DISCOVERY 30TH ANNIVERSARY ORAL HISTORY PROJECT
EDITED ORAL HISTORY TRANSCRIPT

STEVEN BRODY
INTERVIEWED BY SANDRA JOHNSON
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JOHNSON: Today is June 9th, 2022. This interview with Steven Brody is being conducted for the Discovery Program 30th Anniversary Oral History Project. The interviewer is Sandra Johnson. Mr. Brody is in Arlington, Virginia, and talking to me today over Microsoft Teams. I appreciate you working through the technical issues so that we could talk today.

BRODY: You're welcome.

JOHNSON: I want to start first by asking you about your background, your education, and how you first came to NASA.

BRODY: Okay. I guess I'm one of those proverbial children of Apollo. I grew up in the '50s and '60s in West Philadelphia. I'd say that I was always, from the earliest times that I can remember, fascinated by the rocket launches. I remember using my father's binoculars that we used to use to go to the Philadelphia Phillies baseball games. But I liked to look at the sky and ponder, wow, look at how many stars are up there, much more than the eyes can see. With the Apollo Program, well, actually Mercury, Gemini, and Apollo, that made it very clear the direction I was going to head. My dad would joke that I was taking up space as a kid, and I just kept on doing it as I moved into a career.

That led me to study physics at the undergraduate level at Drexel University [Philadelphia, Pennsylvania], and that's a five-year co-op program at Drexel University. My internship, my work-study part of that, the work part of my five-year program, was in missiles in space and trajectory reconstruction, and all kinds of computer modeling having to do with rockets and spacecraft. At the end of that, having worked with some people and seeing that most of them had masters' degrees or more, I felt I needed some more education. I was fortunate to get accepted by MIT [Massachusetts Institute of Technology, Cambridge] to study in the aeronautics and astronautics department, so that's basically going to study rocket science at MIT, which was of course a thrill. Finished a master's thesis involved with planetary science with a professor who was well known in the dynamics of the planets and how their orbits can help test [Albert] Einstein's theories and that sort of thing.

I could have stayed there, and I know one of my advisers said, "Well, how could you leave with just a master's? Even the people who are doing secretarial clerical work around here at MIT have masters'." But I'd been in school at that point for eight years as well with my five years of undergrad, three years including working on a thesis in a pretty esoteric area. The [Space] Shuttle was being developed, and I decided I'm going to get out. I wanted to be an astronaut. I knew that probably growing up, and I was worried that my eyesight—I actually did try to get into and had some preliminary steps to get into one of the military academies, the Air Force Academy. But I recall being told that given that my eyesight was not 20/20 uncorrected, I wouldn't be able to fly. That's when I lost interest in a service academy undergraduate career, so I went the rocket science route.

But then the Shuttle Program came around, so in I'd say two steps, one was finishing and getting out of MIT and going after my first job, the same time I applied to NASA for the first astronaut selection of the Shuttle era. That was the 1978 [astronaut] selection. In the meantime I had interviewed and accepted a job to work on a test that would be part of the process to launch the very first Shuttle, the STS-1 as it was called. I was involved with a small team at a small company. It was a spin-off of MIT to do just that, to help NASA in preparing the Shuttle for its first launch. I was waiting for the decision, which came back, a nice thank-you note for your application to the Astronaut Program, we got so many different applications, and we're sorry we can't take you this time around.

I applied multiple times but was never selected. My second time around in 1980 I got close to being called in for an interview. But through some background information I learned that I was just right on the cusp and didn't quite make it. Later on when I became a parent, I decided my priorities in life had changed, and I stopped going after the astronaut job. But I was involved in the Space Shuttle Program during the eight years in industry before I joined NASA. Five of those eight years was specifically working on the final vehicle tests before launching the Shuttle for the first six flights of the Shuttle. It was a fascinating project. I got to climb all over the actual flight vehicles and work in NASA and industry facilities and simulators, including Rockwell's avionics lab in Downey, California, and what was then called the SAIL [Shuttle Avionics Integration Laboratory] at JSC [Johnson Space Center, Houston, Texas]. That's when I got to meet many of the 1978 class of astronauts, the group I had first tried to join, as several from that class would be paired up with me sitting in the cockpit of Shuttle mockups doing these tests that we were performing on the Shuttle, and they were candidate astronauts at the time, they hadn't been assigned to fly yet. I got to know a bunch of them while working together, often on second or third shift (4 PM to midnight, or midnight to 8 AM).

Through that process, my team got fairly well known to the NASA people at Johnson, and as well at Florida [Kennedy Space Center, (KSC)], where we did the final vehicle integration and testing that my project was involved in. Through that process I met John [W.] Aaron, who at the time had been head of avionics on Shuttle. He had a long history going back to the Apollo missions including helping on the rescue on Apollo 13. There was a point at which I started to wonder what should be my next step after I finish the Shuttle work at this company. I was in a corporate position. The company had asked if I would move to their Houston office, which I did, and take on a corporate role in business development and also lead an effort within the company to gain a role for it on the Space Station Program. That's what was then just starting to be formulated at NASA.

John Aaron had just been selected as the deputy for the Space Station Program. Neil [B.] Hutchinson was the program manager, and John was his deputy there at JSC. I found myself on the same plane probably from Houston to Florida with John, and I privately asked him a question. I said, "John, you know what, I want to come to NASA and formally be part of the Space Station Program."

He asked me, "You sure you want to leave industry, come to government? Most people go the other way. You're not going to make as much money."

I said, "John, that's not what motivates me. I want to be a part of NASA," and I saw Space Station as a challenge of management, a challenge of international cooperation. I had already had my technical challenge having worked on the Space Shuttle Program, which got to flex my engineering skills and physics skills and had a great time of it. But 12-hour days and little sleep was not what I wanted to do, and I really wanted to be involved in the Space Station Program.

John said, "Okay, let's see what we can do." Six months later, going through all the processes to get hired as a civil servant, in January of 1986, which was a prophetic year for me to join, but that's when I joined. Three weeks later I lost a friend and colleague of mine commanding the *Challenger*, [F. Richard] Dick Scobee. I had worked with him as a candidate astronaut, and we had done some acrobatic flying together in a little plane he had. He and Ellison [S.] Onizuka, who were both on *Challenger*, had been drinking buddies of mine sometimes, and when I would come to Houston. And when I joined NASA to work on the Space Station, Ellison Onizuka, Lorna, his wife, was in the International Office where I was, so I got to know her as well. Of course three weeks after I joined NASA we had the *Challenger* accident, which was so powerful to all of us, and so tragic. I remember President [Ronald] Reagan coming and giving a speech there at JSC.

It took a while for many of us to come back strong. Part of that process, there was reorganizations that happened. Long story short, it's available in my LinkedIn bio and elsewhere, I was able to do some things on Space Station, and then get what to me was the prize job, which was I got to be the first liaison for NASA overseas for the Space Station Program.

I was assigned the European liaison job, and I went to the Netherlands in January 1989, where my office was at the European Space Agency's ESTEC [European Space Research and Technology Centre] facility; it's sort of like Houston and Goddard [Space Flight Center, Greenbelt, Maryland] and Huntsville [Marshall Space Flight Center, Alabama] rolled into one facility along the North Sea in the Netherlands. I spent four years there as NASA's first Space Station representative overseas, and NASA also placed individuals in Ottawa for the Canadian interface [Canadian Space Agency, CSA] and in Japan for the Japanese interface [Japan Aerospace Exploration Agency, JAXA].

