Riley Duren

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Interviewer: Erik M Conway

Conway: So my name's Erik Conway here, interviewing Riley Duren about his time on the Kepler project of many years ago now. And it's the 15th of March 2024.

First, really tell me a little bit about yourself. Where are you from? Where are you born? How were you educated?

Duren: Oh wow go way back. So I was born in Duluth, MN, but call Alabama home. That's where I grew up and mom and dad and sisters and families still live in the little college town farming town that I grew up. Montevallo AL. I went to Auburn University and studied electrical engineering and my sophomore year I joined the cooperative education program at Auburn, which placed me at NASA's Kennedy Space Center in Florida.

And so in, gosh, September of 1988, I started work at the Kennedy Space Center as a GS2. I think the lowest federal pay scale worker, as a cooperative education student. And it was I was there in time for the return to flight after the Challenger disaster. And so I was, uh, lucky. I was very, very, very lucky to be brought into a section of the Kennedy Space Center.

There was an entire division that was solely NASA civil servants, and at the time that was very unusual because, you know, probably 90% of the workforce at the Space Center were contractors and most of the civil servants would oversee contractors who did the work on the space shuttle. But I was lucky to be brought into an organization called Level 4, and it was specifically created as a training ground for young engineers. You know, fresh out of college or some of us still in college, under the supervision of some sages from the Apollo program. And NASA recognized that it needed to train the next generation of engineers.

And so it was a group of electrical, mechanical, software engineers all working in one division. It's about 100 at one point, over 100 of us. And we had the responsibility of integrating instruments and experiments from the Space Lab program to the space shuttle for launch. And so that, you know, if you're familiar with Space Lab, that's huge, pretty big program, spanning a couple of decades, including a partnership between the European Space Agency, NASA and other agencies, and literally flew hundreds of instruments and experiments, on the space shuttle. And anyway, that's how I got my start.

Conway: OK. And that was while you were still attending Auburn. Is that true?

Duren: Yeah, the way the cooperative education program works at most universities that have it is that they place students with employers, kind of a work study program where you alternate academic terms with working for an employer and most people try to do something local. In my case, umm, I actually had got a job offer and had tentatively accepted a job offer from the phone company inn Birmingham. Just a 30 minute drive from where my parents live, which would have been better paying and also it would have been cheaper to stay with my parents.

But I remember I got a call on a Saturday morning from Kennedy Space Center. It turned out that Enoch Moser, who turned out to be my first group supervisor and he said, you know, we've seen your application, your SF 171 and your cooperative education program advisor at Auburn says like you're, you're perfect for us because you're just so excited about space. So yeah, they place you in this program, in my case, Auburn was on the quarter system, so for a couple of years, I just alternated every other three months I was at the Kennedy Space Center working, and then I would be back at Auburn taking classes.

So it resulted in me delaying graduation by year because I spent a year working but it was absolutely the best thing that could ever happen to me. Because it, you know, gave me focus and direction and I had a job waiting for me when I graduated.

Conway: So how did you leave Kennedy Space Center?

Duren: It was JPL's fault.

Conway: OK.

Duren: You know, I was lucky when I was at the Cape to have a number of roles on payloads flying on the Space Shuttle, working my way up to be the lead electrical engineer at one point for some of the missions and to two missions in particular that were managed by JPL. One was the Lambda Point experiment, low temperature physics experiment that flew on the 1st US Microgravity payload. It was probably early 90s, probably like 1990. It was either 92 or 94. And so there are a bunch of JPL folks that I worked with there and made my first trip out to JPL, was working on that project. And then you know, worked with them when they brought the payload to Kennedy. Probably even more important was I worked with an imaging radar team, Sir-C, which is the third in a series of a space borne radars. This was built by JPL and there was a German component of it called X-SAR. Basically JPL was building a C&L band radar and then the Germans built X band radar. There was another instrument called MAPS that was actually

Measurement of Air Pollution from Satellites, measuring carbon monoxide from space from Langley and long before we had satellites that would do this.

And I was the lead electrical engineer on that at JPL for that. I'm sorry, at Kennedy for that and so. Gosh, over a period of probably 6 plus years, I was working with people either at JPL or when they came to Kennedy. Ed Caro was the chief engineer on that radar program at JPL. And Mike Sander, who was the project manager, along with the Lambda Point team, when I started making noises about wanting to move on from Kennedy because of, you know, the way things were heading with the human space program, they recruited me.

