AirSpace Season 2, Episode 4

AirSpace Live at SXSW

Speaker 1:

Hey Airspace fans. We are so excited to share this episode with you. We had a great time this past March at South by Southwest in Austin, Texas. Now I had never been to South by Southwest and I envisioned something pretty busy and bustling, but I was entirely unprepared for what the streets were like. And our stage was between two active bars on either side. So in addition to our full house crowd, you may hear some of that stuff in the background. And now without further ado, here's the show.

Emily Martin:

Welcome to Airspace. We are live from South by Southwest. We're here on the WeDC stage courtesy of the Aerospace Industries Association. I'm Emily Martin, I'm a planetary geologist.

Matt Shindell:

I'm Matt Shindell, I'm a space historian.

Nick Partridge:

And I'm Nick Partridge.

Emily Martin:

And we're all from the Smithsonian's National Air and Space Museum in Washington, DC. And later on in our show, we'll be joined by a special guest Bobak Ferdowsi from NASA Jet Propulsion Laboratory. And today we're talking about failure, that sort of unsung hero of achievement. And we're going to tell stories of a few of our favorite failures, failures of technology, failures of economy.

Nick Partridge:

Failure to fail.

Emily Martin:

Is it failure to fail failure or a success?

Nick Partridge:

Ooh.

Emily Martin:

This episode is about failures and how they've inspired so much success in science and in space exploration. That's coming up next from this episode of Airspace from the Smithsonian's National Air and Space Museum with support from PRX.

Matt Shindell:

So our first chapter of failure actually has to do with the history of supersonic commercial transport.

Nick Partridge:

Has anyone here ever flown on the Concorde? I thought not. And there's a reason behind that. There were 16, Matt?

Matt Shindell:

There were 16. Technologically, they did just about everything right. They designed a beautiful plane that was able to fly at supersonic speed. It was able to carry a hundred passengers within the span of about three hours from New York to Paris or New York to London, but it never was able to really achieve great commercial success. The years that it flew from the mid seventies up until the early 2000's, it cost several thousand dollars to buy a ticket on the Concorde. But when you did, you became part of an elite group. You were given special glitzy gifts like silver tie clips and unlimited champagne. It was basically two-by-two seating that's not much more roomy than what we think of today as business class seating.

Emily Martin:

So first-class experience, coach amount of leg room?

Matt Shindell:

Exactly.

Nick Partridge:

So the real experience is when you're back on the ground.

Matt Shindell:

And you also get a certificate at the end saying that you had flown on the Concorde.

Nick Partridge:

That's the mark of an everyday experience for the common Joe. And was it successful?

Matt Shindell:

When they first started designing this plane, they were competing with other subsonic planes that only flew about 80-100 passengers, but by the time it went into flight in the mid seventies, we were flying 747's and you could fly 400-450 passengers on the same amount of fuel from New York to Paris.

Nick Partridge:

Prohibitively expensive.

Matt Shindell:

Yes.

Nick Partridge:

Didn't fly very many routes.

Matt Shindell:

Right. And-

Nick Partridge:

Probably not popular on the ground for people with the sonic booms.

Matt Shindell:

Yes. Because it flies so fast, it creates a sonic boom that can be heard on the ground and that could potentially damage property. So in the United States, in the 1970s, Congress actually banned having the Concorde fly over land. That's why it was only really ever used for transatlantic flight.

Emily Martin:

There was only two airlines that actually had the Concorde.

Matt Shindell:

So British Air and Air France were the two main partners. So, and then another problem that it had was because it flew so high, it was essentially flying in the bottom of the ozone layer. And so there were worries that it could actually potentially damage the ozone layer by introducing nitrogen oxides there into the ozone layer, which could then react and lead to degradation of the ozone layer.

Emily Martin:

But there's a little bit of a silver lining here.

Matt Shindell:

There is a silver lining. So because they never flew a huge fleet of supersonic transport jets, it didn't really pose the problem to the ozone that they figured it would, but because it raised awareness of the vulnerability of the ozone layer, it actually led indirectly to the discovery that there was in fact an ozone hole.

