.

Then one of the gentlemen we're working with notices that all the signals before they go into the computer to measure them, they pass through some relays which are physical metal contact relays. These have been out, outside in the high desert I guess, White Sands, for some time. It maybe corroded a little bit, as we've learned. Some of them were good, some of them were high resistance contacts. Everybody who's worked on an engine before, gapping points or whatever, knows that you just file them down and clean it off. Out here in the middle of the desert there's no hardware store around the corner to go to to get all the tools you could ever want.

We're scratching our heads; how can we file these points down or get the corrosion off the relay surfaces. I remembered staying at the hotel the night before and I had the little sewing kit that for whatever reason I threw in my bag, and it had a fingernail file in it and I handed it to one of the techs and I said, "Will this help?" He said, "Oh my gosh, that's exactly what we need," and he went in there and he filed the points down on these relays, started closing them again, everything checked out, we had the proper resistance, we could actually execute the test now. All because of a little fingernail file that I kept from the bathroom kit of the hotel.

ROSS-NAZZAL: That's funny. Did you keep that as a memento for yourself?

SCHWANBECK: I think I may have kept it in my bag for a while after that, but I don't have that bag anymore. I don't know where it went. It might be in the Smithsonian [Institution].

ROSS-NAZZAL: That's what I was just going to say. You've got to contact them and label it. They have first right of refusal.

SCHWANBECK: They do, they do.

ROSS-NAZZAL: Talk if you would about the manufacturing of the batteries and what your role was as project manager overseeing all of that as that occurred, once you guys finally had all these reviews done and were able to move forward.

SCHWANBECK: The manufacturing of the batteries was fairly straightforward. It was the manufacturing of the cells that went into the batteries that we were most concerned about because there were a lot of things that you can monitor externally. We had redundant voltage sensors and redundant temperature sensors that are voted on by different sources, and that's computer-controlled while you're operating the battery to keep it safe. But there are things that if there's a latent defect baked into a cell when it's manufactured, the only thing you can do is design for minimum risk.

In order to control that, I mentioned earlier the cell we purchased, the LSE134-101, that -101 [suffix] specified that that cell was for the ISS Program. The GS Yuasa LSE134 is a commercially available cell. But we required a few extra checks, a few extra reviews, a few little tighter tolerances on some of the components and some of the ingredients that went into the cell to make that a special variant of a commercial product.

Every time GS Yuasa was producing a lot of our cells, a production run was I believe 99 or 100 cells, and they're all made by hand in Kyoto, Japan, because there isn't a huge market for space-grade lithium-ion cells, they still make them largely by hand, and every time they were doing a production run for us, a small team from our project group would go out. We'd put on some white lab coats and hats, and we'd essentially audit the factory and make sure they were not only following their processes but identifying any additional things that we saw that could potentially create a problem in the future.

Whether it's cleanliness of an item or particle contamination over here or the leak check mechanism isn't as thorough as it could be, or when they do the laser welding and there's little spatter that comes around from that where does that go. All these types of things we would look at. We tried to schedule our audits so that we would see a different phase of the manufacturing every time. That was very interesting. It seemed like we would almost be doing that on a yearly basis, if not more than once a year.

When we started to go out there the Japanese manufacturer got to know us well, and we got to know them well, and one time, I knew they knew what they were doing. They're making cells for NASA. But I wasn't sure if they knew what it was for in the larger sense of International Space Station, what does the Space Station do, what benefits are there for the average person on Earth from that.

I guess it was kind of a last-minute thought. About a week before one of our trips I went over to the Public Affairs Office and I said, "Hey, I'm going out to Japan. You got anything I can show them that explains what this Space Station thing does?" Because we're all technical geeks focused on developing hardware, and I know there's a whole army of people that do science and discovery and all that great stuff. And not everybody is as familiar with that as they should be.

They said, "Yes, we do. We just finished this piece on a JAXA-NASA collaboration." JAXA is the Japanese Aerospace Agency. "It's about growing crystals in space and how when you grow them in a microgravity environment, they can be larger with fewer or zero defects, which then allows scientists to image proteins and create cures for diseases and have molecules interact and just design them more appropriately." The example was with Duchenne's Muscular Dystrophy, and because this was a Japanese and NASA collaboration there were interviews from Japanese scientists, speaking in Japanese but translated too, in this video.

I took this video with me to one of our audits, and before we went out to the factory floor everybody's doing the usual greetings, and what we're going to accomplish, and this is the agenda. I wanted to give them a sense of why what you're doing today is more important than just storing energy. I showed them the video, and it spoke for itself. I didn't have to do anything but give a brief introduction, here is this project, and this is like one of thousands of projects that happen on the ISS, and the room was silent after the video stopped. I looked back at my Japanese colleagues, some of them old enough to be my father, others my age or younger, and they had tears in their eyes. They had no idea what they were doing today would help make possible in the future. Because as I like to tell my team, everything on the Space Station is electric. There's no gasoline, there's no generators, it's solar arrays and batteries essentially. That powers the whole Space Station. All of the electricity for everything up there at one point in time is going to have to through, into, or out of these batteries.