And so I came out to JPL in. . .I started at, I guess at the start of 1996, I moved to JPL. And I wanted to come to JPL to work on exoplanets. As I was finishing up my senior year at Auburn I was working on a one of the Space Lab missions called Astro Ultraviolet astronomy mission. The second one I was working with the team from Wisconsin - the Wisconsin Ultraviolet Photo Polarimeter Experiment (WUPPE), Whoopi. Won the NASA award for most original acronym.
I got really interested in astronomy and was starting to go to Graduate School and, you know, convince myself that I wanted to go work on exoplanets at the time. JPL had a pretty vibrant exoplanet science program with a number of missions like that were being touted like Terrestrial Planet Finder, the Space Interferometry Mission among others.

And so I came to JPL wanting to work on those programs and the way things worked out, the SRTM project started. The Shuttle Radar Topography Mission, which was the follow on to SIR-C and X-SAR, and I got immediately roped into that. That turned out to be a saga in its own right, working on SRTM from 1996 until we launched it. Gosh, was that 1999 or 2000? I was, I ended up being the lead for the metrology system, the optical system and the GPS system that basically told us the position and orientation in space of this radar interferometer. SRTM. So that's how I came to JPL and that's how it got me on the path to doing exoplanet stuff.

Conway: But it was through SRTM. Interesting.

Duren: Yeah.

Conway: So that so that would have ended then, what in 2002-ish?

Duren: I think we launched SRTM in 2000. I believe it was 2000 – a typical two week long, you know, shuttle mission. In this case, we mapped, you know, most of the planet below 60 degrees latitude in about two weeks with the radar. And then I didn't have a big role in the data analysis or processing. So as soon as we were done with that, I was moving on and I moved initially worked on the Space Interferometry Mission for about a year or so. And then a new project was spinning up under the Terrestrial Planet Finder program called Starlight, which was to be 2 formation flying satellites.

It was really a technology demonstration program under what started out as New Millennium programs at NASA and I was the instrument engineer on Starlight for a couple of years. And importantly, I was working for Leslie Livesay who was the project manager for Starlight and ultimately would become one of the project managers for Kepler. We're busy busily working towards the preliminary design review for Starlight - again being the precursor to Terrestrial Planet Finder, which was going to be this massive formation flying thing in space - and the program was cancelled. Starlight was cancelled. Ostensibly because of software overruns on

Spitzer, the big flagship astronomy mission, one of the great observatories and clearly higher priority at NASA.

And so Starlight got cancelled and we were all looking for work. And then this is what led me to Kepler. This would have been 2002 and Larry Simmons, who was the head of the astrophysics program at JPL at the time, and Leslie, called me into Larry's office. And they said, well, you know, we're sorry about Starlight, but we have another opportunity, if you still want to work on exoplanet stuff. And I said yes, I do. And they said, well, we have an opportunity to compete for management of this, this new discovery mission called Kepler. And that the PI is Bill Borucki at NASA Ames.

The whole story of Kepler, if you haven't heard it, is really unusual. I can't imagine NASA would ever do this again, but you know, the Discovery program competes its missions. Bill Borucki, bless his heart, had been through multiple selection cycles with the mission concept. He was finally selected and the initial proposal was that Ames would both be the PI Center, but also the project management, systems engineering, the ground system and they were going to, contract the spacecraft and the observatory out to Ball. Ed Weiler was the NASA SMD (Science Mission Directorate) chief at the time, and he selected Kepler. But then, he said, "Ames, you can't manage it." You know? And so it was kind of a Charlie Brown/Lucy with the football thing.

Ames was required to go get management support from JPL or Goddard and they set up a competition. And so I was asked, and Chet Sasaki was tapped as the as project manager. Nick Gautier was the JPL project scientist and I was the project system engineer and we led a delegation to Ames to pitch our proposal, JPL's proposal, to manage the project and then we were selected and then we moved in implementation. That's the arc for me getting to Kepler, through SRTM and Starlight. But it was that consistent interest in exoplanets.

Conway: So you went up to Ames to make the proposal. Tell me about the proposal. What was JPL proposing to do as the manager of the mission that's different than what Ames would have done?

