Tom Hoffman

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Interviewer

Q: This is Erik Conway. I'm talking to Tom Hoffman today about his tenure as project manager for the InSight Discovery program mission.

So, Tom, we've talked about your time on GRAIL just a few weeks ago, so tell me about your transition onto the InSight mission.

Hoffman: Okay. That's a good transition question. [laughs] So I was actually on the GRAIL mission and we were getting ready to launch in 2011. A few months before we launched, I got selected as the project manager on a Step 1 proposal that was at that time called GEMS, which eventually turned into InSight. Right about the time that we were getting ready to launch is when it got selected to go into Step 2 of the competitive process. So pretty much right after launch, I supported the mission operations for GRAIL, and in parallel with that, I supported getting the proposal turned in for the Step 2 effort on InSight. Then we ultimately ended up getting selected in—I can't remember the exact date. It was actually Bruce's birthday in August, the 20th, of 2012. So about a year later (from the GRAIL launch), we were selected and I started full-time as the project manager, Bruce Banerdt as the PI.

Q: So you were on InSight almost from the beginning.

Hoffman: Yes, almost from the beginning, although the beginning is a pretty fungible thing, I think. If you talk to Bruce, he would probably say he's been working on InSight for decades—

Q: Oh, he did.

Hoffman: —or some version of that.

Q: He did.

Hoffman: And that's true. That's definitely true, yeah.

Q: I was just going to say we spent the first hour of our two hours so far talking about all of the previous efforts before InSight that led up to it. Yeah, he worked on it—a lot of these scientists do. They spend their whole lives trying to get these missions.

Hoffman: Yeah, being a scientist is a tough gig. A lot of them spend decades and don't actually ever end up getting their main project selected, so, you know, it's lucky for Bruce that he finally got it, but it did take him most of his career to get there.

Q: It's challenging and impressive that there are people with that sort of perseverance, especially since they know the odds that maybe a third of people who spend their time doing that actually succeed, maybe less than that.

Hoffman: Yeah, I bet it's actually less than that. Our deputy PI on InSight, Sue Smrekar, similarly, she's really a Venus scientist and she finally got VERITAS selected in the last Discovery call. She'd been working on that, similarly, for decades. It came in very close a couple of times, but just wasn't quite selected until this last round.

Q: Yeah, and then it was delayed.

Hoffman: Yes. [laughter] So it's a tough business.

Q: It's a tough business is right.

So my next question was, what was the state of the project when you became project manager? But the answer to that is you came in almost towards the beginning in the proposal process, so that's not quite a fair question.

Hoffman: Yeah, I had a chance to mold the—within the constraints of the Discovery program, which is cost-capped and a fixed launch date and there's a bunch of constraints on it, but within those constraints, I was able to come up with the plan that would work, so I only have myself to blame at some level for the planning, although the partners and everything like that was selected in Step 1, and, in fact, had been selected in previous instantiations of the proposal, so I came in with those already having been selected by Bruce.

Q: So the major selections are already done, but there still have to be a whole series of other decisions about—I know one of the classic problems at JPL is whether to have JPL make a thing or to buy it, so you still had to do those kinds of things.

Hoffman: Yeah, we actually already had selected—before I came on, Lockheed Martin had already been selected as the prime spacecraft contractor, largely because of their having built the Phoenix, which was originally the Mars ’01 lander, but since we were going to be using pretty much an identical system and that was the right kind of system for us, it made a lot of sense to have already selected Lockheed Martin to do that work.

Most of the major partners were already selected at the beginning of Step 1, but we did have some additional selections to be made. For example, we did not have a solid solution for a temperature, wind, pressure sensor system. There was one that was in the proposal, but once we actually got selected and started digging into it a little bit more, it didn’t really make a lot of sense, so they did have to make a change within about the first year of how we were going to do that. Those particular measurements were highly important for the main science experiment on InSight, which was the seismometer, because the seismometers, generally just seismometers in general, are very good at detecting everything, including temperature changes, small vibrations, you name it. On Mars, because we can’t put it in a vault and basically completely encase it in a humidity-, temperature-, climate-controlled environment, we’re sitting on the surface of another planet, it was particularly good at detecting everything other than Marsquakes, if you weren’t careful. So we needed to have a good system to be able to know what the temperature was, know when it’s windy or not windy, know when there’s pressure changes so that we could then use that data to de-corelate those influences when we got the actual seismic data. In the end, it was

an important aspect of the experiment to have a solid solution for temperature, wind, and pressure.

Q: And where did you get that from?

