Ed Hirst

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Erik M. Conway,
Interviewer

Q: I'm talking to Ed Hirst at JPL. My name's Erik Conway. It's the 27th of June 2023. Amazingly enough, the year's half gone.

Ed, please tell me where you were born and how were you educated.

Hirst: I was actually born in Guatemala in Central America, in Guatemala City. My mom is Guatemalan, my dad is American but born in Costa Rica, and he was in the U.S. Air Force, but I grew up not moving around as much as traditional people in the Air Force or armed forces move around. I spent a lot of time in Panama at an Air Force base (Albrook AFS) there.

Then my dad retired and we moved back to Guatemala, so I went through seventh grade in a U.S. system of schooling. Then I finished high school and did two and a half years of college in Guatemala, where I got a bachelor's degree in math and physics, with just the basics of courses. I then managed to get into the University of Texas at Austin and got another bachelor's in aerospace engineering.

From there, I came to JPL in 1993 and have been at JPL since 1993. I started on the Galileo mission as a long-range mission planner, and then from there I went and started on Stardust, which was the first sample return mission to launch since the Apollo days. I started right around PDR, so I was there for most of development, stayed on after launch, and then when

Stardust got kind of quiet after the launch and commissioning, I picked up Genesis and I was also a mission planner there. Strangely, Genesis launched after Stardust, but returned before.

On Genesis is where I got my first jump into mission management, day-to-day mission operations management, but I still had my fingers on what Stardust was doing. I kind of popped between Stardust and Genesis, depending on what events were happening. When Genesis settled down, it just happened to dovetail nicely into Stardust encounter with Comet Wild 2, and then once we got past the comet, I went close to full-time on Genesis and finished that mission out with the first sample return. Even though Genesis launched later, they were the first to come back. Genesis was kind of an interesting experience just in itself, to be a Discovery-class mission and trying to return the first samples from beyond the Earth atmosphere since the Apollo days.

Then once Genesis ended and had its mishap, there was a little bit of time that was spent on supporting the mishap investigation, but then I got clear of that, then returned to Stardust and applied all of the Genesis experience to the Stardust first return. That went off successfully and all the samples got down to the ground intact.

From there, I spent a year writing a document called "The Sample Return Primer and Handbook," and once that was done, I did some proposal work, then ended up on Juno and have been on Juno since then. (Started as a deputy Mission System Manager, then after the Earth Flyby became the Mission Manager.  After arrival at Jupiter, I became the Project Manager.)

Q: What interested you about aerospace enough to go to UT Austin to get a degree in it?

Hirst: I grew up during the *Star Wars* era. I wasn't so much a *Star Trek* kid, even though these days I like both, but I've always been intrigued by space and flight and that sort of thing. I also had aerospace in my background. My grandfather was one of the first airline pilots that flew into Guatemala. There was a route that went New Orleans-Belize-Guatemala, and he was one of the first pilots that did that commercially. My dad was in the Air Force. He was an aircraft mechanic, so planes were always around us. I had an uncle who was a crop duster in Guatemala and he flew, and every time we would go visit, he would take us up in his airplane. My cousin, his kid, is now an airline—not an airline pilot, but he's a charter plane pilot. I grew up with posters of airplanes and jets on my walls.

I was more excited by jets, but there's a funny sort of maybe "This is going to be your destiny" story in my background, because when I was seven or eight, there was a letter-writing exercise in one of my classes, and we were given a list of companies. I happened to, just by the name of it, pick Jet Propulsion Laboratory, but I thought it was about jets. I thought it was flying aircraft and jets. So I wrote this letter saying, "Hey, can you send me pictures of all your engines and all your aircraft? I'm really interested in that sort of thing."

And I got a response, but it said, "Guess what. We don't do aircraft; we do spacecraft. And here's a bunch of Voyager lithographs," if you remember what those were. And that might have been the thing that just started pushing me in that direction, along with the whole *Star Wars* influence. I just felt that there was more out there (in space) that was worth exploring and learning about, and pursuing an aerospace degree pushed me in that direction.