That's a big responsibility, and so we can't afford to have any mistakes. If they ever doubted what they did was important, hopefully that answered the question.

ROSS-NAZZAL: What was your feeling when you turned around and saw the reaction?

SCHWANBECK: It made me cry too. When I came back and did a presentation with another organization at NASA here, I used that as an example of public outreach, and I even got a little choked up when I was telling the story of how my Japanese colleagues were taking to heart the opportunity to work on something that could touch so many people in a positive way. It was a good random fortuitous event that I didn't plan, just kind of happened.

ROSS-NAZZAL: Before you went over to Japan did you take part in any sort of cultural training or learn any Japanese?

SCHWANBECK: NASA has a very well-defined program for folks who were going to work and live in Russia, and I did a lot of that earlier in my career when I supported operations. But not so much for going to Japan. It was a couple of security briefings, the standard things to look out for, situations to avoid, but there wasn't much in the way of cultural faux pas.

However, the company that we purchased the cells from, GS Yuasa Lithium Power, which is the American subsidy of the factory in Japan, those people were instrumental in making sure we didn't do anything dumb. Because they had traveled to Japan and lived there and worked there and learned some of the language and told us what would be considered the ugly American. Yes, I'll just leave it at that.

ROSS-NAZZAL: Those are good things to know before you go abroad, you don't want to make those kinds of mistakes. When you went over, how long would you be gone, when you were looking at these batteries?

SCHWANBECK: It was at least a week. Maybe a week and a half. For the launch support I know the teams that would go over there to charge the batteries prior to launch would stay for several weeks, possibly a month. But knowing that you use up over a day in transit with the jet lag and whatnot getting there and then you time travel on the way back, you actually come back before you depart, to make it worth our while we had to be there at least a week.

ROSS-NAZZAL: That's a long time.

SCHWANBECK: A long time to be away from the family, but all in the name of science, right?

ROSS-NAZZAL: Yes. When they got to the U.S., it's my understanding you still were checking out the batteries when they got here. I think Tim talked about unrolling them and looking at them. Would you talk about those tests? Were you a part of those?

SCHWANBECK: It depends on what Tim told you.

ROSS-NAZZAL: He told us a lot, but—

SCHWANBECK: I almost forgot about that. As part of our agreement with the safety community here in addition to adding in the extra controls in the manufacturing and the scanning and the testing, one cell from every production lot we would do what they call a destructive physical analysis [DPA], where we would cycle it a bunch of times, in a way that was designed to exacerbate any latent defects in the cells. That's intentional, because you can't put 10 years of cycling on a cell in less than 10 years. You can take it to the extremes of high charge and low discharge multiple times to try to highlight any internal defects. Then under the supervision of this company in Roswell, Georgia, we would take it apart essentially and unroll the anode and the cathode that were very carefully wound up inside the cell. I should have brought one today, I could have shown you, it would have been kind of cool.

ROSS-NAZZAL: Yes.

SCHWANBECK: In the process of unwinding you have your anode, you have your separator, and your cathode. All these different layers that go together. It's interesting to see, and you look for any inclusions that might be in some of the graphite layers and try to determine is that supposed to be there, is that defect potentially going to cause a problem, are there enough questionable areas in the cell to make that whole production lot suspect.

Fortunately, every time we did this event we had experts from Aerojet Rocketdyne, experts from Boeing, and experts from NASA all in the room, plus management folks like myself who sometimes added little value, but I was there to see and provide another set of eyes to try to identify these small inclusions. We're all there at the same time, making a judgment call, are these products going to work, are they going to be safe, is this what we wanted to buy.

There was one instance. Did Tim tell you this?

ROSS-NAZZAL: I don't recall. If you can share with us.

SCHWANBECK: This part might be—

ROSS-NAZZAL: Yes, you can make the decision, the determination, when you read it.

SCHWANBECK: There was one instance where in the process of taking the cell apart—there's still a charge. This is a battery cell. You cut the lid off, you drain the electrolyte out, and then you pull it out of the can, and you start to unwind it. Everybody's wearing grounding straps because there's still a charge. You can't get all the way down to zero. This is not possible. As the electrolyte was evaporating there was particles in the air and there was a little spark that may or may not have caused a fire—a very small fire, a very small, controlled fire in the laboratory.

We always had a safety briefing before any of these events started, and we knew where the exits were and what we were supposed to do, and everybody's always wearing a respirator because the electrolyte could be considered toxic. When that spark happened and when that fire happened, the trained GS Yuasa technicians did what they're supposed to do. They immediately grabbed the fire extinguisher and started doing their thing.

Everybody was concerned about my safety. I don't know why. They're like, "Where's Eugene? Where'd he go?" I was already out the door.

ROSS-NAZZAL: You were following safety protocol.

SCHWANBECK: I was already out of the room. They didn't even notice I ran. Tim likes to bring that up.