Hoffman: We ended up getting an instrument that we called TWINS, which stood for Temperature, Wind for InSight, TWINS. That was TWINS. That was done by CAB [Centro de Astrobiologia], which is in Madrid or near Madrid. It's the same folks that developed that for the MSL and then also followed on with Perseverance. I think they call that REMS [Rover Environmental Monitoring Station]. That was the same set of folks. And that solved two of the three issues.

The third was a pressure sensor, and that one took a little bit more effort to determine what the right solution was, and then it definitely took more effort to get it delivered. We actually got that from a small company up in the Sierra foothills, which I don't remember the name of the company, but it's basically a really good pressure sensor in the end, but it took a lot of extra effort to get it delivered.

Q: Hmm. You'd think a pressure sensor wouldn't be that hard, but I guess for Mars, everything's hard.

Hoffman: Yeah, and that was exactly the issue, because normally what you want, what pressure sensors on the Earth do is they measure the pressure, which makes sense, right? That's what a pressure sensor does. For our pressure sensor to be useful on Mars, not only did we have to, like,

recalibrate it for the Martian atmosphere, which is 1/100th of the pressure of Earth, but what we really cared about was a very quick measurement of the delta pressure. We didn't actually care what the absolute pressure was at all. We just cared about how quickly the pressure was changing, because pressure changes is actually what caused noise within the seismometer. So we were using the pressure sensor in a way that nobody on Earth uses it or cares about it, because nobody cares if you have a 1/100th of a percentage change in your pressure on Earth, because nobody can tell, but a seismometer can. So we were using a pressure sensor in a non-standard way, for sure.

Q: That makes sense. On Earth, nobody would care about a pressure change that small. Certainly meteorology doesn't. It would be irrelevant.

Hoffman: Yeah, and not on, like, you know, sub-second timing either, because a hurricane's not going to hit you. It's going to take days, not seconds.

Q: Not seconds. Right. Fascinating.

Hoffman: As JPL does, we used something in a completely different way than it normally is [used], but it ended up working out fine. It just took a lot of effort because, again, we were trying to use something in a very non-standard approach.

Q: As you were setting up InSight, what did you think your chief challenges were going to be? Then we can talk about what were they actually, but what did you think they would be?

Hoffman: Well, I thought that the big challenges were going to be trying to get the spacecraft delivered on cost from Lockheed Martin, because they had relatively recently, I'll say, built the Phoenix spacecraft, but, from what I know about it secondhand, it had a reasonable cost growth, and we were a cost-capped mission, as was Phoenix. I couldn't really afford a large cost growth there, so my number one concern was are we going to be able to get that delivered on cost. I had had a lot of history with Lockheed Martin, so I wasn't overly concerned, and, anyway, they were going to be providing us the best value. It was just a question of, had we really done a good enough estimate to build a Mars delivery system in the form of a spacecraft, just because that's one area where you traditionally had a fair amount of growth in cost with Mars missions. So that was probably my number one concern going into it.

As we got a little bit further into it, I had some concerns about things like the pressure sensor changes that we had made to the baseline within the first year or so, but in retrospect, I can't say, boy, I really thought a lot about the payloads, because I didn't, and that's where we did end up with problems. The reason I largely didn't think about that is during the proposal phase of Step 2, it seemed like they were well on their way and well ahead of the spacecraft both in terms of maturity and in terms of sort of their test program and already had some prototype units, so from that standpoint, that seemed like it was in good shape.

I'll say the other reason why I was a little bit concerned about the spacecraft is even though we were getting good heritage from the Phoenix mission, most of the—in fact, all of the avionics basically were changing. We had to move from a RAD 6000-based computer system, which is more like a nineties-type technology basis for the avionics. We were moving to the RAD750, which is more the early 2000s, 2010s-type technology basis, and that meant that we

had to have a new set of software, transition all the algorithms to new software, and just making sure that in that transition we didn't make a mistake, which we didn't, but trying to make sure we didn't make a mistake there was an important thing for us. That was part of the focus and one of the reasons why I was more focused initially on the spacecraft. Plus, because we were getting most of the instruments from foreign contributors, foreign partners, there was very little chance for cost growth there, because they're basically coming for free.

Q: But even free instruments don't necessarily turn out to be free.

Hoffman: Oh, there's no free lunch. [laughter] Yeah, there's no free lunch. But even with the different problems that we had, that we started getting closer to the original launch date, we didn't spend huge amounts of money, I'll say. We maybe spent a few tens of millions of dollars, which is not a small amount of money, but in comparison to the spacecraft, which was a couple of hundred million dollars, it's still a relatively small portion of the overall cost of the mission.