Around '90 [November 1989], the Berlin Wall came down, and the Soviet Union collapsed. NASA went through a whole process of reaching out to and formulating a partnership on the Space Station with the Russians. When that was sort of sealed was around '93, and that's when I came back from the Netherlands, and came into what was then the [Space Station] Program Office that had moved from Houston in the interim. It had moved from Houston to Huntsville, back to Houston, up to Washington [DC], where we worked in L'Enfant Plaza in Washington for a while, until an office was selected in Reston, Virginia. We had a program office there, which I only worked in for nine months. I came back to it after finishing my liaison position for Space Station, and that's when NASA decided to close that office and move the program office back to Houston. All of us who were in Reston in the program office went through a job fair and we were offered jobs at various NASA Centers or NASA Headquarters.

I joined a little office at Headquarters that was part of the precursor to SMD, the Science Mission Directorate, then called the Office of Space Science [OSS], which was also going back more to my academic roots. The office was called the Mission From Planet Earth Study Office. It had a quite lofty and poetic name. At that time it was decided NASA's missions were not—we weren't on any kind of fast track to go back to Mars or go back to the Moon, but this little office was to try to keep the dream alive for that by merging some of the robotic work, especially robotic work towards Mars, as a synergistic component of what the human spaceflight side was doing, which was building and operating Space Station, to try to keep basically the likelihood alive that NASA would go back to the Moon or on to Mars.

The little office I was in invested in technologies like the use of in situ resources on other bodies, beamed energy, and some other technologies like artificial intelligence. Then my first involvement in the Discovery Program came in 1997. In 1997 we were reorganizing. The Office of Space Science either at that time, shortly before, or shortly after had merged with the Office of Earth Science to become the Science Mission Directorate. I'm not quite sure the chronology there. I was put in a department led by Ken [Kenneth S.] Ledbetter and assigned as a program executive.

That was the time where the people at NASA Headquarters, the program offices, were migrated to the NASA field centers. Those remaining at Headquarters who would be involved in programs or projects had the program scientist or program executive or program analyst titles given to them based upon their expertise, with most of the engineering types on the executive side, the program scientists with a scientific background on that side, and those doing the budgeting and the policy assigned the analyst role.

Ken Ledbetter asked me in, I believe, February 1997. He said Bill [William L.] Piotrowski had just retired, and Bill had been the program executive for a number of Discovery missions including Lunar Prospector.[1] At the time the way the labor was divided, it was by center. Bill had the projects that were at NASA Ames [Research Center, Moffett Field, California] and JPL [Jet Propulsion Laboratory, Pasadena, California] and others had projects at different Centers. Ken said, "Would you take over for Bill's roles?" He had Lunar Prospector and he also had SOFIA, the Stratospheric Observatory for Infrared Astronomy, the 747 with an infrared telescope from Germany. Lunar Prospector was about a year from launch, and I was assigned to work on it, and that was my first dipping my toe into Discovery. That's how I came to Discovery. I'll stop there and I probably was more long-winded than you would have liked.

JOHNSON: No, it's very interesting. That time with ISS [International Space Station] and everything at Reston, that whole period, we've interviewed other people about that. It's such an interesting time period and complex, everything that was going on. Looking at all that different

[1] Lunar Prospector orbited the Moon to map its gravity and surface composition and was first to find direct evidence of water ice at the lunar poles.

experience and then that international experience, how do you think that that prepared you for this experience as a program executive with Discovery?

BRODY: I felt quite comfortable in it. One thing I did do, just immediately prior to that, as reorganization was happening and the Offices of Space Science and Earth Science merged into Science Mission Directorate, Wes [Wesley T.] Huntress had been the AA, Associate Administrator, I guess. I don't know if it had moved to Mary [L.] Cleave or somebody else yet. But in that timeframe, I also was asked to be the Science Directorate's representative to General [John R.] Dailey's management team in the front office, which produced the first red book, which was NASA's strategic management plan. In that we said, "Program managers are going to go to the field centers." So I was a part of thinking that through and looking at it from a Science Mission Directorate perspective. So when I finally became a program executive, I had bought into this idea.

Part of it was Administrator [Daniel S.] Goldin had said, "We are going to reduce the size of Headquarters dramatically." We were I think 2,700 and we went down to 950 or 1,000. It was either retirements or move to field centers or quit or whatever. I think part of that was this red book team trying to define how we could reduce the scope of the work done at Headquarters. So I guess I was quite comfortable with the idea that I was going to be a program executive. I was not going to have budget authority as a program manager. In my case I was asked to look over the shoulder of both JPL and NASA Ames missions that came out of the space science side of the Agency. Lunar Prospector was at Ames, as was SOFIA, and a couple of other Discovery missions came along a bit later for me that I was assigned to, Genesis[2] and Deep Impact[3], and then a few missions of opportunity and some others.

But I guess Ken and I had a good relationship. We had worked together in his prior role. He was then assigned director of the division. I was one of his program executives. I would attend the reviews. I think he liked the fact that I had had a lot of different roles. I had been a system engineer right out of school working on Space Shuttle, became a project manager for that in industry for that mission. I had this physics background, so it wasn't just a nuts-and-bolts kind of engineer. Then I had this international experience and saw how others did it. I think we worked well together, and part of it was that I felt comfortable and Ken seemed to endorse the way that I played that role. In other words I was not going to know everything down to the depths of knowledge. I guess there was the old phrase that [President Ronald] Reagan used with [Mikhail] Gorbachev: trust but verify. I would trust that the program manager at JPL and at NASA Ames that I interacted with were the most knowledgeable at all the different details a program manager needs, plus their VPs so to speak, the people that would be their head of engineering or whatever. That's where the knowledge is.

My role was trying to make sense of all of it across the disciplines of schedule and cost as well as technical challenges. Where I did have some insight, like in the testing world, since that's where I spent most of my time on the Shuttle, or just basic science kinds of background, I would try to ask leading questions. Have you looked at this? Have you worried about this? I remember from reports about the failure of *Challenger* [STS-51L], *Columbia* [STS-107], or whatever that there was this problem. How are you dealing with it in the project? I would focus more on the

[2] The Genesis spacecraft spent more than two years collecting samples of the solar wind and brought the sample canister back to Earth where it parachuted to the ground.

[3] The primary mission of NASA's Deep Impact was to probe beneath the surface of a comet.

top-level kinds of questions, also looking for things that might fall through the cracks because they were sort of interdisciplinary.

In a nutshell it was a new challenge for me. I was ready after a four- or five-year break to be back on missions where there were real deadlines. After having worked on the Shuttle and the Station, I needed that break, and now coming back to be involved with a lunar mission, Lunar Prospector, was a great joy, because I really saw that as our next stepping-stone for humanity even in the midst of all the Mars versus Moon debates that were going on within the Agency. I clearly felt we needed to learn a whole lot more about our celestial neighbor the Moon.

JOHNSON: You were there at the beginning of Discovery at Headquarters. Wes Huntress basically came up with this idea of how to fly these low-cost, high-flight, community-defined planetary science missions. Of course Dan Goldin was famous for faster, better, cheaper.

BRODY: Many of us learned after the fact, after a few failures, faster, better, cheaper, pick two. You can't have all three.

JOHNSON: Yes. I've heard that from several people. Talk about that beginning time of Discovery when the Program was just getting off the ground, and why NASA decided to implement this program, this PI [principal investigator]-led program, which was not something that had been done as far as most of the missions that NASA had anything to do with.