Emily Martin:

There's a couple of bus stops in between it, but essentially flying the Concorde led us to the discovery of the hole in the ozone.

Matt Shindell:

In a indirect way, yes. So I think the takeaway of this story really is that technological development doesn't happen in a vacuum, whether you succeed or you fail, there are economic and social factors that you really have to take into account in order for a thing to really work. You can get everything right technologically and still have missed some big factor that's going to lead you to fail economically.

Nick Partridge:

Have you guys ever broken down on the side of the road-

Emily Martin:

Who hasn't?

Nick Partridge:

... in the middle of the night.

Emily Martin:

I mean, who hasn't really?

Matt Shindell:

Yeah.

Nick Partridge:

Very frustrating. I have never felt more capable than having a tire blowout at 80 miles an hour in a 1992 Toyota Tercel and steering it safely to the side of the road. But then I don't fly spaceships, so that's a really low bar.

Matt Shindell:

Yeah. Well, I think even worse than being broken down by the side of the road with a blown tire or whatever inconceivable engine problem you might be having, is when you're a kid and you break down with your dad. And that's the moment in a lot of kids' lives, I think, when they realize their dad can't solve every problem, right? He can't just MacGyver his way through a big engine failure.

Nick Partridge:

It's those moments I think when we all wish that we had America's dad, Tom Hanks-

Tom Hanks:

"Hey kids!."

Nick Partridge:

... to help you through it. He's got such a calming aura about him even in the most upsetting moments, like being stuck in a broken spaceship in route to the moon, as we all saw on Apollo 13.

Apollo 13 crew:

This is the crew of the Apollo 13, wishing everyone back on Earth a pleasant evening.

Nick Partridge:

On April 13th, 1970, about 56 hours into the mission, about 205,000 miles from Earth, and only six minutes after they turned off a live TV camera, there was a loud bang from inside the spacecraft and the spacecraft starts spinning. All the power goes out and I cannot stress how upsetting this would be looking out the window and seeing all of your oxygen venting into deep space. So that's where they're at, that's the baseline. And Jim Lovell played by Tom Hanks says the most famous line in the movie, which is say, it with me, "Houston,

Audience crowd:

... we have a problem."

Nick Partridge:

Funny story. That's actually slightly incorrect. What he said was-

Emily Martin:

He set you up there.

Nick Partridge:

... "Houston, we've had a problem." Because test pilots always spoke in a very passive voice to maintain detachment. It just makes for terrible screenwriting, so they altered it a little bit. So we've got this spinning spacecraft, it's in a perilous place miles beyond reach of people from Earth. How did NASA arrive at a place where they were able to deal with this catastrophic failure? Luckily for the crew of Apollo 13, some of the ultimate preppers in human history worked at NASA in the 1970s. And from the very beginning, NASA simulated every possible thing that could happen when flying a lunar mission, especially thousands of different failure scenarios.

Emily Martin:

Really? Thousands? Thousands?

Nick Partridge:

Thousands. Oh, thousands.

Emily Martin:

Thousands.

Nick Partridge:

Thousands.

Emily Martin:

That's a lot.

Nick Partridge:

So there's the ones that you saw in the movie.

Emily Martin:

Sure.

Nick Partridge:

Using the lunar module as a lifeboat.

Emily Martin:

Right.

Nick Partridge:

Firing the engines out of sequence.

Apollo 13 crew:

Four, three. All engines a go. Two.

Nick Partridge:

Taking all of the navigation data from one computer and plugging them into another computer. Do you remember the square peg round hole problem?

Apollo 13 crew:

The CO2 levels are going to be getting toxic.

Well, I suggest you gentlemen invent a way to put a square peg in a round hole rapidly.

Nick Partridge:

That was something that they had prepared for.

Emily Martin:

Wait, was that when they dumped the box of stuff on the table?