Duren: It was clear that we didn't want to break anything. Obviously the team at Ames together with Ball was a winning team. They wouldn't have been selected otherwise. So we, JPL, went in proposing to operate as a system contract, which is what it was. We basically left everything unchanged, with Ball being the both the spacecraft supplier and the telescope, the instrument, and the integration of those things additionally. Ball wasn't doing all the mission operations. They were partnered with an organization back in Maryland that do mission operations. But we didn't really change any of that structure, at least at the onset. We were gonna do what JPL does with other PI-led missions. We were gonna report to Bill Borucki, the PI. There would be a JPL project manager and project office which would include a project scientist, Project System Engineer, Business Office, Mission Assurance manager. And that was it.

I mean the JPL office initially was maybe, you know, six or seven people. And the idea was JPL would bring its institutional capabilities to provide contract oversight insight with Ball. JPL has a lot of experience with that. And that was that was the consideration. I'm not sure what Goddard proposed, but it probably was something similar. I can't imagine anybody was gonna try to tear up things with Ball. And you know, I remember going to Ames and the first meeting with, people who we would go on to spend eight years or so working together in pitching, presenting our proposal, how we're going to manage it.

It was a little surreal because most, you know, NASA doesn't do proposals this way, right? Its was a very different process for evaluating proposals. You don't usually interact directly with the review team, except when it comes to a site visit. In this case, we were asked to come to Ames, give a pitch, and then I remember getting a list of pointed questions. You know, we had questions in advance that we had to respond to and one was why are you qualified? It was a very personal like, "why are **you** personally qualified to be the project system engineer? You've never been a project system engineer before," and I was the person asked to present the answer. So I was in the awkward position of standing up and explaining why I thought I was qualified.

Conway: Now Chet Sasaki had just come off, of I think Genesis, as project manager And he was very hands off. This was right before the Discovery program and NASA decided to abandon that very hands off management method, abandoning the whole faster, better, cheaper approach of the 1990s, and start reimposing a more rigorous, intrusive management style. So how did that affect what you had to do?

Duren: When were the Mars debacles?

Conway: They were in late 1999 and early 2000. And so the whole reconstruction of the Mars program and all that stuff is in in 2000 and 2001. And that's also when the that's also when the JPL design principles and what's the other section set called?

Duren: Flight project practices.

Conway: Yeah, those are all drafted between '99 and 2000 and implemented in 2001 and then reflected up into the NASA Policy Directive NPD 7120 and all that stuff.

Duren: It was an interesting time. I was still new to JPL. But there was a lot of awareness at the lab of, we can't fail again. And there was the pendulum. We were going through one of those agency pendulum swings, right? What was new for me is I had never really worked on a system contract. You know, when I worked at Kennedy like I said, when I started there, I was in a special team that was all NASA civil servants. We didn't have contractors. We did all the work, hands on, ourselves.

When I moved to JPL first big project I had was SRTM. That was all hands on all in-house JPL. You know, only modest contracts. Get your hands dirty. Do whatever you have to do. This is before the design principles and 7120 and, what I remember was, what impressed me when I came to JPL was the incredible breadth and depth of technical expertise and almost every engineering discipline and science discipline. I think I've benefited from being at the lab early enough to have benefited from working alongside some of the giants of the previous era, the pre-faster, better, cheaper era. I mean, talking about people who led Viking and Galileo and Voyager.

People like Bill Layman was the chief mechanical engineer on SRTM as one of the archetypal mechanical engineers at NASA. Very old school, you know, will draw things out on a grid, a piece of grid paper and hand out homework assignments in every meeting, you know, here's a word problem. Go solve it. And Ed Caro and the radar world. And a long list of people in the attitude control, divisions and telecom. All of these where the culture or, the community of expertise, was the people and you just had to figure out who to go talk to. [Interruption]

Conway: We were talking about the old school mentors you had.

Duren: Where I was going with this was, you had mentioned JPL had just started to promote the Design Principles and Flight Project Practices, and this project had been proposed by Ball. They had adopted. . .Goddard has a set of practices for environmental testing called the GEVS and also the Green Book. Goddard has some practices that are analogous to JPLs. Ball had designed the program, scoped and costed it, using the Goddard rules and we didn't want to go in and re-invent the wheel.

Two things. My team had to go in and develop a crosswalk between JPL's Design Principles and Flight Project Practices and Ball's practices to show that we were properly enveloped and we would track things that way. That was one thing we brought in as the project management office.