Q: Right. What you say makes sense to me simply because, as you said, we'd built the lander before, the instruments Bruce would swear were pretty mature going in, and so it really sounds to me, from all the other interviews I've done, that people were pretty surprised when it turned out that SEIS was not really buildable by its original contractor and so forth.

Hoffman: Yeah, and I can kind of get into that now. There were a few contributing factors when I've looked back on how did we get there, when we couldn't get SEIS delivered on time for the 2016 launch opportunity. There were a few different things that contributed to that. Some of

them were technical, some of them were geopolitical—maybe I'll characterize it that way—and some of them were just sort of an expectation.

So the technical aspects came in a few different ways, and probably one of the more important ones was initially, when we had these prototypes that were working around the time of the proposal, the form factor was different than what we actually were going to fly. I don't think anybody, including the people building it, truly appreciated how difficult it would be to shrink those just a little bit. We weren't shrinking them by a factor of an order of magnitude. We were only shrinking them maybe 25 percent, but that ended up being a significant change in the overall design. And the reason that we had to do that is we ended up inheriting the 2001 arm from Mars 2001, which was going to originally be used by Phoenix. Phoenix replaced that with a different kind of arm, because that particular arm on 2001, very good for, like, placing stuff, which is what we had to do on InSight, but not good at digging. It wasn't strong enough for digging. So Phoenix was digging with a different arm.

So, anyway, we got the 2001 arm as part of the proposal, and to build a brand-new arm would have cost tens of millions of dollars, so we really needed to use that arm, even if we had to refurbish it some, which we did have to do. But because of the constraints of how much that arm could lift, we needed to go through an effort relatively early in the project of shrinking the mass of the SEIS, and in the process of shrinking the mass of the SEIS, that's where I think some of the technical difficulties that nobody fully appreciated got partially baked in. So they had to go through and do a redesign of their very broadband sensor, the VBB, and kind of shrink all the internal aspects and the overall size of the sphere. So that sort of kicked off a design effort, but that was characterized to, I think, pretty much everybody, as, oh, it's just simply shrinking the size of things a little bit. So, honestly, I think that was the bigger change than anybody fully

appreciated at the time, and I'm not sure people fully appreciate even today. But I think that was part of the root of the problems, but certainly not the only problem.

Q: Nobody's mentioned that one to me. Most of the stories have been about the cleanliness issues and the vacuum issues, but no one's mentioned an early effort to shrink it by a quarter.

Hoffman: Yeah, and a quarter is a relative—I think it was actually—yeah, it was something on that ballpark, roughly. I think there originally may be 12-ish kilograms. We needed to get them under 10 kilograms, and we were trying to get them to 8, so, you know, it's a relatively close number.

Q: Interesting.

Hoffman: But that did cause them to have to lightweight a fair amount of things, which is partially the reason why we had too thin of a sphere that collapsed at one point, but, yeah.

Q: Yeah, that would make sense, and how the buckling analysis didn't get done and etc.

Hoffman: Yeah.

Q: So it all kind of snowballed.

Hoffman: Yeah. Have you, by the way, on your list of people to talk to, are you talking to Jeff Umland at all?

Q: Jeff Umland? No.

Hoffman: Umland, U-m-l-a-n-d. You might want to talk to Jeff. He's a fellow at JPL, but he was our chief mechanical engineer for InSight, and he definitely was heavily involved in the mechanical aspects of both the spacecraft but more interestingly and more importantly, the SEIS. If you're interested in pulling the thread on the mechanical aspects, he can definitely provide really valuable insight, I think—unintended.

Q: Okay, great, great. I think that would be interesting. I've talked to Ken Hurst already, but, of course, he's still more scientist than engineer, so I need to talk to one of the mechanical engineers.

So let's see. On the spacecraft side of things, what was your development experience? As you say, I know Phoenix had issues, although a lot of theirs were around the landing radar.

Hoffman: Right.

Q: What were yours?

Hoffman: Yes, yes. So we did learn a fair amount from the different issues that Phoenix had, so part of the concern was the landing radar. We did end up flying the same landing radar as

Phoenix. Phoenix had gone through and done like a hot-fire test, a bunch of helicopter tests to verify the whole landing system, and we definitely took advantage of that program.

Actually, we took the unit that had gone through the helicopter testing as our radar unit, because, again, within our cost constraints, a new radar system is anywhere from 50 to 100 million dollars, and I didn't have that much total UFE to begin with, and we had planned to always use this particular radar system. There was not a lot of expense associated with that from the baseline estimate.