Nick Partridge:

Yes. Yeah.

Emily Martin:

I love that part.

Nick Partridge:

Precisely. Yeah.

Emily Martin:

Make it fit.

Nick Partridge:

So all of those scenarios, but also much more. The simulators practiced what to do if there was a political crisis that might actually impact the mission. They practiced what happens if a mission controller has a heart attack. There are stories of instructors sneaking in with a sheet of paper to a mission controller and he opens it up and it says you're having a heart attack. And the acting was so great, they called 911. Really upset the paramedics. All the way to what happens if an astronaut gets measles, which you may remember is actually something that happened.

Apollo 13 crew:

I just got some blood work back from the lab. Charlie Duke has the measles.

Nick Partridge:

Something else they prepared for? An astronaut forgetting to file his taxes. Remember, this happened on April 13th. For anyone wondering, you get an automatic extension. So by the middle of the crisis, the mission controllers have been through thousands of simulations, the astronauts have been through thousands of simulations. They've worked out a plan to get through this. Better planning was the foundation of the failure is not an option culture at NASA and at one point a mission controller radioed up to Apollo 13, "So how do you like this sim?" And Jim Lovell, ever the boy scout, restrained himself and only said, "It's a beaut." Right. Understatement.

Matt Shindell:

We're going to take a short break. But when we come back, we'll talk more about the culture of failure and why it's actually a great thing.

Nick Partridge:

The Jet Propulsion Laboratory in Pasadena, California is the home to many of the marquis missions of deep space robotic exploration. And they have to balance the idea of failure is not an option, which is the culture within NASA, with a tagline Dare Mighty Things. Here to help us discuss how that balance is between historic NASA and the Jet Propulsion Laboratory is Bobak Ferdowsi. He is internet famous, of course, from his... Yeah. Internet famous from Curiosity, but also had roles on Cassini and Europa Clipper. And you are now a fault protection engineer at JPL.

Bobak Ferdowsi:

Yes, that's right.

Nick Partridge:

Do you quote Apollo 13? Either the movie or the actual mission?

Bobak Ferdowsi:

I mean, I draw a lot of inspiration from Tom Hanks in general, so that's-

Nick Partridge:

Don't we all.

Bobak Ferdowsi:

Yeah.

Nick Partridge:

What is a fault protection engineer?

Bobak Ferdowsi:

I mean, we've had a number of failures, of course, in our missions and that's how I kind of learned that this was an area that people could study. Working on Curiosity we had what we call anomalies because we typically try to state things in either it's nominal and it's going fine, or it's anomalous and it's not. And it covers all manner of sin. So anomalies, including... We had a computer reset three days after launch, as we are preparing to do our first burn to get to Mars. And that's really where I learned about it sort of as a, "Oh, we got to design a system." But that's the first time I really had to encounter it personally. And so I typically describe my job as understanding those possible scenarios in advance and trying to design a system that prevents or tolerates some of those as necessary.

Matt Shindell:

Are there any particular, let's say like Mars mission failures, that you sort of use as case studies for preparing for possible failures?

Bobak Ferdowsi:

When you really understand how things break, that's when you actually truly know how they work. Right? I mean, it's that childhood sense of trying to take things apart to understand how they work. That ultimate test of, I know the theory of how to change a tire or I got to change the tire on that broken car. And so Mars Observer is this mission that we thought we were very clever. We said, "Oh, we've got these amazing earth satellites, they operate for years. Let's take one of those, we'll send it to Mars and then we'll do Mars and it'll be cheap. It'll be fantastic." And what they did was right before they got into Mars' orbit, because of the way they test it, they turned off the radios and prepared for this big maneuver. And then we just never heard from it again, because we turned off the radio. And it seems so obvious in retrospect, that you should communicate with the Earth, particular when you're doing something of interest. And then again, if you do make a mistake, at least get the knowledge out of that mistake to not do it again.

Matt Shindell:

Yeah.