ROSS-NAZZAL: He was very kind. He did not mention that. I would have remembered that one.

SCHWANBECK: Okay. I didn't remember it until you made me recall.

ROSS-NAZZAL: But sometimes those are good stories just to leave in, because not everything goes as planned. But safety worked.

SCHWANBECK: It did. Did exactly what it was supposed to do. That's not uncommon when you're taking things apart like that to have a small fire incident.

ROSS-NAZZAL: I never thought about that. With all the lithium-ion batteries that are out now, I'm a little more cautious about them.

SCHWANBECK: Don't take them apart at home.

ROSS-NAZZAL: I have no plans to do so. I'm not a professional. Tim also told me that you worked with the FAA [Federal Aviation Administration] on the batteries. Wasn't exactly sure about that.

SCHWANBECK: The FAA?

ROSS-NAZZAL: Maybe I'm getting my stories confused.

SCHWANBECK: It's not much of a story. But I guess in trying to get the authorities to agree to ship the largest human-rated lithium-ion battery ever made from point A to point B there was some conversations we had to have with the FAA. But I wouldn't consider that out of the norm.

That was part of the job. It was more fun to try to figure out a way to get six of these batteries to Japan for launch. What we ended up ultimately doing, because we couldn't get an FAA permit to fly, is we had to ship them on a boat on the ocean, which took quite some time. You could imagine that these are somewhat expensive taxpayer assets that need to be controlled in order to guarantee their life. They have specific temperature requirements. What we ended up doing is essentially renting these things called Envirotainers that were just big enough for one battery to fit inside. It would keep the temperature inside this box in the sweet spot for the lithium-ion technology, to have it not degrade prematurely before it was launched, so that we could get the most life out of the battery.

Six of these containers inside a container on a boat taking the slow route to Japan was sometimes challenging, because I guess—maybe this is what Tim was getting at, was we couldn't get the FAA to agree, even in a cargo plane, to ship these batteries via air transport.

ROSS-NAZZAL: Why? Is it because of the fear of fire?

SCHWANBECK: The potential fire. The amount of stored energy that would be in one of these would be problematic. As you may recall, the 787 had a battery a fraction of the size of one of these, and we had six, and we wanted to stick them all in one plane. Okay, maybe by two planes. We'll divide.

I even approached the military and the Department of Defense [DoD] and thought that we could get a transport plane. They move tanks and bullets and real explosive things around, not just batteries. This would be like a cat playing with a ball of yarn to them. We thought they would do it, and they would, they absolutely would do it. But the agreement that NASA had with the DoD in place when the Shuttle Program existed was a lot nicer than the deal with the ISS Program. There would be some sort of reciprocity with the Shuttle Program where the military would transport things from place to place if they were already making the trip, no questions asked.

Once the Shuttle Program ended, and that was the time when we were developing the batteries, that agreement went away too. They wanted a significant amount of money to fly one set of batteries to Japan. It wasn't all just the fuel cost. It was the crew, the time, and everything. They had to assume that they were going out heavy and coming back empty, so we're essentially paying for two trips, and that was cost-prohibitive to our budget, which is why we ended up shipping them on a boat, which in the scheme of things was less costly. But it took a lot longer, so it just meant that we had to plan more carefully, account for ships entering and leaving port. Because once a boat leaves, when it gets to the other side is anybody's guess. I didn't know this at the time. But it's fairly common in the maritime industry to be off by two or three weeks.

ROSS-NAZZAL: Wow. What did the ISS Program think of that when you told them, "Hey, we're going to put this on a boat but we're not exactly sure when it's going to show up"?

SCHWANBECK: It took a little bit of explaining to do. Mr. Suffredini initially didn't understand why. But once we explained and showed him the data, because he's a very reasonable guy, he understood that that was the best option. The military transport was everybody's first guess. But without the agreements in place somebody would have to pay the bill. The project didn't have it, so it would be another request to the program, and the program didn't have it, and that was per set. We had four sets. That would have been a lot of dollars.

ROSS-NAZZAL: Was there any discussion about maybe using the [NASA Super] Guppy [cargo plane] or another NASA airplane?

SCHWANBECK: All the NASA assets that we looked at didn't have the range. There was at the time, I don't know if it's still there, right out at just Ellington [Field] down the road here, the DC-9, that we used to deliver cargo to French Guiana in South America for the Autonomous Transfer Vehicle, ESA's [European Space Agency's] contribution to the Space Station. Just to get cargo, I don't know how many thousands of miles it is, but we had to fly from Johnson to Kennedy to refuel, from Kennedy to Puerto Rico to refuel, from Puerto Rico down to the next stop. It didn't have the range. There weren't any NASA assets that had the range and the capacity that we needed to get to Japan. It was either commercial jet or a military transport, which was too expensive, even for NASA.

ROSS-NAZZAL: How closely were you monitoring the ship? Did they encounter any storms along the way?