So we did end up using the unit, essentially the flight spare for Phoenix, which had gone through this helicopter testing. We did refurbishment on it. We pulled it apart, we looked at everything. In the end, we replaced a few parts, retested it, and it took a fair amount more effort and a couple million dollars more than we had expected to get it into a state where everybody, including the reliability folks and independent observers, felt like we were in as reasonable a posture as possible, but we did do that.

There weren't any abnormal hiccups, I'll say, in that development. There's always a few issues, like I think we had a few problems with one of the boards looking a little funny, and we had to decide that it was okay that it looked a little funny. We went through a little extra test program on it, and everything ended up fine in the end. But I think from a spacecraft-development standpoint, that probably was the area that had the biggest concern.

As I mentioned before, we had a lot of concerns about converting from the older RAD 6000-based architecture for the avionics to the more modern RAD750 architecture and the software changes that went with that. That actually went remarkably smoothly. There weren't really any issues at all related to that. There weren't any issues. The software conversion went per the plan. We did have a problem with our aeroshell, in that when they were applying the

ablative material, they didn't follow right process, and so we ended up with some issues with there being some bubbles potentially in the material, so we had a big effort to go through to do a little bit of rework but also to go through a pretty extensive verification program to make sure that we weren't going to essentially have one of these bubbles end up getting burned through by the heat during the landing process.

That was probably the only area where Lockheed Martin kind of had a screw-up, but other than that, they did a great job developing the whole vehicle, rebuilding the vehicle. Quite honestly, I think they would have been under their total contract cost probably by at least 5 million, I think, if we had launched on schedule in 2016, because they had really done a very efficient job in terms of the whole effort there. I mean, they did a great job. During the course of trying to get to the 2016 launch, they replanned the ATLO program, I think probably at least five times, in a hugely significant fashion, and probably a couple of dozen more times with minor tweaks. And they had developed a way for us to essentially almost—if we had delivered the SEIS like two months before launch date, they had kind of figured out, "I think we can get through all the testing that we need to get done, even at Vandenberg, and be able to launch successfully." But, of course, the SEIS never ended up making it there.

But spacecraft-wise, we really did not have much of any issues. It was probably one of the smoother developments that I've been involved in.

Q: So you got to spend your time instead worrying about the instruments.

Hoffman: Yes, yes. Like you had asked me initially, initially I was very concerned about the spacecraft for a lot of different reasons. That kind of relatively quickly transitioned into a couple

of specific things, like the radar was a specific thing early on that we were concerned about making sure we could requalify that. And then probably around 2013, so that was maybe a year in, they started getting a little inkling that maybe things weren't quite as smooth for the development especially of the SEIS as we had expected.

And then 2014, I think about May of 2014, I was getting very concerned with the SEIS, and I started to have regular calls with the project manager from CNES about maybe we should send Ken Hurst specifically, but maybe we should send some folks to Paris area and kind of embed them with Sodern and IPGP. Sodern was the company developing the SEIS as the industry partner, and then IPGP was the university that was essentially running the contract.

And there was a lot of pushback initially. "You shouldn't be sending people there." Part of it was because the CNES people didn't have anybody there and they didn't want JPL people running around talking to those folks without CNES being present, which is not unreasonable. And then there was a certain amount of pride, which is a good thing to have, but there was a certain amount of pride that it was their job, not our job, to get it delivered. So I was pushing on that for a couple of months without much success.

But then in July of 2014, when Sodern was supposed to be delivering a whole bunch of flight VBBs to Sodern for, like, the final testing, they essentially all did not work in pretty much the same way, and that was the contamination issue I think you've already heard about. But after that, we were actually able to start getting a stronger presence and were able to demonstrate we actually would be able to help them, not just hinder them, in terms of the recovery effort, and it really changed the nature of our relationship for the better, I'll say.

But one of the things I found out around that timeframe which was really bothersome was that because of the nature of the way that CNES and ESA and most of the European space

agencies do their contracts, and their history of almost never making a launch on schedule because everything's pretty much a fixed-price contract that they do with the people delivering stuff, almost everything always slips. Once we got close to the timeframe of things are not looking good for making the deliveries, there was some aspect of surprise, almost, from contractors like Sodern that we were actually serious about trying to make a 2016 launch. It was like, "Well, we didn't think you were actually going to make it, so we didn't really put in the kind of effort that we would need to to make it, because we figured everything slips, and we figured you were just going to slip," which really annoyed me, and I read them the riot act endlessly about the fact that that's not the case. But certainly that contributed to us probably losing around six months in the beginning portion of the project, which I never fully appreciated until those six months were already gone, because people just weren't working as hard as they could have or should have to make a 2016 launch. But that's one of the geopolitical, kind of cultural things, I definitely did not appreciate at all heading into the InSight mission, but now I understand lots of things about the culture and how those projects in ESA and CNES are run.