Q: And you wound up on some interesting missions pretty early on. You mentioned you were on Galileo, so were you mission planner for Galileo first?

Hirst: I was a long-term mission planner, so we did things that were a year or two down the road. I remember one of my first major tasks was writing the operating strategy for the release of the atmospheric probe, and I started writing that right off the bat in 1993, and the probe wasn't released until six months before December of '95, when JOI was. So that's kind of the time frame that we would look at. We would look well down the road and set the standards or the basic infrastructure and the strawman plans that the detailed planning would then fill in as we got closer to the event. When Galileo had its first extended mission, I wrote the extended-mission mission plan. So it was really on that time frame.

It was interesting to see how that job was so focused, being on a big project and then going to a small project or a smaller project like Stardust, where the teams were smaller, so that gave an opportunity to do more things. In addition to developing the mission plan on Stardust, I helped with trajectory modeling (thruster forces from the "bang-bang" attitude control system) and things like that. So that was a little bit more experience, and I was able to connect with the Lockheed partners a little bit more. I had more exposure to spacecraft operations and wasn't as isolated from the core engineering that was going on, as compared to on a bigger mission. This was especially true after launch when the development team disappears and you have to fly the mission. Being the mission planner, it was the first step in the planning process, but you then got to watch how the rest of the sequence development and execution proceeded, which helped in setting the ground rules for planning the rest of the mission.

It was that way on Genesis as well. However, I think some of the connection with the spacecraft elements really helped position me to jump into a mission management role, because I built up a good rapport with them and knew what was going on day to day, even though I wasn't doing the day-to-day building. I fell naturally into a management role on Genesis, and then that just dovetailed and snowballed into a similar management roles on Stardust and on Juno.

Q: Did you think the broadening that you got in the smaller project was also part of that preparation for moving to mission management?

Hirst: Yeah, definitely. I mean, when you're the mission manager, you need to know enough about everything to know when to penetrate more deeply and understand how all the pieces play together, and it's essential to have that skill as a mission manager. I loved that part of the oversight role – that you know a little bit or enough about everything and you're not a specialist, but you know how it all plays together and how it all comes together. That, to me, is just very attractive. I was never one to be a specialist. I just loved the broader picture and understanding it all, and then making sure that it played well together.

The instrumentation on both Genesis and Stardust was pretty straightforward. It was pretty simple. It was like two or three instruments, and the focus was in gathering the samples, so a lot of the true day-to-day interaction was with the spacecraft elements. Even though there were the occasional instrument things that we had to pay attention to, the day-to-day operations of the instruments didn't dominate the conversations. But at the same time, there were still enough of the instruments that you still gathered how to interact with scientists and make sure that you were addressing their concerns and that sort of thing. So, yeah, it was really good experience to lead me to mission management.

Q: Was there anything unusual or novel, maybe is a better term, in Stardust operations? Any new concepts introduced or new processes or procedures?

Hirst: Yeah, I think it was one of the first or second time some sort of auto-navigation was utilized. I'm not the subject matter expert on that, but when the spacecraft was approaching the comet, there was one axis that we could control that would be selected by tracking the comet position in the camera's field of view. Also, we picked the flyby direction and the distance from the comet based on dust-cloud modeling. There's probably somebody in the science department that could talk about the dust modeling that was probably innovated, where they were taking pictures of the comet and then trying to wrap that back into the modeling so that we could make a decision on how close to fly to the comet to gather the samples.

I think this was also the first time Aerogel was used to capture comet samples, so that was innovative as well. I don't know if the person who developed that is still around. I don't think he is. His name is Peter Tsou. So I think that mechanism to capture hypervelocity particles—the PI, I think, is still at University of Washington, Don Brownlee, so he would have been involved in some of that as well (https://astro.washington.edu/people/don-brownlee).