SCHWANBECK: No. We got lucky. We were very fortunate. We had tracking information. The boats have beacons on them, so we could log in and monitor their progress on a daily basis. But most of the situations that we ran into were not with respect to our cargo on the boat, but the fact that the boat may or may not make an unscheduled stop along the way and pick up some additional cargo, because it's in their best interest to make the trip worthwhile. How long that would take we would never know. They'd be sitting in a port. Then they'd take off again and they'd get to the destination, but they wouldn't be allowed into the next port because there was a traffic jam with all the other boats making their deliveries. It's challenging but we were able to overcome.

ROSS-NAZZAL: Yes. You finished early, so obviously it didn't impact schedule too much.

SCHWANBECK: Yes. Right. Not the only, but one of the main reasons we were able to finish early was the accelerated production rate. We didn't accelerate the design or the development or any of the testing, because that's where you don't want to cut any corners. But in the production, we initially had maybe three of these large test sets to test and monitor and qualify the design, make sure everything functioned as planned, before it was delivered. Early on in the project when we learned of our challenge to deliver early, Boeing had the foresight to increase that to five. So now we can do parallel processing of multiple orbital replacement units, the batteries, the ORUs, at one time.

That propagated through all our phases of testing, not just the electrical, but the environmental testing. They made multiple fixtures that you could mount batteries on when you did the thermal testing and the vibe testing. They had multiple vibration fixtures so that you could do more than one at a time, or at least have one ready to go as soon as one wasn't done. All these little things seem trivial, and they were somewhat costly up front. But like I said earlier, when you finish a project early and you no longer have to pay for all of the facilities and the overhead associated with it and the salaries of all the people that operate those facilities, you get all that back at the end, and we did return what I consider a significant amount back to the program.

ROSS-NAZZAL: Kudos to you. Hopefully you received some sort of award for that or recognition.

SCHWANBECK: I think Mr. Suffredini said thanks.

ROSS-NAZZAL: I suppose that counts for something.

SCHWANBECK: But most of that, to be honest, was because of Boeing. We challenged them. We incentivized them financially. We got some creative contracts folks on our side working at NASA. We worked out a deal with Boeing that if they could help us meet our new target, they could share in some of the reward. And it worked, it was a win-win for everybody.

ROSS-NAZZAL: That's great. So why do you have to take batteries from Japan and send them to Georgia?

SCHWANBECK: Cells, cells. They're not batteries at that time. Those are just the cells.

ROSS-NAZZAL: But why do you take them from Japan to take them to Georgia to take them back to Japan? Would you explain that?

SCHWANBECK: Because those are just the cells. The cells are made in Kyoto, and they're shipped over to Roswell, Georgia, for the incoming inspection and the DPA that we mentioned earlier to make sure that lot of cells is acceptable. Then from Georgia they're shipped to Canoga Park, California, where they are put into the battery.

ROSS-NAZZAL: Oh, I see, okay.

SCHWANBECK: They have to be packaged. They're physically compressed. They're under a certain load. They're wired up, very intricate process of all the interconnects, all the sensors attached to the cells. There's an actual computer inside this battery box. Where the previous nickel-hydrogen batteries didn't have that much smarts in them, these lithium-ion batteries do.

As a sidenote, one thing that my Boeing counterpart, Tom, who I don't think you've talked to yet, he would always ask me, "What keeps you up at night? What are you most concerned about?" For a long time I was most concerned that we wouldn't be able to get any electricity out of these batteries, because we were making them so safe, and there were so many safeguards in place, that if the temperature exceeded a certain value, boom, that cell would be taken out of the circuit, never to be put back in. Same thing with the voltage level. If it exceeded a certain value, a high or low, that cell would be taken out of the battery circuitry, never to be introduced back in. The deadface relays and the fuses and everything else, there was so much focus on making sure that these batteries were safe that for a while there I thought we could put power into them, but we're never going to be able to get it out.

Fortunately, that hasn't been the case. But back to your question about why they travel around the world, we're back into California now, Canoga Park, assembling the batteries, putting them into their ORUs, only to have them shipped from California to Kennedy Space Center in Florida to then be put on a boat to be sent all the way back to Japan. So yes. They made the trip around the world before they went to space to then really go around the world.

ROSS-NAZZAL: Yes. What was their path when they left Kennedy Space Center? Did they go through the Panama Canal to Japan? Do you recall?

SCHWANBECK: I'm unsure right now. That's a very good question. The Transportation Office took care of that for us and they scheduled the shipments. I don't know. I don't know. Actually, now that I'm thinking about it, I may have to correct some statement I made earlier, where it may have been another project that had to ship these batteries. We may have been able to fly these on a commercial airplane inside those Envirotainers that I mentioned. I think it was with the acid-filled tanks on another project that I worked that had to go on a boat.

ROSS-NAZZAL: Oh, okay.

SCHWANBECK: So, from Kennedy Space Center then I do believe we were able to fly them to Tokyo. We couldn't get them to the launch site directly. We had to fly them to Tokyo, and then via a truck drive them to Tanegashima, which you had to take several vehicles and a boat because Tanegashima is an island off of Japan. That's the boat transport I was confused with. I apologize. Too many stories.