The second thing JPL brought to the table was JPL technical experts to reviews. JPL has always relied on a combination of formal reviews, like the gate reviews, and informal reviews, engineering reviews, we call them tabletops. So a part of my job was just to bring in, kind of by the drink, support from different JPL technical experts along the way. We did lots of reviews, because our job was to provide oversight.

The third way that we, you know, managed the engineering part at Ball was really me and my system engineering team worked with Ball on requirements development, further requirements development, tracking performance, V & V, verification and validation.

There are people on my team who had lead roles in the project. I was, for example, I was the overall owner of the science performance analysis, so I worked with the PI to develop a series of merit functions that translated the engineering performance of the observatory into, or allowed us to relate, the engineering performance of the observatory and the data pipeline into the science objectives. But I also had a person who focused on V and V, verification and validation.

And so there were those 3 things. It was basically pushing the JPL flight project practices and tracking those with Ball. It was bringing a host of subject matter experts to bear. And then technically adding to the team, there were certain functions that we felt that nobody else in the project was doing.

And the latter two things I felt most comfortable with starting out because, my whole management style, I am very technical and my focus was to understand the science objectives and then drill in and understand the sensitivities of the science to the engineering and vice versa. And so I that's kind of naturally where I gravitate to. And then being able to tap a lot of JPL experts was something I was comfortable with. The new thing was the design principles and the flight project practices and finding a way to harmonize that with what Ball was doing.

And I guess the last thing I would say is, by way of background, is because I was new as a project system engineer, JPL assigned me a mentor and that was Gentry Lee. Gentry had recently returned to JPL after, you know, being gone for years writing books with Arthur C. Clarke and his own stuff. When he left JPL, it was before the faster better cheap era. He was the chief engineer on Galileo. Before that he was the mission director for Viking. And when he came back, he said, I'm really kind of worried about JPL just becoming a cookbook culture. People are just gonna go follow 7120 and read through the Design Principles and I remember, one of our first meetings together he dragged me along for a meeting with the division management in Division 31 and he said, quote, “when I left JPL 10 years ago, system engineers were kings and princes. And now they're clerks.”

He said, they're clerks, you know, they're just following cookbooks. And if you know Gentry, you know he can be hyperbolic. But there's also a lot of truth in what he says. I say that because the other thing I did as we started up Kepler is I spent about a year or so being actively mentored by him. He was both the review board chair but also I did a stint working with him in the Mars program office. Working for Firouz Naderi at the time. So it was me and Charles Whetsel. We were working for Charles Whetsel. But it was me and Gentry, Charlie Kohlhase who was the "grand tour" designer for Voyager. And people like Rob Manning who was at the time the MER (Mars Exploration Rovers) chief engineer.

So I spent a year working on the Mars program. Which again, was not what we were doing with Kepler, it was more of a JPL way, big internal in-house mission. Working alongside some of these elder sages who represented what I would call the traditional old school way at JPL They very much influenced me on how we dealt with Ball.

I'll let you ask some more questions. I can say more about what it was like, you know, trying to do that.

Conway: Well, one of the questions is about managing Ball technically. They actually had two contracts, one for the spacecraft, one for the photometer. And one of which was held by JPL and one by Ames, I guess. But, but talk about how you had to work with them on technical matters. Given all the decisions that had already been, that was supposed to be a relatively hands off project.

Duren: Yeah, yeah, so I remember when I joined the project, the deputy PI, David Koch, who's since passed away, unfortunately, straight up told me this. "This is what we proposed. Ames, we proposed to write a check to Ball then have them do everything. They're gonna design the photometer. They're going to design the spacecraft. They're going to integrate test and launch them. They're going to operate it. They'll deliver the data to us. And we'll process it."

And that was the Ames approach and that's why they got directed to go to JPL to manage the project because that wouldn't have worked. And you're right, initially, about the contract management. JPL has a spacecraft contract manager. There's an Ames Photometer instrument contract technical manager and then a JPL project manager.

We went along for a while and then, things went off the rails. You know, cost started to skyrocket, Ball was falling behind schedule and over running. And JPL had an intervention. They replaced the project manager. They brought in Leslie Livesay and Jim Fanson. We had to do a Delta CDR (critical design review), a pretty major one with a lot of significant descopes.