BRODY: Yes. I wasn't involved in those earliest discussions. When I started out in February of '97, I believe it was already NEAR [Near Earth Asteroid Rendezvous],[4] [Mars]Pathfinder[5], and Lunar Prospector had been selected. I think it was '97, Pathfinder landed on Mars. I remember hearing people saying, "Well, we put Pathfinder into Discovery." It wasn't really a Discovery mission at the beginning. I'm not sure if NEAR was in that category as well. Those were sort of like the two that were coming along, either had landed or were on their way. Maybe in NEAR's case it was on its way to the asteroid. Lunar Prospector was still on the ground being finished and the main focus of our technical investigations on Lunar Prospector was more about the rocket because we were going to use a modification of a Lockheed Martin Athena rocket, which had had some failures. There was more concern about the integrity of the rocket.

I accepted the PI mode and everything basically with open eyes and open arms because I loved innovation, and I also was impressed by the people around me, and certainly of course with Pathfinder, which was a mind-boggling success of epic proportions given how much they tried to do, how much new technology they put in there with the airbags and all that, and the fact that it worked. It blew everybody's mind.

I think I was enamored. If there was a process that got NEAR and Pathfinder going, got these various players, Applied Physics Lab, Jet Propulsion Lab, Lunar Prospector was NASA Ames, get these different parts of NASA to work on these really cool projects, I just bought all in. I really don't recall much at that moment why. The faster, better, cheaper mantra had played out a bit. I didn't mind trying new things. I certainly had seen behemoth missions take decades and

[4] NEAR was the first spacecraft to orbit an asteroid and land on one.
[5] Mars Pathfinder was designed primarily to demonstrate a low-cost way of delivering a set of science instruments and a free-ranging rover (Sojourner) to the surface of the Red Planet.

longer, so the idea that you would go from selection to launch in three years, which I think was the original challenge in Discovery, it sounded good to me.

I also took it to heart that we said, "We are ready to cancel missions that would not meet the guidelines," either budget, firm fixed price budget, or firm schedule, or whatever we judged to be the mission success criteria before we would have a viable mission. I listened very closely to my seniors there, Wes or his successor, and Ken and others, saying, "We are not going to be shy if we have to shut something down." Because the greater good is maintaining the Discovery Program and its integrity and its support from Congress, or whoever needed to support the line item to keep this pipeline of smaller missions coming that would also be in sync with—and this really spoke to me as a former grad student—the life cycle of a graduate student. Somebody who would be working on their PhD could actually start on one of these projects with their professor perhaps as the PI or deputy PI, and before they graduate or get their PhDs, they could actually see their missions launch.

That sounded like a great formulation. I don't think I had any hesitation embracing it. I do recall—and let me know if you want to ask a different question. But I do recall a moment when there was some pushback about why NASA was going forward with a mission to the Moon. It was from somebody in industry who I can name if you want. Somebody in industry, who was trying to commercially send missions to the Moon, wanted NASA to keep hands-off. Said, "You guys planted your Apollo flags on it. You're planning to go to Mars and do these other things. It's time for us in the commercial sector."

This was in the '90s. This isn't the [Jeff] Bezoses and the [Elon] Musks of now. These are before that. I remember this, I think he was the president of a company called LunaCorp, who said, "We are trying to get investors to fund a mission to the Moon, and the fact that you are sending Lunar Prospector to the Moon is undercutting our ability to get finances."

I said, "I don't see why you see it that way, because I would think that having NASA show interest in the Moon would be like a seal of good approval to others."

But there were these different perspectives, and in that timeframe, the '90s and maybe before and after as well, there was a lot of those who had animosity towards NASA doing things that they felt the commercial sector could make a profit and do on their own. You saw it in the launch industry side as well, with people saying, "How can we justify a launch of a rocket when NASA is saying everything has to fly on the Shuttle?" The military after *Challenger* turned that policy around so that the military would have other ways of getting their stuff into space. Commercial folks were thinking the same thing. They were trying to get a launch industry going, which eventually did with some enlightened management, and I'd say some people who realized that it's better to work with NASA than to try to fight NASA.

There are people within NASA, and I count myself as one of them, who had an expansive view of the commercial space possibility someday. One of my favorite products during that three- or four-year period before I joined Discovery was commissioning artist Patrick Rawlings to do a painting for our office of what the Olympics would look like on the Moon someday. *The Lunar Games*, actually it's hosted on JSC's computers, a scan. (Unfortunately, it doesn't appear to be there anymore.) Rawlings did an original oil painting of *The Lunar Games*, and we made 200,000 lithographs for use by the education and outreach centers of NASA and disseminated it, just to break the paradigm that it's only going to be astronauts or test pilots, that someday humanity will be not only on the Moon and not only exploring, but living, learning, working, and playing on the Moon. That's what *The Lunar Games* was all about. I was steeped in that sort of projection. Some of it stems from growing up reading science fiction. Arthur [C.] Clarke and [Ray] Bradbury and [Isaac] Asimov and [Robert A.] Heinlein. I had these visions that I expected—and *Star Trek* [television series]—they were going to happen, maybe in my lifetime.

When I was working on Lunar Prospector it didn't sit well with me to have NASA challenged about why we were going to do a lunar mission, because we were doing it for science. It was very clear Discovery was science-driven, that the PI leading it, and it wasn't NASA saying, "This is what we want to do." It was the PI saying, "I'd like to do this and it meets one of the strategic goals of NASA, whatever's in the five-year plan that the National Academy has done for NASA." I talk too much and you should know that, but you've caught me actually remembering a lot of good things. I think partly my bike ride this morning has the endorphins going. Please raise your hand or jump in if you want me to stop.

JOHNSON: No, it's all good information. That's what oral history is. The way you were describing it, I'm thinking about okay, in a position as a program executive, and coming into this with like you said, Lunar Prospector. You mentioned that you worked as a team along with a program scientist and a program analyst, so there were three of you that worked with these teams or were there for the teams to report to. Let's talk about that, and that work that you did as the program executive for some of the flights that you mentioned like Lunar Prospector. I'd like to get into Genesis and Deep Impact also because there were some interesting things going on with both of those too. If you want to start with Lunar Prospector. You've talked about going to the Moon and having that challenge. And if you want to give that person's name that's perfectly fine. You can always change your mind later. But just talk about as a program executive what you did in your position, and maybe some of the anecdotes that explain what you did with those missions.

BRODY: I was given the helm of Lunar Prospector within I think it was the Office of Space Science still at the time, or maybe SMD, after Bill Piotrowski had retired. He had taken it through the early stages. It was much more instructive to me and for my own personal growth when I did get assigned Genesis and then Deep Impact because I could see them from selection, and that's when there was some very early good coordination, especially with the program scientist to formulate the original mission success criteria document that had to be signed off, this is what the mission is set to accomplish, and set the budget up, which came out of the acceptance of the proposal.

I think that might have been the first time I met and/or started working with Craig Tupper, who at the time I think was a program analyst for at least one of these missions if not several. For Lunar Prospector it was Dave [David] Lindstrom I think was the program scientist. He and Marilyn [Lindstrom], his wife, were members of the Science Directorate, whether it was SMD or OSS. I believe it was Dave that was program scientist.

With Lunar Prospector it was one year to launch. Spacecraft was very far along, and in fact was a lot off-the-shelf. It wasn't from scratch. It was one of the reasons why it was priced—it was I guess probably the smallest cost mission of Discovery that wasn't a mission of opportunity. I think it was around—you probably have the numbers somewhere—but in the $65 million range, not only for the spacecraft, but for launching it and operating it. Part of it was that Lockheed Martin made it a very sweet deal because they were trying to commercialize the Athena rocket, so they said, "We would launch it on the Athena rocket for probably a prayer." Whatever was part of the package deal.