ROSS-NAZZAL: Yes. You've had a lot of experience.

SCHWANBECK: Sorry.

ROSS-NAZZAL: Did you go out there for the first launch of the HTV? Were you out there helping to get the batteries ready and loaded and charged?

SCHWANBECK: I wanted to. I really wanted to. But NASA thought that my time was more valuable spent here. That was viewed like maybe a reward or a vacation, even though you're working in a different country in a different time zone around the clock, it's not that fun. I know from the guys who actually went there. Tim was part of the first group and probably the second group to go out and do the initial charging, I was not. I heard about what they did but I wasn't physically there.

ROSS-NAZZAL: What were you doing back here at JSC while that was going on?

SCHWANBECK: Making sure the rest of the batteries were still being manufactured and helping resolve the challenges that came up in that process, because we did launch the first two sets I think while we were still manufacturing the rest of them. Once we were all finished the batteries remained in the freezer at Kennedy Space Center until those H-II Transfer Vehicles were ready to launch. Then they were shipped over there in advance and then launched. By the time the last batteries were launched and installed on the Space Station we had finished making them two and a half years in advance of that. They were in storage for a little while.

ROSS-NAZZAL: What are your memories of those HTV launches?

SCHWANBECK: It's pretty spectacular. I saw two of them in person. It's different than a Space Shuttle. It happened at night, so it was fairly hard to miss. The countdown took place mostly inside, where they had some presentations that they were going over. It wasn't just safety precautions; it was mostly the history and the cargo and the mission and the purpose. Then nearly at the last minute, they would allow us to go outside on the top of a building that had a really good view of the launch, and then we would see it go off. You'd see it, and then you'd feel it. It's very hard to describe the feeling. It's almost anticlimactic as it fades off into the distance because you've worked for the last six years building the thing that's inside that little speck of light that now you can hardly see.

I think the Tanegashima launch site is one of the nicest ones in the world. I've seen a couple in my day, not all of them, I haven't been to the Russian launch site in Kazakhstan. But I've seen a few. It's basically like Malibu with a rocket essentially. Beautiful beaches, waves. In the daytime. In the nighttime you can't really tell where you're at, but in the daytime beautiful sand beaches, waves crashing in, and oh, hey, there's a rocket there. You'd think Kennedy might be like that. If you've been, it's not. It's nice but it's not that nice. That was my impression of the launch site.

ROSS-NAZZAL: When we were first chatting you were talking about a press conference that you participated in over in Japan. Was that at the launch site?

SCHWANBECK: Yes, it was right after one of the launches. As luck would have it, you have to launch at a very specific time in order for the rocket to be inserted into the right orbit to catch up to the Space Station that's constantly moving at 18,000 some odd miles per hour. This one was very early morning launch. Around, I don't know, one, two o'clock in the morning. Right after the launch the Japanese hosts wanted to have a press conference, as anybody would after they have such a great accomplishment, successful mission.

The Deputy ISS Program Manager, Dan [Daniel W.] Hartman, and myself were there for that launch. They paraded us down into what looked like a classroom. It had all of the Japanese press on one side and a little row of desks up at the top for us to take our places. It was interesting to me that we were obviously in the minority of English speakers, there weren't a lot of people on the island that spoke fluent English, but in the space center where they actually controlled the rocket, I believe it's pronounced Tsukuba, that's where they had the fluent English speakers.

We were all outfitted with microphones and headsets, and we would get a question from one of the Japanese press people, and somebody in Tsukuba, which was on the other end of the island, would translate it for us. Nobody else in the room could hear it. It would just appear in our ear. Then we would have to sit there and smile and nod, wait for the translation, and then answer the question in English, and then wait for the people to retranslate that back into Japanese. They were extremely proud of the fact that they were contributing to the International Space Station, but it was a lithium-ion cell that was manufactured in Japan that was flying on a Japanese rocket that was powered by lithium-ion batteries made by the same company in Japan. It's a long lineage of Japanese products on that. A lot of their questions were focused on why do we pick them.

ROSS-NAZZAL: You mentioned that it was challenging, because you didn't want to get into proprietary or endorsements, I guess was the issue.

SCHWANBECK: We couldn't endorse them by name. But the statement that the Deputy Program Manager and I agreed that was okay that we could say at the time was that this product was the best for our application. That was the qualifier. It's like this isn't the best in the world, although they might think it is. At the time for our application, it really was the best in the world, because we had started with like I said 8 to 10 different companies and downselected and downselected up to 2, a California company, and then this one in Japan. Ultimately for our particular application that was the best.

ROSS-NAZZAL: How closely were you following the batteries once they made it up to Station and then when they were getting installed? Were you watching?

SCHWANBECK: Very closely. Oh yes. It was very exciting. In addition to the battery there's another ORU called the adapter plate that was actually manufactured by a company here, local, Stafford, Texas, [Atec, Inc.] not far away from Houston.