And in what I call the near-death experience, we had a termination review with Alan Stern who had taken over as SMD chief for Ed Weiler. And we, were able to pull it out, but you know, in terms of managing it, the situation that JPL walked into was the way Dave Koch described it. The Ball team probably went from thinking, hey, we're gonna have a complete autonomy to suddenly, "oh crap we're dealing with JPL."

And part of the reason why they picked me is that I am not necessarily a super by-the-book person. I wasn't going to come in and start reading them the riot act on requirements in 7120. My approach was, let's do what makes technical sense. And you know, I think one of the most important lessons I've learned as a system engineer is that you have to be able to manage through influence.

You rarely have the power of the purse. Unless you're working on a multi billion dollar flagship mission, you cannot drive everything with requirements and contract change orders. It can't all be CDRLs (Contract Deliverables and Receivables). Ball told us up front, "look if you come in here and do it like some militaristic top-down NASA thing and CDRLs, we're gonna hit you with contract change orders." And Chet and I both said we don't want to do that. And so we didn't.

I think if anything initially we were too hands off because we were trying to make the partnership work. We were getting all this push back from Ames and Ball about being too pushy. But when the wheels came off and the management changed, it was, you know, the JPL position, I think it was accurate, is that we needed to be more directive. And so things did change when that management change happened, I think, in terms of us being more directive. But again it was always through what I would call the people element – the relationships. Jim Fanson and Peg Frerking and I spent a lot of time in Boulder, you know, parked at Ball, not being contract managers, but rolling up our sleeves and being part of the meetings and problem solving on the ground with Ball – along with our colleagues from Ames.

And it, you know, it was rough at times, but at the end of the day we developed a pretty integrated team and I really think it was the people-to-people relationships between, my team and the Ball team and, and Ames folks that was key to managing it. It was not, by no means did we go in and just direct everything with contractual orders. That would not work.

Conway: Right. Right, that makes sense. I understand a big driver of what had to be done was understanding the sensitivities of the system and the interactions of various systems. So talk about that understanding that, from the systems perspective.

Duren: Well, I mean, there were 3 things that made Kepler hard. There's building a big optical telescope and photometer that can provide the precision. And how you operate the telescope, really what I call the observing strategy. Because at the end of the day, Kepler is a survey mission, right? And the cadence, the survey cadence. The completeness and what we came to call contiguity of the measurements because you have to deal with periodicity in orbits of that the planets you're trying to find and you couldn't have big observational gaps – particularly at cadences that align with the planets. So any planned activities that took us away from observing the sky – like pointing at the earth periodically to downlink stored data - had to be carefully managed.

So the "how does the machine – the observatory itself work"? Is the first hard part. The second hard part is analyzing the data it produces to find planets, right? The data analysis really was what Ames developed, in particular people at the SETI Institute, Jon Jenkins developed new techniques for, you know, pulling signal out of noise. Getting that 20 part per million photometry for stars that have equal or worse stellar variability than our Sun and all these systematic errors that can happen. So the analysis and data processing is another part.

And the third challenge is what's going on in the universe itself, physical behaviors in the sky that affect our ability to detect planets, right? There's uncertainty in what's really happening with the orbits of planets and how stars pulsate. Before the Kepler mission was launched, astronomers' understanding of those things was largely limited to theoretical models of the universe. What do we really know about how the world, how the universe behaves.

And so a big challenge in designing the Kepler mission was pulling those 3 things together with analysis and understanding how things vary with assumptions. From an error budget or, if you will, a system model perspective, how do you pull together all the different things that matter with the machine, the observatory; the data processing; and then what we do and don't know about the universe.

And so one of the things that I thought was fairly innovative on Kepler is Bill Borucki and I, after a lot of arguments, developed what was called the science merit function. That is, if you want to think about it as drawing a curve on a whiteboard, the question was, "what is the sensitivity of science objective X to the engineering parameter Y."

One example is, how does the size and geometry of the focal plane affect our ability to detect planets? We had 84 CCD channels because Kepler was a big wide field instrument looking at a big chunk of the sky over 100 square degrees. A big camera needs a big focal plane so we had to arrange a large number of CCDs into an array. So if some of those CCDs failed and resulted in gaps, and, not just how many fail, but where they failed in the symmetry of the focal plane (combined with how we had to rotate the field of view on the sky every 90 days) could have profound impacts on the completeness, or how well the survey worked. Another science merit function involved how mission duration coupled with the orbital behavior of earth-like solar systems. You could draw a curve of what the science value was. This is a little subjective, but for each of these metrics, science value scored on a scale of 0 to one hundred.