But from an engineering perspective, in addition to using the Aerogel to capture it, the navigation team had some AutoNav or some features onboard where, depending on how the images that were being taken tracked where the comet was, it would turn the spacecraft to enable photographs to be taken, and that was a little bit of onboard autonomy that I don't think had previously been used. I think there's still a gentleman here (at JPL) who was the architect of that and maybe even wrote the code. His name is Shyam Bhaskaran. He would be worth talking to about that part of it as well.

I think the other interesting part of both Stardust and Genesis were that despite the need for some phases of the mission to be very precise in navigation, we were dealing with spacecraft with unbalanced thrusters, and that created a whole area of analysis to understand how well the spacecraft performed in certain attitudes and with certain commands. Extensive, I mean extensive navigation modeling was conducted, more so on Stardust than on Genesis. Genesis was a spinner, so that helped tremendously, but it complicated Earth return due to the combination of where the thrusters were located and the configuration [attitude and spin rate] of the spaceraft at the time of releasing the sample return capsule. On Stardust there was enough of the unbalanced behavior that the navigation team was able to create models and really trend it and get a good feel for what that would do for the final Earth targeting. So, yeah, there were several elements for Stardust and Genesis that were new or challenging for what we were trying to do.

Q: Thank you. Talk about the comet encounter with Stardust. What were the key issues that had to be, I guess, preplanned, and what had to be responded to in real time or almost real time?

Hirst: I think it was the two that I was mentioning, that the decision-making and the modeling of the dust—we were flying on the sunward side, so normally—well, comets have tails that get pushed out. We were flying on the sunward side, so it wasn't so much the tail of the comet, but there was still a significant amount of dust modeling to pick the risk between—and the spacecraft had Whipple shields, these shields that were called Whipple shields, at the front, so it was protected, and we had to fly in a certain orientation. There was a whole decision process of taking images, feeding those into the models, updating the models, and then calculating how far we should fly so that we could balance the risk of any sort of destruction or damage to the spacecraft, versus capturing sufficient samples of the comet dust.

The other challenge was what I was describing about the attitude, seeding the onboard software with where we thought the comet was after a series of OpNavs, and then allowing the onboard software to make the decision to turn the spacecraft to keep the camera that we had onboard able to take images as we flew past the comet.

Those were the two key things that I remember were the focus of the team, and it was a strange—not a strange balance. It was an interesting balance between what we did at the comet to make sure we were gathering samples versus what we did to acquire science with the camera. But it was just kind of a mindset, just make sure that you're not risking the sample collection because of something you're doing with the camera, although this one degree of freedom that we had was a nice balance in the design to make sure that we could do both, because the comet collection, the dust collection, didn't really care about this roll axis that we had the freedom to change. As long as we were flying through the right part of the dust cloud, we would gather the amount of samples we needed to. Yeah, I think those were the two things that I recall being the biggest topics of discussion.

Q: And a similar question about Genesis. Though it's a longer sample collection from—I guess it was an orbit around L1, what were the decisions criteria to begin sampling and then changing collectors and so forth? In a previous interview, you mentioned that a lot of that was automated with Genesis, so talk about that.

Hirst: There was actually one thing that happened before we even got to sample collection, and there's probably more detailed references on this somewhere in the system, but the sample return capsule was painted with a white paint, and if I'm recalling this correctly, the capsule itself started to heat up more than was predicted, so we had to crack open the shell so that we didn't violate any thermal conditions, and we had to study this paint to determine, while we were collecting samples, whether we would violate any thermal limits on the inside and the outside of the capsule. If I recall right, that delayed the start of sample collection for something like six months until we figured this out.