There had been a lot of instruments—this is what I was told—that were able to come together for Lunar Prospector rather than being developed. They had been maybe slated to fly on something else, and so Lunar Prospector was more than anything pulling together a portfolio of existing instruments, integrating it onto a spacecraft, sticking it on this Athena, which was going to be Athena II, because they had tested and had some failures with Athena I. Lockheed Martin proposed the Athena II, which had never flown. That “raised the antenna” of concern of course, for everybody at Headquarters. It went through lots of reviews. Just as I was joining, I believe the decision had been made, we will accept that Lunar Prospector will be the first launch on Athena II, based upon the success that had been shown in fixing the problems that Lockheed had with earlier versions of Athena I.

I would say the whole year from when I was assigned February of ’97 to the launch of Lunar Prospector in January of ’98, I’d say 95 percent of my time was focused on the launch vehicle as basically was Ames as project manager, and at the time the project manager was Scott Hubbard, who went on to be a center director at Ames. He was project manager for Lunar Prospector and for SOFIA, the 747 aircraft, which wasn’t part of Discovery. But I was program executive for both of those. We were relying on Scott and his team. Sylvia Cox was head of operations and ran the ops team at NASA Ames. Really a first-rate team.

Then the Lockheed Sunnyvale [California] people, who were integrating the spacecraft, and the Lockheed Denver [Colorado] people, who were building the Athena II. I remember several very top-level meetings, one in particular right in one of the conference rooms there wherever SMD or OSS was headquartered, where it was the associate administrator and Ledbetter and the other deputies of the office and myself as program executive and the program scientist, and we had the president of Lockheed. We had the head honcho, so to speak, of Lockheed Corporation coming in to do a review of the readiness of that launch vehicle, and it was a big deal, and the go-ahead was given with a number of actions that had to be met. Not only was it going to be the first launch of Athena II, it was going to be the first launch off of a commercially leased pad at Kennedy. I forget exactly which pad it was, but it was one of some historic significance that I think has evolved into Space Florida, and the other kinds of things that they're doing down at KSC to have their own spaceport authority. But from what I understood, Lunar Prospector was the first launch off a pad that was being operated by a commercial entity under a license, rather than by the Air Force or by NASA, and it was the first launch of the Athena II.

There was a lot of digging into what are you doing, Lockheed, what is Ames doing as a value-added to check what they're doing, and what should we do at Headquarters. I was learning, so this was in early stages. Since this was all about some final testing, I felt pretty comfortable asking questions, so I would ask questions. Fortunately they pretty much all got answered positively. We had our fingers crossed that on the first launch of a new vehicle it would get our little "spacecraft that could" to the Moon.

There's one other anecdote and if you want to follow up on it, we can. I remember the one other thing that really sticks in my mind aside from all the attention to the launch vehicle. By the way at the time, a little anecdote, my son was, let me think, in '94 my son was two. My daughter was born in '95. I'd say we got to go to Sunnyvale. My wife and I and our two children, my daughter was probably a toddler, about one year old. The principal investigator of Lunar Prospector, whose name escapes me, a pretty intense gentleman, he was showing us the spacecraft.

JOHNSON: Is that Alan Binder?

BRODY: Alan Binder, yes, thank you. Alan Binder said, "Oh, Steve Brody is coming, he's the Program Executive." He takes us in the Lockheed Sunnyvale chamber where the spacecraft is being put together. There's this chain-link fence around it, and he's standing on the spacecraft side of the chain-link and my wife and I and my four-year-old son and my one-year-old daughter are here. He's going through this is this. My one-year-old daughter goes underneath the chain-link and starts to head towards the spacecraft. Alan Binder's eyes almost popped out. He said, "Ah, stop her, stop." We grabbed her and brought her back. That was another memory from that time.

But the other significant policy issue that came up was Dr. Gene [Eugene M.] Shoemaker, who was a renowned geologist who had trained the Apollo astronauts, had this devastating head-on collision, he and his wife, in the outback of Australia, and died. A long story short, his grad students, one who's now probably on a NASA advisory committee or whatever, very prominent scientist, lobbied to have Gene Shoemaker's ashes flown on Lunar Prospector to the Moon, because Gene had said he'd always wanted to go to the Moon. They got his wife's okay if NASA deemed it okay. It was almost a no-brainer that we could put a little vial and attach it to the spacecraft.

But then a Native American tribe protested and said that the Moon is a sacred icon in their faith and NASA should not be sending ashes. Because the plan was that Lunar Prospector, after its year, which turned into a year and a half, of circling the Moon, the end result would be that it would be deliberately descended and crashed on the surface of the Moon as its end of mission. That's what they were protesting.

It was a big deal in the office. I remember whoever the public affairs officer was, Doug [Douglas M.] Isbell I think was his name. Doug Isbell, he had to write up the release. Essentially, we made nice and we came to some accord that satisfied. We did fly the ashes to the Moon. I don't know what was done to mollify the Native American tribe but there was something done.

NASA bowed and asked for forgiveness. Or put out a press release that gave them some nice accolades. That's conjecture on my part. But I know it went forward and Gene Shoemaker's ashes did indeed go to the Moon and land on the Moon at the end of the Lunar Prospector mission, which was extended from its nominal one year to a year and a half circling the Moon.

Those are probably the only major things that really jump out at me over that learning period from being thrust in the middle of a project already down the football field so to speak towards the end zone, and then I did get to see and take the family for the launch. Later, I went in to see my son's kindergarten class to talk about it. My son described it. He says, "It was like a beautiful candle going up in the sky." It was a night launch. That was a thrill as a dad to be able to give my kids that experience.

JOHNSON: That's a wonderful experience. I can imagine how exciting that would have been to a four-year-old.

BRODY: Exactly.

JOHNSON: The Genesis mission, I think it was actually selected in 1997. I was going to ask you too, as a program executive, did that job start once the mission was selected? Or did you have any input in the announcements of opportunity or any of the selection process before a mission was selected?

BRODY: Not at all. I think for programmatic reasons the line was drawn that program executives, at least in my day, were assigned upon selection. I remember my first exposure was we selected the mission. The program scientist I believe was involved. Then there would be a Headquarters presentation. I remember Don [Donald S.] Burnett, the PI on Genesis, coming to Headquarters with his team. I may be mixing this up with Mike [Michael] A'Hearn and Deep Impact. But probably in both cases there was a presentation. I was introduced. "Steve will be the program executive. The mission is now selected. First order of business is you program executive, you program scientist, you PI put your heads together. Come up with a mission success criteria document that we will sign at the very top level."

The PI would sign and then the AA for the Science Directorate or OSS would sign. That would be the contract. The program scientist may have signed as well. I was more of a facilitator since this was principally the science objectives of the mission. Although there were some programmatic aspects in there. I guess I was the one as program executive that would then convey, "Here's the steps that are going to take place. We're going to go through certain gates." I think upon selection there was another—now the term occurs to me: confirmation review. Between selection and confirmation review would be this maturation of the design and the costs and the schedule. You'd formulate the mission success criteria and have it ready to sign, and a confirmation review, if I haven't gotten the horse in front of the cart or vice versa, that's when the AA would actually buy off that you can now go build it and we're on the march to launch.

It could be canceled up until the confirmation review. There are also terms where a project beyond confirmation, if it starts to step outside the bounds of cost or schedule or success, could also be called in for a termination review. That was a fairly drastic step meaning you were not progressing as had been agreed to at confirmation.

I was assigned at selection, that's when I became involved.

JOHNSON: That success criteria, you were a part of coming up with that, or an overview of that success criteria being written? Was that the first time that was done for a mission? Or was that already in place for any of the other ones that came after Lunar Prospector?