I ended up finding out that Wednesdays in France, kids under the age—I think under third grade, they don't go to elementary school, so the moms have to stay—it's always the mom, or almost always the mom has to stay home and watch the kids, and so if you have women that have younger children, they almost never work on Wednesdays, and it's just a known thing, so there's a kind of built-in inefficiency there.

I also found out that it's a requirement to take two weeks in a row off in the summer, and if you don't take two weeks off in a row in the summer, the company actually gets fined by the government. So I had to go through a process of—I actually talked to the education minister about can we get exemptions for people during the timeframe that we needed to have work done

in the summer so that Sodern didn't get fined. It was crazy. It was, like, these things that you never actually think about that are very important within one culture that definitely affect your ability to get planetary missions launched.

Q: That's interesting. Yeah, it's very much not JPL culture, anyway—

Hoffman: No.

Q: —where missing a launch is a crisis.

Hoffman: Not to say it's wrong. Yeah, it may be much more—the work-life balance is definitely in full force in France, in fact, most of Europe. The Germans, which you always look at as, you know, perfectly efficient workers, they kind of have the same rules, they're just quieter about it, and somehow they manage to somehow get all their time off and still get their work done, but they have kind of the same rules, as it turns out.

Q: Yeah, there's much more—I don't know. There's more integration in corporate and union management in Germany than we have ever been used to, and we don't, of course, have unions, but the rules for us are set very differently because of that, I think.

Hoffman: Yeah, like in Toulouse they actually require that people only have to really badge in to get into the facility, but they're supposed to badge in and badge out of the cafeteria because they want to be—from a rules standpoint, you have to give your workers at least an hour for lunch.

You can take an hour for lunch, and if you end up not going to the cafeteria, then there's something else. I don't know exactly what you have to do, but you have to basically attest to the fact that you didn't just work through your lunch.

I mean, there's lots of things like that that I never had any appreciation for and then I became kind of an expert at. Like the school year, there's like three different times during the year that you can pretty much be guaranteed that most families are going to be out of work, not at work, so you can't really guarantee to get anything done.

Early on in the project, I always noted that there was, like, these issues getting meetings established at certain timeframes, like right after the Christmas break. Like, you think, okay, well, the first week back, you could do a meeting. Well, it turns out that first week back for most people in the U.S., there's still another week off for people that have kids in school, and daycare's not established, generally, in France, at least, and so the parents usually take that extra week off. And then there's a week in the spring that pretty much everybody takes off, and then there's a week in the fall that pretty much everybody takes off.

And it wasn't until probably a few years into it where I got to know enough of the managers well enough that they kind of let me know exactly what was going on, but I found out, oh, yeah, you can't really expect any work to be done in those three weeks of the year, because half the team is going to be gone. And that's just the way it is. They're going to be gone, whether they want to be gone or not, almost. So it was just fascinating, fascinating culturally. [laughs] Irritating as a project manager for a planetary mission, but it was very interesting.

Then I don't know if Ken told you, but, like, at Sodern, they would do barbecues on Wednesdays, and they would have, like, some beer in the afternoon, and so basically every Wednesday in the summer, at least, you wouldn't get any work done after, like, 10:00 o'clock.

Q: Yeah, because your whole afternoon is at the barbecue, yeah. [laughs]

Hoffman: Because they go to the barbecue and then they have some beer, then you don't want them around flight hardware at that point.

Q: Right. [laughs] So it's good for morale and not good for getting work done.

Hoffman: No, no. [laughs] Yes, those people, they were all very happy. [laughs] But they weren't overly productive in the sense of how we measure productivity, certainly within the U.S. or especially at JPL.

Q: Fascinating.

Hoffman: It is. I learned many, many things from InSight, and only some of them were related to engineering and project management. [laughter]

Q: Well, knowing your partners' schedules would certainly fit into the project management bucket, anyway.

Hoffman: Yeah, and understanding the cultural aspects of people is also extremely important in terms of both expectations of what productivity can be, as well as motivation, because one of the bigger challenges we have, and certainly I had, is on these missions where you're partnering

mostly internationally, but when you have a partner who is making a contribution, meaning you're not paying them to do something, they're doing something with their own money and giving it to you for free, essentially, you don't have any direct ability to tell them what to do, because it's the gold rule, right? They who has the gold sets the rules. If you're not giving them any money, you can't exactly tell them what to do. You can make suggestions, you can do whatever you need to do.