The way Tim likes to describe this, I'm sure he did, was in a flashlight when you have your two D cells together, you need both of those there to complete the circuit. In the original design of the Space Station, there's two nickel-hydrogen batteries that are connected essentially back to back to make that section of the power channel function. The lithium-ion batteries were a lot more energy-dense, so we could replace two nickel-hydrogen boxes with a single lithium-ion box. But in order to make that electrical connection where there once was another whole battery, we made this item called the adapter plate, which provided a convenient place to launch the battery, and it was stowed on top of it, and it had heaters in it that kept the battery thermally conditioned during the launch phase. But it was also used to make that electrical connection. There was a wire that came off. Once the adapter plate plugged into the Space Station, there's a wire that came off the top of it that had to physically be connected to the lithium-ion battery to make that series connection. It allowed us access to a few more commands and a few more telemetry lines that we could have additional sensors inside the lithium-ion battery because of that.

When the first set of batteries went up and the first set was installed, I remember very clearly, I invited some of the people from Stafford because they were local into the Mission Control Room, and we're sitting behind the glass. We're not in the flight control area, but we're in what we call the fishbowl, with the family of the astronauts who are on orbit doing the EVA and making the installation at the same time and watching it real-time in mission control. They just thought that was the best thing in the world. I used to be a flight controller for 10 years prior to moving into project management. That was just another day in the life to me. But for these folks who had never set foot on NASA soil before, and then they found themselves inside the Mission Control Room, seeing a piece of hardware that they machined with their own hands in their shop in space being installed, and such a critical component of the International Space Station. I tell them the same thing I tell everyone else. Everything up there is electric. Without that adapter plate, as much care as we put into the batteries, they wouldn't work. That was just as critical as the quality of the cells made in Japan to have everything function. It was really exciting, the first set.

Then the second set slightly less exciting. Then the third set. Then there was a little bit of a delay before we got the last one up there.

ROSS-NAZZAL: Each time were you at mission control or in the MER [Mission Evaluation Room] while this was happening?

SCHWANBECK: No. I didn't have to work in the MER. I know Tim did, and he liked to keep his MER certification up for probably that very reason. But I had hung up my headset a long time ago. Like I said, I had done operations for 10 years prior. Most of the time these events don't happen when it's convenient.

ROSS-NAZZAL: Right, they happen overnight.

SCHWANBECK: For lack of a better word. But for the first few obviously, whatever, whenever, I would have been there, and I was. But after it got a little repetitive it was sufficient for me to read about it after the fact.

ROSS-NAZZAL: Was there much press interest? Were reporters contacting you after these EVAs wanting to talk with you about the batteries and their importance or what had happened?

SCHWANBECK: Not necessarily. At the development phase there wasn't a lot of knowledge outside of NASA what we were even doing. Then when it's time to do the installation it's the operations team's turn in the spotlight essentially. The development team—and I never noticed this as much when I was in the operations team. But when we would activate whole modules on the Space Station nobody ever thought that there was a project manager who had to not sleep for months at a time to develop that hardware and test it and make sure it functions. It was just magically handed over and you plugged it in and it worked.

All the press I think was for the operations team, the crew members who were outside doing the physical labor, and the folks in the control room who were sending the commands to make it happen. I don't think anybody that I'm aware of from the development team was contacted. But we did have a few opportunities along the way to go to some conferences.

NASA puts on a battery workshop every year in Huntsville, Alabama, where we would regularly status the progress of the development and then once they were flown and activated and being used our core group of team members would go present on that data. I took a presentation to the ISS Research and Development Conference one time in Boston, which was very well received. Just telling people what we had created and the timeline of the development. To be able to say, "And six of these are on orbit right now," is kind of like the icing on the cake.

I recall the first time I did one of those conferences I got several job offers before the end of the day, and I didn't know what to do. I'm a NASA civil servant, I can't go work for this company in Germany. But it was flattering.

The second time I did a presentation like that was at the European Space Power Conference in France. Again, we develop what we do to share with the rest of the world, and not having a lot of press on the development side, I felt like I would do my part and get the word out there and let people know what we did and the benefits and how the nickel-hydrogen technology compares to the lithium-ion technology. After that presentation I had a couple individuals from Italy come up to me and ask me for my autograph.

ROSS-NAZZAL: Oh, wow.

SCHWANBECK: Which really surprised me, because I didn't think my autograph was worth anything. I still don't. But there's a first time for everything, right?

ROSS-NAZZAL: That's awesome, that's great.

SCHWANBECK: Yes, thank you.

ROSS-NAZZAL: You mentioned how the ops team sort of didn't really know there was a project manager when you were in ops. You're activating these modules. What do you think were some of your biggest challenges as project manager for the Li-Ion Battery Project, if you had to pinpoint a couple of those?

SCHWANBECK: The obvious ones I guess you could say. Keeping it in the cost and schedule box. That's always a constant battle. Someone always has a better way or a better idea. Or I never met an engineer who didn't want to do one more test. That kind of stuff.