BRODY: Here's where my timing is a little bit uncertain. I remember because it was instrumental in Genesis and Deep Impact. It was instrumental to be able to go to the mission success criteria and say, "Did we achieve that?" Genesis, because as you know we had the catastrophic landing. What I like to say, because I had been a gymnast in high school, we stuck the landing, but we just stuck it too hard. Because navigation placed it so accurately, we were still able to accomplish mission success. I always relied on the PI or the program scientist to put the number on it, but I seem to recall somewhere upwards of 90 percent of the success criteria as eventually being claimed that we accomplished, even though we had what at the time was considered a mission-ending error.

A lot had to do with the fact that we didn't hit a granite mountain in Genesis and splinter all over the place. We landed in the soft clay of the Dugway Proving Grounds [Utah] right in the spot where we were prepared with trucks and could get it. A lot of extra effort, and maybe some good luck in certain respects. But allowed a lot of the science to come out of it.

I'm not sure what was done for Lunar Prospector, or whether there was a mission success criteria document for that or for Pathfinder or NEAR because there was an evolution of the program. If you have talked to Mark [P.] Saunders, he was one of those people right at the beginning. I imagine he might know something about that. Or some of the other program scientists. But I do know for Genesis, which was the first one after Lunar Prospector that I was assigned to and the one I was with from the very beginning, that yes, indeed, it was told to me, it wasn't like make it up, Steve. It was told to me, "This is how we do it." I don't know if it was

Tom [Thomas H.] Morgan for Genesis or somebody else there at Headquarters who was my companion program scientist. I believe it was Tom Morgan who worked most closely with PI Don Burnett to develop the Mission Success Criteria document.

Then I would be the third person in that, saying, "You know what, that phrase, I don't know how to test that. Or I wouldn't know how to answer that that statement is actually going to get accomplished." I'd sort of be a sanity check on the criteria—I had enough science background to be able to say, "Well, yes, isotopes. I know what isotopes are. You're going to isolate this. I could see where you're saying you're going to collect this percentage at such a certain richness." I could conceptually get it. But my job was to try to nudge the other two to come together in language that me and the others, including our bosses, could understand, and we could also communicate with our public affairs officer to say, "Yes, look, this is why this mission is important. In Genesis' case we're going to learn about how the diversity of the solar system that we now see, how did that come out of this nebulous solar nebula way back when. These particles we're collecting in Genesis are representative of what that way back when state was because they haven't been perturbed by the Earth's environment. We collected them 1 million miles away."

I remember taking it very seriously and trying to listen to the mantra, which was the success is the science we bring back. Engineering is just a way to get there. But the success is satisfying what that PI proposed as the science we're going to get out of it, answering questions that he or she was answering when they proposed the mission. That's the be-all and end-all of these missions, they're science-driven.

JOHNSON: That one, as you mentioned, I've heard it described as the Rosetta Stone for the solar system.

BRODY: Nice. I think I may have heard that. I'm glad it has that connotation.

JOHNSON: Yes. I thought that was pretty interesting. But obviously it was supposed to land in Utah differently than it did.

BRODY: With helicopters. In fact most of that last year the operations team was working on this. They called them 'Hollywood' helicopter pilots because they had been on films and all that. But they were the top helicopter pilots, and for them this was going to be a walk in the park, because these parachutes were going to put it in a very lazy spiral, and the helicopters just had to sync up and grab the chute with a hook and then lower the capsule down. That's how it was supposed to work.

JOHNSON: Best-laid plans. I read also that you spent a good deal of your time dealing with the public or the people in Utah that would have been concerned, convincing them that you weren't going to hit a city, that you weren't going to hit anybody.

BRODY: In fact, not just in Utah. I probably spent a good bit of my programmatic time briefing the White House, representatives of the Joint Chiefs of Staff, FEMA [Federal Emergency Management Agency], and the senators of the states, because JPL or somebody had come up with this ground track that showed where the possible points of intersection with the ground would be if the spacecraft didn't perform the final maneuver properly. It had a great deal of influence on the operation because NASA changed it. There was a point at which—and it was during that last year because I remember being involved in it—the decision was made that the final maneuver to land the capsule in Utah would be performed after there was great confidence there would be the correct burn.

Let me see if I can get my thoughts aligned properly. I was in the control room at JPL when this actually played out. We had certain thresholds, and if they weren't met, which meant that we weren't going to end up landing in the Dugway Proving Grounds, we were going to either land in Salt Lake City or we were going to land downrange in Arizona or someplace in Mexico or whatever that track was. If we were not sure that we were landing where we wanted, then we would not do that final burn, and the spacecraft was going to pass by the Earth and we would lose the mission. But we were prepared to say if we weren't almost 100 percent sure that where we're headed to right this moment is the right place, we were going to give up the mission.

That's basically a lot of the attention that I had to spend in briefing, and also saying, "Okay, well, if we're slightly off is FEMA ready to come in to put out a forest fire? What's going to be on the capsule? Is there anything that a farmer could pick up that could cause whatever?" There wasn't any radioactivity on it but things would be hot and that sort of thing. There were a lot of those kind of preparations. What did we call the document? Contingency Plan, which we had to have for each mission, that laid out who was going to do what, when, who made the call about now we have a mishap. Boy was that a trying time.

I was there with the project manager for Genesis, Chet Sasaki, and his boss at JPL, Chris Jones. Then we were in the control room at JPL when we had to look at all these numbers—or they did and I was there watching—to go through the checklist. "Is this ready? Is this ready? Is this ready? Everything lined up okay. Go, we are go for Dugway. We're right on track for

Dugway." Then the three of us were whisked from JPL to Burbank Airport, put on a private jet, I don't know if it was the NASA plane or whatever. Three of us were flown to Dugway.

We landed just as the helicopters were taking off to get in position to be there to be able to grapple the chute, whisked into the building where we were watching the very high-tech imagery that the range had, the real long-range cameras. We watched this thing tumble and hit the ground. I like to say—I don't like to say it—I often tell especially the students and the grad students that I mentor at the International Space University and others. I say, "That was probably the lowest moment of my NASA career, being within NASA." I'd say *Challenger* probably was the lowest moment working on the space program overall because I knew two people that died on that flight. Then when I joined NASA, that moment, because I'd worked from whatever date you said, '97 I think it was. Do you know when the landing was? I forget.

JOHNSON: Hold on. I can tell you when it landed. [September 8, 2004]

BRODY: All right. But for those many years having worked on that, it wasn't my sole job, because I picked up Deep Impact, and had SOFIA. But to have that catastrophic thing hit us, which wasn't in our list of survivable events, we didn't expect it was going to be survivable, meaning that we wouldn't accomplish any of our science goals or any of what was in our mission success. Public affairs, it might have been Doug Isbell, public affairs officer. He said, "Steve, we got these media requests from all over the world. We need you to go in this booth, put on headphones, and take questions."

I went in there. At the time we did know that it had landed where we wanted it to land or was on track. We were getting to it and we were collecting the pieces and getting them back into this quarantine area. I was able to say without being untruthful that we don't know what we have. We're going to have to wait for it to play out. We are here with all of the talent we had hoped we would have. We hope we'll be able to recover from this, and if not, we'll learn from what went wrong. I took a number of those calls.

The next 24, 48 hours was quite an experience. If you want me to talk more about bringing in the investigation team.

JOHNSON: Please, because it's interesting. That whole story about what was recovered, how it was recovered, and the investigation. Yes. I would love to capture that.