But once the collection started, there were two main sample collecting components—well, there were actually maybe three, depending on how you count them. There was a solar wind concentrator in one part of the capsule. The challenge with the concentrator had to do with two high-voltage grids that were at the front end, and we ended up having these high-voltage sparks or discharges from one grid to the other, which would cause the high voltages to shut down. We ended up determining or thinking that it was a manufacturing problem where there were things (wire protrutions) that were too close to each other. As the high voltages increased on these two grids, you'd get sparking or arcing over, and it would shut down the system. To address this, there was automation that was put into place to detect that the discharge had happened and in response reboot and restart the concentrator system (the scientist in charge of the concentrator was Roger Wiens, currently the PI for "supercam" on M2020) – it ended up that it was benign to automatically reboot and restart the system. But this concentrator was an important part for certain elements of the science to concentrate certain ions onto different parts of the target that was on there.

The other thing was the [sample] collection arrays. There were, I believe, four arrays. Three of them could move. The deployment of the arrays was commanded by an onboard autonomous process – Genesis had two instruments that were measuring the solar wind, the GIM (Genesis Ion Monitor) instrument and the GEM (Genesis Electron Monitor) instrument. They were developed out of Los Alamos in New Mexico, and they would sense the solar wind and the onboard processing algorithms would determine the speed of the solar wind. A specific collection grid would deploy or stow, depending on the solar wind that was being detected by these instruments. Those algorithms had to be tweaked a little bit as we got experience. Each of the collection grids had octagonal wafers that were of different materials and different thicknesses, because the science just wanted to be comprehensive about the possibility of capturing the ions. There was a static array at the top of the stack and then the solar wind-specific arrays would deploy or stow, depending on what the GIM/GEM instruments and associated algorithms would determine the solar wind was doing. So that, I think, was pretty innovative at the time as well.

There were also some collectors, just bulk collection, on the inside of the topside of the lid of the sample return capsule. When the capsule was in its sample collection configuration, those collectors would be exposed to the solar wind – so the design took advantage of almost every surface available to do the sample collection.

Operationally, all of this automation made it pretty routine, except the occasional thing where you would get an instrument response that you didn't expect and you'd have to look into it and fix it. Once we got past the (white paint) thermal problem, we were able to collect for the full time we had intended; after the team got everything deployed and up and running.

Q: I assume after the end of sample collection on Genesis is when you go over to start preparing the return, so talk about that.

Hirst: So the interesting part of that history is twofold. One is just internally to the project, we knew that we were doing the first sample return since the Apollo days and that we were the first of at least two and of hopefully a series for NASA. The Japanese (JAXA, the Hyabusa mission) have done things since then. But, there was two facets that I personally found interesting. One was just the project mentality, along with the institution, of "You're setting precedents with what you're doing here." So we came up with this concept of generating documents (Entry Targeting and Entry Safety Plans, Vol 1 Safety and Vol 2 Go/No Go processes and criteria; in use today by OSIRIS Rex – returning to Earth in Sep 2023) that would address the hazards on the ground to property, and personnel – all of measures that were based on doing the right thing so that when you return the capsule you don't hit anything that you shouldn't be hitting, while meeting the documented requirements; for the range (Utah Test and Training Range) and with NASA.

More importantly, there was a lot of discussion of "This capsule will probably survive entry and land in other places outside of the Utah Test and Training Range, but was that really the right thing to be doing?" To address this, Genesis set some criteria that were pretty stringent in terms of "If you're not going to fall within the range, you're not going to come back. If you're going to violate one of the requirements to protect property or personnel, you're not going to come back (meaning we wouldn't command the release of the SRC capsule)." So we had this internal dialogue going with Gentry Lee, who played a big role in this part.

As an aside, another characteristic of this decision process is that the default condition on-board the spacecraft was to not release the capsule. Normally, we (as in the larger we/space operations in general) program things for success and we only send commands to intervene if things are going poorly. For sample return missions, we set the precedent that the default was not to release the capsule and that we would command the release activity only after we had proven that it was going to be safe. Genesis set this precedent, Stardust followed suit, and OSIRIS-Rex has also followed that precedent.