Nick Partridge:

What's the most redundant element of a Rover? What's the system that you can plug-in in a thousand different ways just in case?

Bobak Ferdowsi:

I mean, Curiosity is a great example. Missions like Cassini are what we call our flagship missions. Are where we often... And of course the human space flight has even more of this redundancy to the point where in your... Initially when they did shuttle, they had independent teams code software for shuttle. So that even if you made an error in your code, that another team should, in theory, not make the same coding error. And that is a level that we don't do with Curiosity. Although we do have two versions of software always, one that's the latest version and one's the previous version. We can lose a computer effectively, or at least parts of it, have another computer come online and start poking at it and be like, "What happened? Send me your last bits of data. Let me understand why that computer failed."

Nick Partridge:

Is that the equivalent of changing a tire on Mars?

Bobak Ferdowsi:

It's like the equivalent of having a spare tire effectively. Right? Which is this backup computer. But also it gives us a way of understanding what the failure of the first tire was. Right? And so that once we have the new tire on, we can say, "Well, listen, you're going to have to change the way you drive so that you don't get another blown tire. And in the meantime, drive cautiously on the donut."

Emily Martin:

I've been thinking about it in my brain, the Mars exploration rovers, which were really only supposed to be doing their science for what? Like 90 days, 60 days, something like that. It was an incredibly short mission. And we just lost opportunity after what? 15 years of service. And I'm curious about how the aging of these space robots helps inform your ability to mitigate unexpected failures, right? With an aging spacecraft, things are going to fail because it wasn't meant to last 15 years. It's incredible that it did. So is there a way in which, how those rovers aged and bits started to fail that helped inform the future of those kinds of exploration?

Bobak Ferdowsi:

Yeah, I mean, at various levels. Because obviously the great thing about the Mars program is we can have lots of missions and Curiosity's development started even before Opportunity and Spirit had landed. So you can't learn everything possible from them, but we definitely learn a lot, both from the successes and the failures. So, Opportunity and Spirit demonstrated some of the first levels of self-driving autonomy and the driving. Curiosity benefited from that. In the case as they age, Opportunity also had some kind of near Alzheimer's, where it could not store everything and every day you had to load from memory various parameters. And so as you woke it up, you're like, "Hey, remember all these things that you are supposed to be doing." And it's a pretty amazing... And it really speaks to the resourcefulness of the team.

Nick Partridge:

So 90 days versus 15 years. When you launch a new spacecraft, you put a new robot on a new planet. What's the expectation that it could exceed the advertised life expectancy of a 90-day mission?

Bobak Ferdowsi:

I think we always expect it to exceed that. I mean, and part of this robustness, part of this preventing failures is we test components to three times life often. So, every motor gets operated. If it's two years for Curiosity, it's operated for effectively six years of life and seeing how it does. You want to make sure that it's not a statistical anomaly. That the one thing that you tested and it dies after two and a half years, you're like, "Oh, well that's good enough to meet the two years." Well, what if that was the high end? So you test it for six years and prove that if it makes it all the way there and you do a few of them, it's going to work. And it's kind of the warranty, right? It's like, you want to make sure you have a good enough product that half of them aren't going to fail before the warranty expires.

Nick Partridge:

So in the event of premature failure, would you guys fly the Maytag man up there to-

Bobak Ferdowsi:

That's right. Yeah.

Nick Partridge:

... change out the-

Bobak Ferdowsi:

Personal friend. I mean, we've got him on speed dial.

Nick Partridge:

Yeah.

Bobak Ferdowsi:

Yeah.

Matt Shindell:

So on that note, can I give a little shout out to the engineering models and the test vehicles that actually are responsible for doing a lot of that testing on Earth?

Bobak Ferdowsi:

Oh yeah.

Nick Partridge:

Disclaimer, they are all in his collection.

Matt Shindell:

They are what I collect for the museum and I love them and I want you all to appreciate that they are not just the best possible representation that's not the spacecraft. They're actually mission critical, right?