BRODY: Yes. That was I'd say the lowest day. It was such a bounce back from that the next day. What happened, I remember in a meeting, we were having these very frequent meetings, and officially a mishap had to be called by the AA I was in touch with. I think it was Ed [Edward J.] Weiler who was then the AA at the time I believe. I said, "Ed, you have to declare a mishap." That triggers all these steps like securing all the databases at the contractor site, at JPL, and all that. He did that. I was on the phone. I was essentially the point person for Headquarters at Dugway with the project manager and senior management from JPL, senior Lockheed people there. I was the one on the horn with Headquarters, and we would have probably more than daily calls in the first 48 hours.

The first positive sign came from when—and I remember it was probably Don Burnett, the PI, explaining how they were able to gather the capsule. You've probably seen the picture. It's a very iconic photo of this crumpled capsule in the clay of Dugway on the ground. It's probably the most publicized. Not the one that I show, which I've given to AAAS [American Association for the Advancement of Science] conferences where I show the day after some of the samples that actually got collected, which is the old adage that failure or success is somewhat dependent on time. What was a failure that day became a successful mission in the end if you look at what the mission success criteria asked for as success, which was the science. In fact I was probably a bit in the hot seat, the fact that there wasn't a statement in the mission success criteria that we would have a soft landing. Because we were told, "Boil down success to what the science is you're going to get out of it." It's not an engineering test. These aren't engineering test missions; these are science missions. So if we get the science, that's success. How we get it isn't necessarily the mark of a successful mission.

I guess I feel maybe a little defensive about that, because it was hard to say to those "Wait a second. You had a crash in the desert and you're saying the mission was successful." I said, "It's how you judge success." We have this as you said, Sandra, the Rosetta Stone of samples that are now hopefully still being examined around the world and in laboratories and curated down there at Johnson. To look back and say that was a successful mission, some would say, "Wait a second. Here's my picture." They'll pull up that crash picture.

The day after the landing, we were going to have the big celebratory dinner. It was already planned. Lockheed, who knows, was paying for it, or somebody was paying for it. We were all going to gather for this nice meal at this nice location. We had to make a decision, were we going to have it or not. I said, "Look. We got to get people together. They need collective support. People are hurting." There were a lot of people trying to figure out what went wrong. But there's this other team trying to recover the samples.

Don Burnett comes to me probably that second day. It was one of our hourly tagups or however often we did them. He says, "You know the little mirror that your dentist will use to look into your teeth?" We used something like that, if not maybe one of those, because we realized when we got the broken capsule into the chamber there at Dugway in a closed ecosystem and we got all suited up that there were cracks in the capsule. It wasn't intact. But when we placed these mirrors in, we could see the number one science instrument, which was this disk about so big I think [perhaps 4-5 inches in diameter]. About so big. Which was in quadrants. It was different materials in each of the quadrants. It was like glass, but materials with different elements. This gets into the chemistry that I'm not qualified to talk about. But each quadrant was designed to capture different ions of hydrogen and oxygen and whatever else was coming off the Sun. Based on the accumulations in each of these quadrants, because the quadrants were made up of different materials, it would yield information about the ratios of these ions in the solar nebula.

That was right at the top of the science objectives of what we wanted to collect. He said, "Peering with these little mirrors through the crack in the capsule we could see that at least three of the four quadrants hadn't broken. They were still in the structure after this free fall crash." Burnett, he was over the Moon almost, saying, "We may well have a prime piece of science that this mission was meant to collect. We may still have it."

We were able to bring that message to the team for the dinner the following night. I also used an example from the classroom visits that I had been going to. My kids were growing up through elementary school through this, so I was often a visitor to the classroom. I would give the kids—a big TV show was *Who Wants to Be a Millionaire* with Regis Philbin. Part of my classroom visits—and this is something I actually teach at the university level of techniques to use when you visit K-12 classrooms—was to put together my own game show called *Who Wants to Be an Explorer*. I would have questions with multiple answers. The contestants would use their lifeline to the audience, which would be their remaining classmates, to guess the answers.

One of them, the ending, after asking which is the tallest mountain in the solar system, and having some funny answers so the kids get a laugh, my ending answer of all those game show questions was "NASA sent a spacecraft to bring back a piece of the Sun. How did it do it?" I gave three multiple-choice. I said, "Was it 'A,' they went at night?" Depending on the age of the kids, some of them, the elementary school kids were thinking, "Hmm." The high school kids would know I was joking. "Was it 'B,' we didn't have to go to the Sun because we just had to get away from the Earth and use things like glue traps to collect these particles of the Sun?" putting in layman's terms what Genesis did. "Or was it 'C,' I'm just kidding, it's impossible; that was just a joke question?" Most of the kids would answer "C," that I was just kidding, it's impossible. That's how in the classroom I would say, "This is what exploration is all about and what NASA is all about, doing what most people think is impossible."

At that dinner, wherever we were in the Dugway environment, I said, "Look, we have some hope here from what we hear from Don Burnett. But let me tell you, we just did what 9 out of 10 people in this country would say is impossible. We brought back a piece of the Sun. It may be very challenging, and we're not sure exactly how much of that piece we're going to be able to recover, but just think. You've done what people think is impossible. Don't let what happened yesterday, the crash, take away from the 99 percent of things that went right to get us to this point, able to ask the question: Do we really have what Don Burnett is hoping we have?"

That sticks in my mind very vividly because it plays into something I share with the grad students at my university about when they talk to K-12 kids and be ambassadors to the classroom—don't just share your successes. Share when you have tough days. Because you really can connect with kids who have science projects that don't work, who fail tests, or whatever, to know that adults—and maybe adults that are only 10 years older or 20 years older than them—they have difficult days too. If you are really committed to what you're doing, that's what's important. If you learn from whatever challenges you have along the way then you've gotten a lot out of it. So there I go talking a lot. But that's part of the lessons learned that I try to convey. I give a lessons learned seminar to the grad students of the ISU [International Space University]. I did it last year as well about various missions. Everything from ISS through things like Genesis and Deep Impact. I see we're at 4:00. I'm okay to go to about 4:30 or longer. Or if you want to—what's your pleasure?

JOHNSON: Let's finish out Genesis. I don't know how much you were involved in the investigation into what happened. Or if you want to talk about that for a few minutes.

BRODY: Yes. I was told, "You're not going anywhere, Brody, you're going to stay there in Dugway. We're sending in," basically I think the team was like an NTSB, National Transportation Safety Board-gathered investigation. We did have one or two members from the aviation community that were investigators par excellence. I remember that's the first time I think I met Mike [Michael Ryschkewitsch]. He was the Deputy at Goddard at the time. Really good guy. He led the team for NASA. Sent down to run the investigation. We had these others. There was a formal team, and there were reports that came in. I would sit in, answer questions if they were put to me. It was mostly directed at the Lockheed folks who very quickly—this was impressive and to their credit—opened up their books figuratively and said, "We're going to look at everything."

They proceeded to dig really deeply and surface the root cause, which was the installation of the accelerometer in the opposite way. I don't know if you know about this or not. This was the little device that would sense gravity. It would sense when you're feeling the force of gravity as the spacecraft is slowing down, coming through the atmosphere, and when it hit 3 Gs it would send a signal to fire the pyros that would open the parachutes. They had tested this. This ties into the lessons learned about when you accept heritage, heritage with a capital H, because very often misbelieving in heritage as something that's "good enough." That means you've flown it before, it was on a previous mission, you've tested it before. It's heritage to this program. You don't have to test it as thoroughly.

There was a process they went through at Lockheed Martin during the development of Genesis that said, "Well, Stardust," which was a parallel spacecraft that did in the end go and collect dust particles from a comet and return them to Dugway successfully, Stardust had come through the factory before Genesis and had proven that this accelerometer was going to work, and that everything around it, firing the pyros, everything was going to work. So when it came time to test this for Genesis and they knew they were on again faster, better, cheaper kind of a model of what can we cut out, what can we cut out because we've already tested it on Stardust.