You know, do you get a hundred points, 0 points or anywhere between - and in an ideal world that that curve would be this linear straight line, but in many cases some of these curves have knees in them – or where the science value quickly degrades or improves when you pass a certain threshold. And that became kind of the concept behind the merit functions. There was a family of curves, maybe 6 or 7 curves that related some of the key engineering parameters to the science.

And, you know, Bill had to code this up. At the end of the day, he was the one who really understood the science sensitivity, but it was me driving him to say, we need these metrics so that we know where we are on this curve. It turned out to be really critical for two reasons. One is because of the cost overruns that occurred with the photometer about midway through development. We were *this* close to being canceled. I mean, I was in a meeting with Alan Stern, worst meeting I've ever had in my career. And we were in Boulder and Stern had the project manager from JPL, the senior VP from Ball, he had JPL Lab director Charles Elachi there, Pete Worden from NASA Ames, you know, all the top managers.

And we, you know, we had had this big meltdown with the budget and we proposed what our response was and at the end of the briefing, Stern looks around the room and he goes, “I'm not happy with this and I think I'm ready to cancel the project and fire all of you.”

Conway: Nice.

Duren: That was his management style. So he sent us back to the showers – gave us a second chance. We were this close to cancellation, and we had to do something pretty drastic and so we descoped a lot. We took a lot of capability out to eliminate hardware and cut costs without eviscerating the science value of the mission. We initially had a gimbled pointing mechanism so you could move the high gain antenna. Regardless of where the telescope was pointed, you could always down link data to the Earth.

That was too much. We had to descope all of it. And then we had to fundamentally change how we operated the observatory to point, to body point, the antenna at the earth. That meant that about once a month we'd have to stop observing for awhile to do that – which would impact data completeness and contiguity so we had to use the science merit function to evaluate that.

There's a bunch of other things that we did to cut back. And our team, the science and engineering team at Ball, JPL and Ames, we spent 60 days running through a hundred trade studies.

You know, what can we descope? What are the costs? What are the risks? Ultimately, we were successful in trimming costs without ruining the science return and Stern approved us to proceed.

And we couldn't have done it if we didn't have this merit function there where we could just immediately go through and triage. For each descope option, where do we end up on these curves in terms of science impact as a function of observatory capability? Does it break the mission?

And then the second place the merit functions became important was late in development when we started having technical problems with the actual hardware. We had problems with CCDs and the supporting instrument electronics. Turned out some of them did fail on orbit and we knew the gaps in the focal plan would impact science so we had to analyze those cases. We also had problems with the reaction wheels used to point the observatory. We experienced a long-running problem with our reaction wheel vendor which came back and bit us later during operations when two of the reaction wheels failed.

And then we had this thing, you know, late in cold testing of the observatory shortly before launch. We were in thermal vacuum testing and we started seeing electronic noise in the images being read out of the focal plane array. We're getting this pattern noise, this weirdo ringing behavior.

When these things happen late in the program, you unless you've got an unlimited budget and a very forgiving sponsor you just don't have the time and resources to go back and rebuild and redesign. You often have to make a decision. Am I gonna launch like this? Will it get worse in space? What's the risk? What's the impact if the worst case happens? So again, having the merit function where we could do these "what if" analyses to make decisions like, if the reaction wheels stop working after 3 years, could we tolerate the impact on the science or do we have to put the program on hold for several years and secure funding to completely swapout the wheels with those from another vendor.

At the time, convincing the PI to develop a merit function like that was not standard practice. It's still not. There is a discipline at JPL now that I help found called science system engineering. That's what I'm talking about. How do you develop tools for every mission that allow you to do this kind of analysis and decision making?

But it absolutely turned out to be critical on Kepler. I do think at the end of a day, that that, along with just JPL being JPL and bringing a lot of expertise to the table, is a big part of why the mission was successful.

I can think of, you know, a dozen ways it would have crashed and burned had we not been there. But more importantly, we were there as part of the integrated team: it took committed individuals from Ball, Ames and JPL who put their institutional badges aside to pull together for mission success. At the end of the day we were all passionate about the mission and the science. And, you know, it really paid off!

Conway: Well, we're out of time, so we should do a follow up at some point after I get these transcribed.