But if you understand the culture, then I think you have a better shot at figuring out how to motivate without a contract or without money. So certainly with both the French and the Germans, they have a lot of pride, and that was one of the things that you can appeal to in terms of motivation and trying to get them to do what we consider the right thing, whether it be additional testing or coming through on their commitments for delivery on a certain date of a certain element or whatever it is. So once I kind of figured that out, it made the discussions of trying to get them to do the right thing, by our definition, a little bit easier. There's still a lot of discussion, a lot of just constant talking to get things done, but at least I came at it from the standpoint of having some knowledge of what that discussion should be around. So I don't know if that made sense or not, but—

Q: Yeah, I think that does make sense. Knowing how to influence people that you can't command is a leadership quality, right?

Hoffman: Right, and you need to understand what the motivation is, and some of it is a cultural thing, so, yeah, that's exactly it. It's like how do you motivate people that you have no direct control over. And a lot of it comes down to personal relationships and appealing to them, their

sense of pride as an engineer or manager or scientist, making them feel like they're part of the team, which they are, and then letting them know how their contributions as a valued team member is going to make a difference in terms of the overall success of the project, and how the overall success of the project is going to reflect positively on them, and that's important, and positively on their team and positively on their agency or their company, and then ultimately on their country. It actually ended up it is a big deal for France to have had the seismometer, actually I think one of their most expensive instruments they ever developed.

Q: And ultimately very successful.

So one of my questions I've got down here was precisely about how JPL went about supporting the SEIS development. You're saying we sent Ken Hurst over and ultimately a number of other people. How was that organized and paid for at JPL, given that initially you started out with those instruments supposedly being free?

Hoffman: Yeah. So we had a few different types of people that we sent out there, because initially our problem was contamination, so we sent Ned Ferraro, one of the best contamination people on the planet, out there to help them out, and we thought it was going to be initially just like a review. It ended up that Ned and another contamination guy spent a huge amount of time out there, first figuring out what the problem was, figuring out how to fix the problem, and then installing processes, procedures, and facilities that would not allow that problem to continue, and that took several months of Ned's time and other folks'.

Also at that same timeframe, we brought out—we actually had two different guys that were there from the QA [quality assurance] standpoint almost continuously, Vazarik

Gharakanian and Greg de los Santos. But they were there almost the entire time through ultimately delivery in 2017, so they spent like five years almost constantly in the Paris area, sometimes going to Madrid or Berlin for the other stuff. So there's those two aspects.

Then we had the engineering support where Ken was the main person as the SEIS instrument systems engineer. Our mission assurance manager went out several times, Linda Facto. Our overall payload system engineer, Jason Feldman, was out a lot. And then Jason Willis, our PSE, was out there a lot. Then I went out a fair amount as well. Our payload manager, Ed Miller, went out there a fair amount to sort of provide the management for us. So I guess we had maybe four different aspects. We had the engineering arm, which was a variety of different people, but Ken by far the most, the contamination control aspect with Ned, and then the overall mission assurance, quality-assurance leg, and then the management leg. So it took kind of all of those efforts pushing at different parts of the sponge to eventually get stuff delivered.

We had planned some of that effort, a little bit of time from Ken, certainly the payload manager initially, but the rest of the effort, which ended up being about—I calculated at the end it ended up being about maybe $20 million—that was all paid for out of my reserves.

Q: So those supplemental—it was entirely in your previously-planned reserves.

Hoffman: Yes, and then when we missed our launch in 2016 and had to try for 2018 launch opportunity, the plan that I put together included a significant amount of effort for supporting folks in France and in Germany, but we also took on some additional scope. We took it from Sodern, which was specifically for building the whole sphere, what we called the evacuated chamber. Building that whole effort, building that whole thing, including the connectors, was

done at JPL, so that was another—I think we spent, in the end, around 13 million, roughly, for that, to get that delivered to Sodern and help with the integration of that activity and everything to get qualified, and that effort was led by Jeff Umland, so that's why he might be a good person to talk to at some point.

Q: Okay.

Hoffman: So probably our total effort to get the SEIS delivered maybe ended up being between 30 and 40 million dollars over the course of the project that was unplanned for, and then I know that CNES—I don't think they have an official record, but they spent well over $100M of their own money getting SEIS delivered.

Q: Good heavens.

Hoffman: So it was not a cheap instrument.