Stardust, and I don't know the size, but it was a capsule maybe this big [gestures][6]. Genesis was out like this [gestures][7]. They put Stardust in some kind of a spin centrifuge where you could check the direction of gravity that would trigger this accelerometer in three dimensions. They could wiggle it around, doing all this kind of stuff. When it came to Genesis, to build a centrifuge to house it was going to be a major major expense. So the engineers went through a process. Functionally we need to check. These are the things we need to check. Do we need to build a different centrifuge? If I have my facts correct, the decision was no, we don't. We need to make sure this accelerometer—and it was brought into our table. I remember very distinctly sitting

[6] Stardust sample reentry capsule was 0.8 meters in diameter and 0.5 meters high.
[7] Genesis sample return capsule was 1.5 meters in diameter and 1.31 meters high.

around the table with the investigating team and the engineer coming in with the schematic of how to install the accelerometer, and the accelerometer and what it looked like. If you remember the old number two pencils or any pencils, the little pink eraser on the end, that was the size of this thing and the nondescript nature (a very uniform appearance). Which side is up? There's no way to tell.

There were some markings on it, I expect, at the small level. But it was very clear to the uneducated eye how easily one could think that this and this are the same thing. It turns out there's a schematic of whichever, there was a notch somewhere or some kind of marker. The schematic said to install it wrong. The schematic had it installed, let's assume it's got a plus and a minus like a battery. I don't know what the marking was. But it had the plus up here and the plus should have been down here. The installer did his or her job. I think it was a man. He was so devastated, but he followed the schematic; installed it exactly as the schematic said. But the schematic was wrong. It should have had the plus at the other side. Or the marking, not the plus, because there wasn't any plus probably. But the marking should have been on the other side.

What happened that didn't test it, they decided well, we know everything around this is working, we need to just check that all the little gyroscopes and things that are inside the accelerometer, when they feel that force of gravity, it's going to send the signal. So they had it wired, and they built a small apparatus that would simply go like this [making sound] or [making sound], so that it would feel the force of gravity like coming down through the atmosphere. It was sort of like a one- or two-dimensional test and not a three-dimensional test.

The signal from the accelerometer was sent. Was it sent when they did this? Or was it sent when they did this? Because it was this kind of experiment and the signal was sent. They said, "Check that box. The device works." But it did not during the mission. Somebody should have asked—and I don't know whether they did ask and it wasn't answered properly. But somebody should have asked, "If the thing was put in backwards, would it give us the same signal during testing? And therefore we not only have to do this, we have to do this and test that. We have to do this and test that." (Test not only the 3g magnitude was sensed, but also test it was in the proper direction.)

In the end they had cut out implementing the big expensive centrifuge needed to do a three-dimensional test of this device, because they accepted the heritage from Stardust. The other problem was Stardust didn't fly until after Genesis. Should you have accepted heritage from a mission that hasn't successfully completed? That was a question mark. In the end they say, "Well, Stardust did work properly." Because after Genesis they went through all of the documentation on Stardust and they made sure what they had done. They did do that centrifuge test because it was a small one, and it was successful for Stardust. Stardust's parachutes opened. I don't think they had to be caught by helicopter. My understanding is a simple parachute drop for Stardust was sufficient as it was not as delicate. What we're collecting in Genesis was so delicate that we felt we needed the parachute to be captured by helicopter. In the end we didn't capture it, but we still got good science out of it.

I guess the investigation concluded pretty quickly, because I think that installer probably was near nervous breakdown when he realized that he had put the thing in upside down. Even though he followed the schematic design. The backup to that would have been the testing, if the testing had been done right. So two things had to happen wrong. The engineering of putting it in wrong, and the fact that the testing, which was supposed to check all these different functions of the spacecraft, didn't catch that one. The accelerometer worked but they couldn't verify that it had worked in the right direction, that its polarity might not have been reversed and still worked.

I don't know how long we stayed there. Probably a good week or maybe two. There was a report I'm sure that came out after that [Genesis Mishap Investigation Board Report].[8] Then I guess the major effort then was to see how much science could we truly accomplish. I remember the other breakthrough and I don't know whether this occurred in a presentation back at Headquarters. It probably didn't necessarily occur at Dugway because it wasn't as time critical. But I remember seeing a graph of the wavelengths or whatever one uses to break down the composition of whether you've got iron, whether you've got oxygen, whether you've got all these different chemicals. One of the axes was different. Maybe it was like the element, the number from the periodic table of what the element was. The other one was sort of a quantity on the other axis. There were like two humps, and they were separate. It was like a camel with two humps. I remember it was either the program scientist or the PI Don Burnett saying, "This hump is the good stuff. It's the ions from the Sun that we're looking for. This over here is the clay of the environment that's corrupted the environment." In other words we can separate the dirt from the science or the signal. Some people call it separating the signal from the noise.

What was created by the accident, the proliferation of the debris and everything that corrupted what was supposed to be a pristine environment, we could devise chemical processes to remove that portion of the elemental table that we can say that's the clay of Utah, and here is what Genesis brought back. That occurred pretty early on, on the science side of the investigation to give us hope that we could accomplish a lot of what was in the science criteria document.

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[8] Genesis Mishap Investigation Board Report, https://www.nasa.gov/wp-content/uploads/2015/01/149414main_genesis_mib.pdf

Mike Ryschkewitsch was the Genesis Mishap Investigation Board chair. He went on to be Deputy at Headquarters or Chief Engineer or something or other, really good guy, very solid engineer.

JOHNSON: I was going to ask you one more question. I would like to talk more about Deep Impact because that may take a while too. You were talking about taking those pictures. The first picture that became famous was the capsule or landing and broken apart. Not the picture of the obvious, the things that weren't broken. But after that first initial reaction that NASA crashed something into a desert and the mission is lost, those kind of headlines that we always get about NASA before people understand what had happened, did you have anything to do with promoting what happened afterwards as far as the science that was achievable from that mishap? Or did you work with PAO [Public Affairs Office] to do that?

BRODY: I may have been involved with PAO. Generally it was the program executive's duty to sign off along with the program scientist on any press release. Sometimes it was a cursory readthrough, make sure something wasn't just factually wrong. I probably would have been in the concurrence loop on that. But any matters of science I would have deferred to if it was Tom Morgan or whoever the program scientist was on that. I may have said to him, "Tom, take a look at this. It doesn't sound right to me but what do I know?" in drafting it. But if there was any press releases about the accident and what NASA was doing in response to it, I probably was involved in reviewing. I remember I took it pretty hard. This was an emotional difficulty for me. I forget which came right before or right after. Do you know when the Genesis crash happened?

JOHNSON: September 8, 2004.

BRODY: Okay.

BRODY: I was involved with the Mars ’98 missions, which were failures [Mars Climate Orbiter and Mars Polar Lander]. Again my involvement was like for Lunar Prospector, except a little different. I was given them to oversee after they were already in flight towards Mars. I had no involvement in their development. The Mars ’98 failures really added to challenges I suffered during Genesis to really have a cloud over my shoulder, which took quite a while to get rid of. There were others, like Mike R. who was involved in the investigation board and put together the final report. Then others who probably—well, certainly at JPL and Lockheed. They looked at their own processes. Why did they not realize that they were not testing this accelerometer in its polarity and not just in its functioning? The fact that it had to function in a certain direction. That investigating was all done.