One of the challenges for me—and I think I was kind of in a unique position to do this, having been a former operator, and getting hardware essentially just dropped in your lap and say, "Go run with this now for the next 10 years." It was clear that the people who developed it met all the requirements, but they didn't develop it in a way that was meant to be easily operated. To take an operator's lessons learned and things that you know people are going to have to do with this, and bake that into the design now so that you're delivering a product that is on cost, on budget, on schedule, and thoughtfully designed so it can be easily operated by anybody was a fairly undocumented challenge that the Boeing team and the NASA experts as well as the Aerojet Rocketdyne team, they did a great job of tackling all those.

I don't know if they expected that. But I think that's a unique thing that I was able to add because of my previous background.

ROSS-NAZZAL: Would you talk about that a little bit more?

SCHWANBECK: I guess because the initial nickel-hydrogen batteries were already launched, installed, there was no need to have electrical connectors on them that you could deadface, that you could ensure would never be energized without receiving a command from the ground. So that was kind of an operational change to this battery design, because astronauts had to take these off of a pallet from another vehicle and float them over to the truss and then plug them in.

When you took an old nickel-hydrogen battery out, they could discharge it fairly well down to nothing. But in order to survive the launch loads of the rocket, the vibration and the acoustics getting into space, the cells of the lithium-ion batteries physically swell up when they're charged. That holds them in place when you shake around. So, we had to launch them at a high state of charge.

Taking them off of a pallet nearly 100 percent state of charge with electrical connectors that any gloved hand could potentially wander into presented a hazard. Our solution to that was to add these deadface relays, which is a very important operational concern, so that was one delta that we put in there.

Having the redundant telemetry, multiple temperature sensors, multiple voltage sensors, the software control that was built into the battery. I mentioned earlier this is a pseudosmart battery. There's a computer inside of it that's constantly monitoring all the sensors at a faster rate than the telemetry can get sent back to the Space Station, then sent down to the ground, and then have a person react to it and send a command back up to try to do something. A lot of that work I guess was automated, built into it, as opposed to something that would be applied after the fact by monitoring telemetry and then reacting to it.

ROSS-NAZZAL: That's pretty cool.

SCHWANBECK: It's different. But because of that there's autonomous actions that the battery could take to safe itself and disable components of it never to be used again. That created that concern I had that I mentioned earlier about we made this so safe, you can't get any power out of it now. But so far, knock on wood, that hasn't happened yet. Hopefully it won't. But if it does it's there for a reason. It's to keep Space Station and the people inside it safe.

ROSS-NAZZAL: What do you think was your greatest accomplishment as program manager?

SCHWANBECK: Oh, I should have a stock answer for that one, but I don't.

ROSS-NAZZAL: It's hard for most people to choose one.

SCHWANBECK: I tried to recognize the people involved that did key things along the way. I would make it a point to send—it doesn't cost anybody anything to send note or an e-mail or make a phone call. But I know when it comes time for performance reviews and managers are scrambling for inputs and what did this guy do for me for the last 12 months, I don't even know—my managers would tell me that. So I thought well, an easy thing I can do every month or every time an event required it would be to send little paragraph, nothing fancy, five, six sentences, to an individual and their manager and their manager's manager. I would try throughout the life of the project, when somebody did something that was noteworthy, to take the six or eight minutes, whatever it took, to recognize that and get it out there.

I didn't hit everybody on the team because it wasn't supposed to be something that would be equally distributed to everybody. It was those stars that shone a little brighter. They know who they are. They got a little something in their stocking at the end of the year, I hope.

ROSS-NAZZAL: About how many people worked on your team? That was not clear to me.

SCHWANBECK: The immediate NASA team was probably maybe 20, 30 people that would touch the product. But then you open it up to Boeing and they had 60 to 80 people, and then you put in their subcontractors with GS Yuasa, another 25, and then Aerojet Rocketdyne probably had 40 or 50. It was well over 100.

Interestingly enough—or maybe I was just naive at the time—but when I would attend the reviews of my supplier's supplier—like for instance the folks in Stafford, Texas, that are making the adapter plate for us were on contract to Boeing. That's who they worked for. They worked for Boeing. But Boeing is on contract to NASA. That's who they work for. If I was to attend a review in Stafford, which I tried to, as many as I could because they're so close, why wouldn't I, everything was directed at me. Like NASA is in the room, NASA is in charge. Like that's not how it's supposed to work, guys. I have no direct mechanism to work with these people. But I understand. I appreciate it. We're the ultimate customer.

Everybody treated everybody with respect and dignity and that was never a problem. But it was somewhat surprising to me. I had to be careful of asking for something as a project manager. I think that might be in contract terms considered a constructive change if you nonchalantly mention something in a review that the subcontractor takes that as NASA direction to go off and do it, next thing you know you get a bill. So, it's a balancing act.

ROSS-NAZZAL: Did that ever happen?