The other part that most people probably don't know or might not appreciate is the fact that we had done a lot of work under the institutional radar because at the time Genesis was overlapping with MER, the rovers. The rovers landed in January of 2004 and February of 2004. (Genesis Earth return was scheduled for Sept 2004). My spouse and I, we have this joke where once the MER landings on Mars happened, the institutional "Eye of Mordor" shifted over to Genesis. We had a bunch of people who had all this Mars EDL (entry descent and landing) experience come over to look at the Genesis plans and our processes and what we were planning to do. The entry and descent stages of the rovers had a lot more capability – a lot more ability to fine-tune the entry parameters. Being a Discovery mission, our return capsule did not have anything like that. The EDL process was firmware. There was one sequence of events that was going to be followed, and we didn't have a way to change or fine tune any performance parameters. The capsule was built this way and we release it, and it does what it's going to do, and make it through the atmosphere. We could change the delivery targeting, but we couldn't change anything about how the entry capsule performed. And all these people had come over from MER, where they had more capability to change it, so there was kind of a culture shock [laughs] of going from something like EDL on the rovers to EDL on the Discovery platforms that we were flying.

In the end, it all worked out. They came in, they asked a bunch of questions, they became comfortable with the risks involved, and we proceeded, but those first few meetings were intriguing, to say the least – the difference of technology that we had available between the two programs.

Q: It is interesting that NASA decided to do the first sample returns in the Discovery program, which is supposed to be cost-capped and low risk.

Hirst: Right, right. You also have to recall that this was during NASA's "faster, better, cheaper" phase. We (both Genesis and Stardust) were approved to fly in that same era, and we were probably the last ones, because after the '98 series of failures, NASA kind of—the pendulum swung in a different direction, but we were already too late in the development or flight pipeline to make changes. We didn't have a lot of money. We did get additional funding in the last year of both Genesis and Stardust to shore up the robustness as much as we could, given the vehicles that we had flying. We had very little ability to change what we were flying, but we could improve the risk assessment process and at least expose those risks to the institutions involved and to the agency as we were getting ready for Earth return.

Stardust Earth return benefited tremendously from the experiences on Genesis. Perhaps the pendulum swung too far, because in the primer that we wrote, it shows that the amount of review activity that happened on Stardust as a result of what happened on Genesis (i.e. the mishap) was significant. There was a significant amount of external review and oversight on Stardust compared to what we did on Genesis (29 external reviews on Stardust in the last year).

Q: None of which could actually change anything if anything went wrong.

Hirst: Right. Well, we could change how we were releasing things and how we were targeting things, but as far as the capsule, how it was going to perform, we couldn't change any of that. So we went through all these processes to convince ourselves that we had a good chance of success, enough of a chance of success that we would push forward.

The mishap on Genesis had nothing to do with that whole part (the flight operations). I mean, we couldn't have done anything to detect in flight that the G switches were inverted on Genesis. The inversion was found fairly quickly after the mishap happened. However, the mishap process continued with its process, trying to find all the tendrils that could have led to the inverted G-switches and all the pre-launch functions that should have helped detect the error. But as far as mission operations, all of those events were perfect except for the fact that the vehicle didn't know it was going to hit Earth and it didn't know it had to deploy its parachutes. [laughs] (also see https:// www.nasa.gov/pdf/149414main_Genesis_MIB.pdf).

Q: Yeah, unfortunate. You mentioned targeting and so forth, and I think there was something about having to develop kind of go/no go criteria, whether or not you were actually going to release, depending on what the entry was going to look like. Were you involved in developing that?