I don’t recall any activity (additional involvement in Genesis on my part), because by that time I was very deep into both Deep Impact and also SOFIA, which was outside of Discovery, which was going through a couple termination reviews and probably kept me pretty busy. Deep Impact did as well. Went through termination reviews. I know I had at least one mission of opportunity, maybe two. I think the MMM mission [Moon Mineralogy Mapper][9] which was an

[9] The MMM instrument flew aboard Chandrayaan-1, India's first mission to the moon, and provided the first mineralogical map of the lunar surface.

instrument that flew on an Indian spacecraft. And another one, Aspera[10] may have been the first mission of opportunity, and it was again an instrument that flew on some other spacecraft.

It was part of the paradigm shift that had occurred way back from that management document that I helped work on with General Dailey, which said that instead of having a program manager like there was at Headquarters before the downsizing that hit Headquarters, one person assigned to one mission, we would have the program managers at the field centers. The program executives at Headquarters would have multiple missions because they wouldn't have as much to do, because we really are relying on the managers at the centers to fully manage not only their missions, but they would hold their margins, they would have budget margins and all that, and they would call in investigation teams if they needed to. So there was again this faster, better, cheaper model that ended up with at one point, I had five missions that I was program executive for. SOFIA, the Mars Climate Orbiter that failed, Mars Polar Lander that failed, the Deep Impact, and I forget the fifth one. It might have been the Aspera mission or some other.

Looking back on it, it was just asking too much for that person to be able to answer all the questions. Very often I would have to say, "Well, I'm going to have to get the JPL project manager to get you an answer by tomorrow." Some managers at Headquarters, some of my bosses at Headquarters, were not as humane in that respect, in how things go from pendulum swing to pendulum swing. They'd say, "Well, that's not good enough. I need you to know the answer, you shouldn't have to go and ask him." That was the paradigm we shifted to, is that in certain cases if you're going to have five missions given to one person to work, my value-added is not going to be knowing the answer down deep in the well. It's going to be to be able to integrate what these

[10] Aspera was an extreme ultraviolet (EUV) SmallSat mission designed to image and characterize the distribution of warm-hot phase gas emission from nearby galaxy halos for the first time.

others are saying and present it in a way that you can understand and then know who to go to to get the answers when that's not sufficient. It was kind of a tough time.

It probably led to my early retirement from NASA in '06 that things just weren't as "fun" anymore. I'd been through three major failures and three investigations, with some great successes. Lunar Prospector, Deep Impact, with all the lashes I have on my back from that one, and having had a small role in Kepler[11], and then becoming the program executive for Discovery overall and just shepherding the whole thing and seeing that we were holding true to putting missions out in the pipeline every so often and it hadn't derailed. It was still producing good things for the science of our world so to speak. That's probably a good place to stop.

JOHNSON: I think so. I think it kind of wraps that one up.

BRODY: You can see if you have enough information on this. There was a major challenge that Genesis faced while it was in flight, which was thought to be perhaps something we would have to end the mission early. In the end we didn't have to. It was about the thermal environment. The batteries were heating up and they heated up beyond what they were qualified to handle. There was a lot of debate whether we were going to have to bring the mission home a lot sooner than the full two and a half years of circling L1 Lagrange point. We lucked out having those batteries being tested by the military for something else in a facility in parallel with us having the crisis, and we were able to find out that these batteries had so much more margin than they were qualified at, that

[11] The Kepler space telescope was NASA's first planet-hunting mission, assigned to search a portion of the Milky Way galaxy for Earth-sized planets orbiting stars outside our solar system.

we could follow the increase of temperature on the spacecraft, but we could draw the redline a lot higher than what we thought we could draw.

I would say that was the major operational challenge of that mission that turned bad, in addition to the fact that this was a mission that I'd never seen anything of a robotic mission that had so many different mechanisms that had to work. All these different bicycle tire size collectors going in and out, four of them stacked like a pancake fanning in and out based upon what the Sun was doing over a two-and-a-half-year period. Then this whole clamshell had to securely close with all this alignment and seal up enough that it could come down through the Earth's atmosphere and be a closed environment, then had the parachutes come out. All those things worked right, things that we thought were the higher risk of failure points, we all got by them. And the parachutes didn't open? That goes back to rocket science 101. That's why they call it rocket science. Sometimes it bites you.

There's that thermal incident. I don't know, it was more of a technical challenge than we realized early on. We started to see the temperature going up, and people saying, "Jeez, this is going up a lot faster than we thought. What's going on here?" They started to look at it.

This was another one of these heritage questions because it turns out they qualified some materials, including the white paint that was used to be reflective of the Sun. They qualified certain materials and processes as having had heritage because they had flown on other spacecraft. What I learned later on is that yes, it had flown on other spacecraft, but in Earth orbit. It had never gone outside of Earth orbit to the L1, one million miles away towards the Sun. There was a lot of company proprietary stuff. It got into quite a bit of a pissing contest about you better not say our paint failed. You couldn't really prove it. Was it the paint? Was it the application of the paint? Was it the substructure below the paint? I'm not a thermal engineer but I knew those who were diagnosing what could have caused the temperature to go up gave several different factors that could have been the root cause, one of them being that this paint maybe wasn't reflecting as well as we thought. But because it might have tarnished the reputation of the company and they would have sued NASA possibly if we had said, "Oh, it is the paint." And none of us could say with 100 percent accuracy that it was because there were these other plausible scenarios of how the paint was applied, how it was stored before it was applied, all that kind of stuff.

We decided not to go there, and it in the end did not stop the mission. We were very lucky. Luck was involved there, because for NASA to stand up another test of those batteries and get to the point where we would have had to get to, to know if they could withstand the temperatures they were then going to see, would have been a monumental task for NASA. And it just turns out I think it was somewhere down in Sandia [National Laboratories] or the White Sands [Test Facility, New Mexico], there was a military facility testing those exact same batteries for their own usage, and was far along in the thermal testing, and we could just sort of say, "Can you send us the results? Keep sending us the results. Oh, could you look at this?" They were very collaborative, and that saved the mission from having to do something drastic like reduce its time from three years to one year. That would have influenced the amount of science we would have collected. That's one other thing that stands out as something we worried would be a mission killer, especially if we couldn't bring it back in time before the heat reached a point where it would do damage within the capsule.

JOHNSON: Very serendipitous that they were working on the batteries at the same time. That's wonderful.

BRODY: Yes. If you want, I have the picture of the capsule crashing and the collection of samples, because I was on an AAAS panel on success and failure in the space program, and my thesis was in a lot of cases, things that the public views as a failure end up being successful. I say no better example is the Hubble Space Telescope. All the press around the Hubble and how its mirror that wasn't polished right, that was the biggest news item of the day, and now that's just a footnote in the history of one of the most phenomenal scientific achievements in space science of our lifetime. I reference that one and also with Mars exploration. We had the Mars Observer mission failure that predated a lot of our later successful Mars missions, and Genesis. In my panel presentation, I also use the Genesis example. I said, "Look. If you google Genesis and NASA and you look for images, this failure image (the crash at Dugway) is probably the one that's going to come up. But let me show you what the scientists look at." I showed where they had successfully collected all these samples and had tons of things to send to the different laboratories. It's again trying to raise the awareness. I said one of the takeaways is that ties to how we did the success criteria document, because we deemed that judging success for the Genesis mission was not engineering. The success was bringing back science for humanity to benefit from. That was a takeaway. Knowing that mindset of what you're evaluating to judge success.

JOHNSON: It's interesting because that's actually one of the things I've been asking on these interviews is just how do you balance the science and the technology to create the kind of mission that Discovery wanted to accomplish. That's interesting, that's a good example of it, that science was the value.

BRODY: Yes.

JOHNSON: That sounds good, I think we'll go ahead and stop there.

[End of interview]