SCHWANBECK: I did ask for some things in some reviews, but they were to Boeing mostly. I tried to make that clear. At the time they seemed like they were good ideas. But in hindsight probably I could have thought about it a little bit more. For example, the battery that we developed had to have a charger made for it, a battery charger. It's not something you can just go down to the electronics store and buy a space lithium-ion battery charger. Everything we did was custom.

When Boeing came up with the design for the battery charger, it was in a standard computer rack that had a monitor for the computer, a keyboard, some power supply, some safety equipment, a big red button on the top in case there was ever a problem, and some cables to make the connections.

In one of the reviews, I pointed out to my counterpart that this rack is almost empty. Why are you using a full-size computer rack when you don't have a full-size rack of stuff? It looked funny. It was a cartoon. It was just like an illustration of the design, what it was going to be.

The engineer that was designing that took it upon himself to find a smaller rack because I was displeased with the empty space, which was never the intent. And they came up with a three-quarter rack which they do make. They're hard to come by but it's a three-quarter height standard rack. Next time the hardware was built and presented, boom, there it is, look, it's not as empty.

Great. Now when we had to ship these racks to Japan to charge the batteries prior to launch nobody could find a three-quarter size rack shipping container.

ROSS-NAZZAL: Oh no.

SCHWANBECK: They don't make those. So, in hindsight, I should probably just keep my mouth shut sometimes.

ROSS-NAZZAL: Well, how would you have known? That's pretty specific.

SCHWANBECK: It took like four years for that one to come back and bite me, but it did.

ROSS-NAZZAL: Yes. I just had one other question. You've mentioned several times that Penni Dalton had said that these were the largest Li-Ion batteries ever utilized for a human-rated spacecraft. I wonder if you would just explain the significance of that. Because people do know of lithium-ion batteries. They have them in their homes. But what does it mean to have it on board a spacecraft in such a large quantity?

SCHWANBECK: It's the amount of stored energy in one spot, is really what it comes down to. There has likely been, and if it hasn't there will be, larger lithium-ion batteries made for a satellite, or some untended item in space that's launched.

What makes it different is the fact that okay, it is in space. It's not easily serviceable. Once you launch it it's got a life of its own. You very rarely get a chance to touch it again. But the human element adds an additional layer of complexity. The design in our experience has to be that much more robust because if a satellite has a problem—and there have been satellites that are working one minute and the next minute they're not—and people theorize well, maybe the battery blew up, we don't know, you'll never know.

We can't—or at the time we couldn't—afford to have that ever be the problem. To make the design as robust and as fault-tolerant as we did is what made the development take so long. With the risk mitigation testing, and the determination of which levels that we could approach, whether it's a voltage or it's a temperature, and not have a problem but when you cross this line in the sand then there might be a problem, and then this other line oh, there definitely will be a problem. To make sure you never get into those ranges and still meet your performance requirements to generate the amount of I guess you'd call it useful service life—these were 10-year batteries—they had to be able to be stored for a certain period of time, and then they had to be operated for a minimum amount of time, which is 10 years. All the while knowing that every cycle of charge and discharge the battery degrades ever so slightly.

So, it has to be big enough to not have a problem but yet gracefully degrade over time to still meet all of your requirements after 10 years. Not a foreign concept to any project by any means. But the human element that is added in there of making it so you can't have a problem, or if you do have a problem, you contain it within your volume and not propagate it to another system on the International Space Station makes it very unique.

The fact that the batteries are located out on the trusses away from the pressurized modules is a huge plus. But the fact that people in space suits have to physically handle these batteries and install them and put them in place when they're at 100 percent state of charge because they have to be launched that way or else, they wouldn't survive the vibrations of the rocket on the way up to space, it adds to the challenge.

So that's why Penni likes to say that. Hopefully you'll get a chance to talk to her.

ROSS-NAZZAL: She's on the calendar, yes.

SCHWANBECK: She's an extremely intelligent and rational battery engineer. NASA is fortunate to have people like her and like Tim and their technical counterpart at Aerojet Rocketdyne, Sonia Balcer. They're all just like a little hive mind. I like the fact that there's three of them so that if we had to vote on something you'd always get an answer, it was never a fifty-fifty, there was three of them, so it's like okay, what do you guys think about this. Sorry for the wordy response.

ROSS-NAZZAL: No, that's great, that's perfect. I wonder, since you brought your papers, if there was anything else that you wanted to talk about, if there was something that we didn't discuss. Like I said, you will get a chance to review things.

SCHWANBECK: I think I hit all my undocumented stories, at least the ones that we can share, in the process of answering your questions. Appreciate the opportunity to come in and to talk about this and explain some of my experiences. Hopefully this will add some value to somebody someday. Like I mentioned earlier, looking through the list of the names of the people that you normally talk to, I don't know why I'm on the list. But it's not me, it's the project, so I understand.

ROSS-NAZZAL: Thank you for alerting us to it. We really appreciate it.

SCHWANBECK: Thank you.

ROSS-NAZZAL: Enjoyed it, thank you.

[End of interview]