Hirst: Yeah, I, along with Gentry and others on the team, we were the architects of that whole process. The Genesis experience set a baseline, and we matured that same baseline on Stardust. I don't have enough visibility into what OSIRIS-Rex (I do since, and they are following a similar paradigm, but with improvements – see Ron Mink from GSFC/OSIRIS-Rex, but they are a New Frontiers Mission) and what MSR's considering, Mars Sample Return (POC might be David Way, a JPLer) is considering, to know how much of that heritage is carrying over, but it was important for us to be in constant communication with the institution and to be in periodic communication with Headquarters so that everybody was walking along the same path on what we were doing to develop these criteria so that we didn't arrive at the readiness review and have somebody object strenuously. So we did a lot of pre-reviewing and pre-briefing to make sure that everybody was marching along with us on the same page.

But at the same time, we had fun with it as much as we could. We called the "go" criteria, if we were go, it was the "green button", and if we were to stop, it was going to be the "red button". Jim McClure actually built a—I forget what he built it out of. I could probably find a picture of it. It had a red rotating siren on the top, and it had a big red button on the side. [laughs] You could hit that and it'd go [demonstrates]. That was the big red button. I think we had that in the MSA on return day off to the side. We probably didn't want it in any of the press photos or anything like that. [laughs] It was fun to do, actually, to be in that place where you know you're plowing new ground and you're keeping everybody aligned as to how we're doing it and all the considerations we're taking into account, and just feeling that we were setting a standard of excellence to how this should be done.

And then on Stardust, it was just being able to refine those concepts and make them more palatable and apply the lessons, address some of the awkwardness of going through it the first time (Genesis), apply those lessons to Stardust. The Stardust architecture was very similar to the Genesis architecture in terms of Earth return criteria.

As far as at JPL, the team, the two primary people who were involved (on Genesis) in both that and the entry safety part of it was myself and Tom Wahl, who's no longer at JPL. We both then went over to Stardust and did the same thing, but did it more efficiently and better. We improved it as much as we could.

Q: Could you give me an example of what's improved between the two?

Hirst: Well, the most obvious example was actually for the ground recovery part of things, and I wasn't involved in the detailed planning of that, but we were much better prepared for things to go wrong once the samples hit the ground on Stardust. Post Genesis, the recovery operations were the big elephant in the room – the perception of how we handled the mishap (both relative to recovery operations and in dealing with the press). The post-impact operations on Genesis was not the best – we were much better prepared on Stardust. Luckily, we didn't need all that on Stardust.

As far as from a criteria standpoint or from Earth entry safety, the Earth entry safety part of the preparations just went more smoothly because we knew the steps we needed to take in advance – steps to assure everybody that we were going to be okay to enter on the vehicles. This included things like getting three separate assessments of burnup and breakup of the vehicles that were entering the atmosphere, if an anomaly were to occur – you know, what would survive to the ground, that sort of thing. The work scope was just known from the get-go, so it was much smoother to get all that up and running.

Criteria-wise, I probably have to look at my notes to really pull out a difference. There were enough differences between the vehicles, because Genesis was a spinner with unbalanced thrusters and Stardust was also unbalanced with “bang, bang” three-axis stabilization. So some of the criteria, like the Genesis criteria were in some ways a lot more complicated because we had several targeting steps that would shift where we could hit on the ground (as we rotated the vehicle, spun it up) and got it ready to release, but we weren’t as vulnerable to a safe-mode entry. On Stardust, it was easier to get on the landing target, but we were more vulnerable to the targeting going off in one direction or another if we had a safe-mode entry.

If I was to pull out another one, it would also be relative to work scope/coordination. With the experience of having gone through Genesis, we knew what we needed to do to get through it all, and we knew the benefit of pre-briefing everybody and keeping them informed, so we could do that in a more structured way and not necessarily have, like, offshoot briefings. We knew we could benefit from just people attending the reviews or the briefings that we already had planned, so we weren’t kind of chasing our tail as much. When the institution started to pay attention to Genesis, we were six months out from return, and there was a lot of work that was packed into those six months that we hadn’t necessarily foreseen because we were a small Discovery mission doing what we could afford to do, with what our budget was, to get to the end game. Then the institution and Headquarters started paying attention. “We would like to see all this other work be done.” So that’s where the influx of money came and help came. But, still, it was six months of time, whereas on Stardust, we started a year out and we pre-negotiated all the extra help that we were going to need. So it was a just much more organized process going through it a second time.