Q: Nope. It wasn't a cheap free instrument. [laughter]

Hoffman: No, not for anybody.

Q: No. Amazing. And also a little troubling, too, because there have been dreams of sending multiple seismometers to Mars, and those dreams sound even more like fantasy now because of what you're saying, just in cost.

Hoffman: If they wanted to reuse those, they probably could get them built a lot cheaper. In fact, they are flying the spares that we built, and they're using them on the Moon, some of the same people.

Q: Right. I remembered that they were also part of an upcoming Moon mission.

Hoffman: Yeah. Pretty much all the same people. Pretty interesting. [unclear].

Q: But makes sense. [laughs] Yeah, it should be a great seismometer for the Moon, right?

Hoffman: Yeah, yeah.

Q: So let's see. How were the project's challenges with instruments, delays in spacecraft, etc., communicated to JPL management and to Headquarters?

Hoffman: So that's one area that I think we did a really good job on, frankly. As soon as we started having problems that were noticeable, like in May of 2014, I started communicating with my director, who at the time was Firouz Naderi, and his deputy, who was Keyur Patel. I had a couple of different ones that went through at different points. But I started communicating with them pretty clearly right away and let them know what my plan was in terms of trying to get people sent there, and letting them know, "Look, I'm having difficulty with CNES allowing us to

go there," and I think they were good about communicating that up to Charles Elachi, who was the JPL director at the time.

When we had the problem when we didn't get stuff delivered in July, I doubled down on the reporting and the concerns and everything. I can't quite remember exactly when it was, but I think it was probably sometime maybe in early 2015, I think, is when Charles started helping by having a monthly phone call with his counterpart at CNES, Marc Pircher—who Charles knew from all the different activities that they had done in the past, and basically it was just mostly a management call to let their management know that JPL management was concerned, and having them step in and provide some additional support and assistance to the CNES team, because they were a little bit chronically understaffed initially, and so getting that extra support, I think, was helpful to them.

At first, they were reluctant to get it, but then after a little bit, they realized, "Oh, we should be able to use this to our advantage," which they did. The got some additional staff. They put a resident person at Sodern and IPGP. Took them a long time to find the right person, and we already had somebody there, but it ended up working out pretty well from that standpoint.

I wasn't shy about communicating the issues forward to my program executive, who communicated that with SMD, and I think there was certainly a lot of reporting, even in 2014, but by 2015, when we were getting to the point where we really had to get stuff delivered in order to make the launch, I was having, I think, at least weekly reports up to Grunsfeld, who was the SMD director at the time, probably starting about mid-2015. So he was getting every week a report from me on what the progress was, what our setbacks were, what our plans forward were.

As we were going through 2015, we had a few victories. Late 2014, we solved the contamination problem. Early 2015, we started having some other noise problems. We

essentially got through all of the VBB-related problems by the summer of 2015. The team did a great job in solving that set of problems, so that we had good VBBs, we were getting them manufactured at a reasonable rate. We didn't have a lot of them. We only really had three that were good, but we had enough VBBs because we only needed three.

Then we started in on, like, the overall qualification program of the package, and that's where we ended up with the sphere collapse, which delayed the qualification of the overall sphere, which then delayed us finding out about the fact that they had procured the wrong type of connector. They didn't procure connectors that were actually going to ever work at our temperature or vacuum considerations. By that point, that was about, I think, August of 2015 that we had the notification that basically they had failed their final environmental test at CNES in Toulouse when we were going out to get ready for a pre-ship review. That was the worse pre-ship review of all time, in my opinion. It set us back. But we had spent so much time trying to solve the VBB problem, and then we had the sphere collapse, it never allowed us to qualify the overall evacuated container portion of the system.

Then we—I'm sure you heard about it from Ken—we launched a huge effort to try to figure out how to basically put a Band-aid on it through a variety of different methods, and we spent a couple of months on that. We failed again in October, early October. I remember that specifically—it was the 8th of October—because there was a science team meeting in Zurich. I was supposed to be getting on a nice boat to do a tour of Lake Zurich with the rest of the science team. I showed up a little bit late. They were nice enough to hold the boat. I get on the boat. Literally as I step onto the boat, I get a call from Jason Feldman saying, "We've failed the test," which was not a terrible surprise, but it was still hugely unfortunate, because we thought this was our last best chance to fix the problem.