Nick Partridge:

A plug for his pet robot.

Bobak Ferdowsi:

You know, we fail early in the test program in order so that we don't fail in the flight program, and that's where these units come in handy.

Nick Partridge:

What is NASA's reaction as an agency to an individual failure and how do they prepare you for it?

Bobak Ferdowsi:

So, I mean, we talk... You know, we have the old hands who come and give you the war stories of like, oh, what it was like to be on a Mars Observer, of course. And it's very hard. I have not been through a mission that has truly failed in the sense of we lost it. Part of me is like, I want to have that experience so that I'm prepared for it. A part of me is like, well, you know... Or I could just succeed all the time, that would be great too. But I think in terms of preparation, again, talking about the gremlins, for example... Sorry, I say the word gremlins, but you're talking about giving people the thing like a heart attack during the dress rehearsals. We do that, right? We call that team gremlins, the folks who kind of give you the failures and they inject the failures.

So we test the human element of operating our spacecraft as well as the technical element of it. And so I was called red carded. So during the middle of one of our tests, I was asked to go home with food poisoning and had to leave the room for about two hours so that everybody could prove that they know who to contact in case I wasn't available, make sure that the replacement person could come in, things like that and mid activity. So we are testing that human element as well. As somebody who actually has sent the wrong command to a spacecraft, which is a relatively embarrassing thing to do. Luckily it cost us no more than a day. We basically... The command failed fortunately. We also design our systems so that a human operator, generally speaking, cannot easily do something bad on the spacecraft and ruin it.

Now we have had issues of course, with older spacecraft as teams age out, as a mission lasts for 10, 12 years. That a new team, right? Like a fresh out of college person doesn't know all the little tricks and like, "Oh, don't do this after this or kind of stuff." And sometimes we have had issues with that, but again, we try to build into the system the possibility of a human failure. Very likely actually, case of a human failure, like in my case, where I sent the wrong command one time, but luckily it was ignored.

Matt Shindell:

Well, and I would imagine that on some of these missions where you have the nominal 90-day start, people are working around the clock and it's probably pretty easy to make a mistake in that environment.

Bobak Ferdowsi:

It really is. And I mean, to the country, one of the things that helped Opportunity last so long was a very dedicated team who really understood that rover and spent their every day thinking about how that rover works and what... And they put an extreme effort to try to rescue it after the dust storm on Mars, but that's another case of where investing in the team is a big part of investing in the success and avoiding failure.

Nick Partridge:

It must be really difficult to encounter failure on your own and then try to extract all the lessons from it. Is it important that everyone have the same lesson from a single failure?

Bobak Ferdowsi:

We try to do that, right? We have a team assemble after every failure to understand what the failure was and particularly understand what the lesson learned was. But I mean, my experience has certainly been, you don't always learn the same lesson. If I have a bicycle accident, my inclination is like, "I'm going to get back on my bike, but maybe I'm going to be a little bit more aware that I come to a complete stop at a stop sign or wear a helmet while I'm doing it." And other people might be like, "You know what? Peace. I'm done with bicycling. I'm going to start driving cars instead."

And so it is interesting to see that... I think what we're trying to do, and for the most part have been very successful at NASA, is really get at the core of what caused that failure, right? The grass roots thing. So talk about a failure of a part, a computer, for example, we don't always say, "Well, we got to have two of those." And the next time another part fails, "Oh, put two of those." Instead, we say, "Well, parts can fail. So let's look across the board. Which parts are more likely to fail? Let's strategically choose the ones that need redundancy or good."

Nick Partridge:

Bobak Ferdowsi. That's it for this episode of Airspace live from South by Southwest. Follow us on Instagram @airspacepodcast. All photos curated here by Emily.

Emily Martin:

Airspace is produced by Katie Moyer, Jocelyn Frank, Lizzie Peabody and mixed by Tarek Fouda.

Nick Partridge:

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Matt Shindell:

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Speaker 9:

From PRX.