Q: So the future sample return missions simply need more time than the six months they had for Genesis.

Hirst: Well, and I think a lot of them are started in development, you know, a luxury we didn't have on Genesis and Stardust. Earth return was this thing that was in the future, after launch, "We'll worry about that then," whereas now I think people appreciate the value of doing a lot of the work that we did in the last few months early on in the mission development to understand the influence of Earth return to the basic mission architecture. I think both OSIRIS-Rex and Mars Sample Return, my exposure to their work confirms that they're paid attention and continue to pay attention now to a lot of the things we did – laying the groundwork early, based on the experiences that we went through late. So that when they get to Earth return phase, they're really just implementing what has already been designed both operationally and on the vehicle. So they've paid attention and they've taken advantage of the groundwork that we (Genesis and Stardust) laid. It's great to know that.

Q: It's great to know that they're learning from a previous project. I knew about your primer. I have a copy sitting on the desk next to me. But not everyone actually goes back and reads a document from twenty years ago. [laughs]

Hirst: Right, right. Somebody from OSIRIS-REx, reached out to me recently and said his version of the primer has dog-ears all over the place and little tabs all over the place of things that they've looked at and are learning from. There's no bigger compliment than that.

Q: So I think you said in the previous interview it was Gentry that scraped up the money to have you write the primer?

Hirst: Yeah, he convinced somebody at Headquarters to give us—I forget what it was. It was half a million dollars or something like that. We took the better part of a year, maybe nine to ten months. We got subject matter experts in navigation and systems engineering and on the spacecraft and in recovery, programmatics, things like that, and I was the editor and I wrote a few chapters myself, but we put this together and convinced NASA to publish it publically.

And the other thing we did that was not necessarily released to the broader community—it was available when people asked—was we put together a library of all of our documents, all of the reviews we went through, so that this was all in one place and people could go take advantage of all that information.

(It is now all posted here: Documents > 02 STARDUST Docushare Files > Documents and records from Sample Return Primer and Handbook; https://alfresco.jpl.nasa.gov/share/page/site/stardust/folder-details?nodeRef=workspace://SpacesStore/3cccdac3-72f1-4d8e-9513-1665d2a122db)

Q: I haven't seen that. I don't know if that still exists. I just have a paper copy of the primer.

Hirst: It exists. I have some CDs, which I know is kind of disappearing technology. I need to find a place where to put that institutionally on some repository so that it doesn't get completely lost. I've shared it with whoever's asked, so if you want a copy of it, I can get one to you. I can either give you a CD or let you borrow it to copy onto whatever you want.

Q: I can borrow it to copy it onto the laptop, assuming I can find a CD drive that will actually work on a current MacBook. [laughter] It's strange the way the technologies have evolved.

Hirst: Yeah.

Q: I'm not prepared really to ask you much about Juno just because I haven't spent any time looking at that mission yet, but you go on to Juno. Were you the mission manager for Juno when you first go onto it?

Hirst: When I joined Juno, it was also around the PDR time frame, so I come in as a deputy mission system manager. Steve Matousek was the system manager and I come in under him. I stay a deputy through Earth flyby, which is about two years after Juno has launched, and at that time I become the mission manager and I stay the mission manager until about a year and a half after orbit insertion, and then I become the project manager, and that's where I am right now. I'm the project manager, and now we've completed our prime mission and we're pretty much two years into a mission extension, a four-year mission extension, so we've got another two years to go before we either run out of money or run out of vehicle.

Q: [laughs] One of those two things.

Hirst: Yeah, because we're in the radiation belts and we've only got so much fuel, so it's kind of a race condition. It's really a race condition between the radiation and the fuel we have onboard as to which would expire first. Right now things are still going fairly well. There's a few radiation challenges that we're dealing with on some of the instruments, but they're still running and ticking.