Bruce was on the boat with me, Philippe [Lognonne] who was the SEIS PI was on the boat. Ken was not there, he was also at the test. So we spent the entire boat ride, which I understand was a beautiful boat ride, talking with Jason Feldman about what to do next. Basically, when we finished the conversation, we had redocked. [laughs] So I never actually looked out. It was, like, a sunset cruise. I never actually got a chance to look out and enjoy the view. But that was kind of par for the course, because I never had a science team meeting until the very last one after we launched, that something bad didn't happen that required that I stop attending the science team meeting for pretty much either a portion of a day or the rest of the science team meeting. So, entertaining.

Q: Entertaining, but you don't make it sound very fun. [laughter]

Hoffman: No, no, it was not overly fun. Actually, I thought I was going to have fun on the science team meeting in—I think it was 2016. No, I'm sorry. It was 2017. It was early, it was, like, springtime. We were going to Oxford for the science team meeting, and as soon as I landed in London and started on my way to go to Oxford, where I was presenting on the first day, I started to get word that things were, from a schedule standpoint, not so much technically, but things were not going well at Sodern. There was some consternation we were going to lose like a couple of weeks, or we'd already lost a couple of weeks; it wasn't exactly clear.

So I gave my presentation on Monday. I think I landed on a Saturday. I spent Sunday in London, and that's where I heard about this potential issue. On Monday, I gave my presentation, and then I took the train over to Paris at the last minute with the guy who was running the SEIS

delivery at the time, Brian Bone, and just so I could have a conversation with them about needing to make sure that they didn't miss their delivery, which was in, like, two months.

So by the time I got there, actually, the fact that I was coming, the problem got solved, but, nonetheless, I never attended the science team meeting, other than my presentation. Science team meetings never were very good for me on InSight. Almost every time, there was some kind of issue.

Q: We're about to run out of time, so we'll probably have to come back to this, but I wanted to ask you to tell me your story of the day you decide you have to delay the launch.

Hoffman: Yeah. So kind of continuing with the previous discussion, I had been communicating pretty clearly with my management, with Charles. Along the way, I was sending out the weekly reports for months, leading up to the problem that we had in August, the problem that we had in October of 2015, how we're going to try to make ATLO still work and not be too risky. We had had lots and lots of those discussions.

After the October incident, we kind of knew we had one more chance, and this was really going to be our last chance, and we knew it was not likely to work. I let people know, "Look, we're going to try one more time to seal the sphere. We think we have a solution that might work, but it's not really high probability."

So I got notified on December 22nd, 2015, that the last chance really to have a shot at it had failed, and, of course, the team, to their credit, had figured out another way. "If we just do this other thing, maybe we'll make it."

And I'm like, "No, we've tried hard enough. We've done enough."

So I was actually sitting at my cabin up in Mammoth, because I was going to try to have a decent break, but I was still working, of course. So I'm sitting up there. I think it was actually a holiday day for JPL. I call up Firouz, I call up Charles, I kind of let them know. I said, "I think I need to let Grunsfeld know." And I said, "Do you guys want to call him? You want me to call him?"

They said, "No, you go ahead and call him. If he has questions, you can address them." Because I think at that point they had enough confidence in my messaging that they didn't feel like they needed to be on the call.

So I called up Grunsfeld on his cell phone and let him know we had tried, what we had tried, to let him know, "I told you it probably wasn't going to make it. It's not going to make it. I think really the right thing to do is to pull the plug." I said, "I'd like you to give me a chance to come back to you and tell you in March what we need to do to make a 2018 launch, because I think I can get to a plan by then."

So he agreed, "Okay, let's do that."

Then I sent a note off to the team and let the team know, "Look, we're going to stand down. We're going to scrub for the 2016, but we're going to pull together and figure out a plan for a 2018 launch." But I told everybody, "Just don't do anything until we come back on the 4th," or whatever the day was, the next Monday after New Year's. "Take the next week and a half," or whatever it is, "off. Don't think about InSight. Let's come back batteries partially recharged and let's figure out what we need to do to go forward."

So I started traveling that first week and helped everybody come up with a plan that ultimately got us to 2018. But, yeah, that was tough. It was not a fun call to make, but it was the right decision.

Q: Yeah, and I'm sure it caused a lot of angst for people who'd worked very hard to get to that point and just couldn't make it.

Hoffman: Yeah, and they kept wanting to try and try and try, but ultimately you have to say when enough is enough, and that was that point for us.

Q: Yeah. Okay. Well, thanks for your time. We're out of time, so we'll probably have to come back to finish up. They're great stories, though. So thank you, and we'll talk again. I owe you still your corrections from the last transcript, and, of course, you'll get this one again in a couple of weeks.

Hoffman: Okay. No worries.

Q: Thank you.

[End of interview]