Q: I know Galileo had a lot of radiation incidents and damages in its operations.

Hirst: Right, right. There's a few people that were on Galileo, like myself, that are actually on the program, so we have a little bit of that experience around, but Galileo was a very different vehicle than what Juno is, and the way we manage radiation is very different as well, so there's only so much—it's only kind of skin deep what you can do to compare Galileo to Juno, but it's interesting to try. [laughter]

Q: The electronic parts are dramatically different too.

Hirst: Right.

Q: I understand the nature of the components matters.

Hirst: Right, right. And they (Galileo) radiation-hardened each of their parts, whereas we (Juno) built this radiation vault and stuck the most sensitive parts inside the vault, so it's just a different approach.

Q: What haven't we talked about but should have, relative to Genesis and Stardust?

Hirst: I guess the only thing that I would maybe say a little bit more about is just the whole Genesis mishap. I mean, that was devastating in many ways, and it ended up being the outwardfacing side of the project in terms of readiness for being able to talk publicly about what had gone on (recall the Genesis capsule was going to be snatched out of the air by a helicopter). That's another big lesson learned from Genesis, because when the mishap happened, I think it just caught everybody flat-footed, and if you go back and you look at how the press was handled and the post press conference, there was this dichotomy between those that were like, "The samples are on the ground. We're going to get good science out of these samples. We just have a little bit more work to do," versus those that were just kind of shocked [laughs] and were in just a state of shock about what had just happened, what they had just seen. I mean, I was probably lucky that I was back here at JPL, and by that time was at home [laughs] wallowing in whatever wallowing I was doing.

But again, by the time we hit Stardust, we had a lot more in the pipeline ready to go, should something similar happen. And there was a few of us in the Stardust MSA that had also been in the Genesis MSA, and during EDL for Stardust, there was a few times where the indications from the vehicle were not what we predicted or they were a little bit off, and the three or four of us were looking at each other like, "Is this happening again? Please no." And then the drogue chute popped out, the main chute popped out, and everybody was happy. From then on, it was great. But it's an experience that I think—not that we want to promote failure of anything, but going through that, through a mishap like that, creates a lot of growth and resiliency.

I used to keep pictures of the Genesis crash on my wall as I was preparing for Stardust return, and people would come in and be like, "Why do you have that on your wall? What are you trying to remember?"

I'm like, "Well, I'm trying to not let that happen again." [laughs] Even though, again, operationally we wouldn't have done anything different.

So that's probably the only thing that you might want to do something with.

Q: My boss was Blaine Baggett, and he's told me that their public presentation after the Genesis mishap was not great—

Hirst: Right.

Q: —that people said the wrong things, that the people that they really needed before the camera were disappearing, and so on. I haven't done anything with that yet, but maybe I should. One thing I want to do in the book is more with the public face of JPL. I'm just not sure how to do it. That's a little challenging for me to figure out how that should be in there.

Hirst: The other thing that I'll mention just real quick is even that public perception also affected the way recovery operations were done, because one of the most publicly visible mistakes, if I can use that word, on Genesis was the fact that one of the sample recovery people, in his mind, he followed all the proper procedures, but the way it looked on the screen was that he approached a damaged spacecraft without being careful. There's a picture where the capsule is broken open on the ground and he's looking inside and he's trying to determine what the state of the battery is and that sort of thing, but he doesn't have any PPE on, he sort of rushed up to it, and so all of the leadership part of the institutions on both sides were like, "That just looks wrong, and we shouldn't do that." So in the end, he wasn't allowed to participate as fully on Stardust as he might have wanted, but we learned a lot from that as well.

Q: Great, great. Well, we'll talk again about Juno when I know something more about it.

Hirst: Okay.

Q: Thank you for your time. I'm going to turn off the recording.

[End of interview]