Sue Smrekar

July 27, 2022

Erik M. Conway,
Interviewer

Q: This is Erik Conway. I'm talking to Sue Smrekar. Sue, tell me, first off, where you were born, how you're educated.

Smrekar: I was born in Farmington, Maine. Let's see. I moved a ton as a child, so I lived in many places besides just Maine, but I ended up getting my high school degree at Hebron Academy. I went there as a day student. I went to Brown University and got a degree in geophysics, applied math. A little break, I worked at Johnson Space Center as a summer intern, then for a little while longer, and then started my Ph.D. at Southern Methodist University in Dallas.

Q: What got you interested in geophysics?

Smrekar: I didn't really know what I wanted to do when I went to college, maybe anthropology, maybe astronomy, and then I kind of settled in on physics for a little while, and then took a class in planetary science and decided that I fit better into the geology department than the physics department. Then I took a class in geophysics, and I was like, "Yes, this is it. This is what I love. I can write equations that describe the natural world." And that's what hooked me.

Q: Fair enough. How did you make the move to JPL?

Smrekar: So I got my Ph.D. right around the time that the Magellan mission arrived at Venus, and so during my postdoc at MIT, I got to come out to JPL pretty often and see the new data coming in, and that was an immense thrill to be amongst the first to see the surface of a new planet, or a newly revealed planet. So, yeah, I decided to interview for a position at JPL, came kind of thinking I wouldn't stay forever, but here I am. It's worked out. [laughs] So, yeah, it was through working at JPL during the Magellan mission that I was exposed to working at JPL.

Q: So that's 1989-1990 time frame.

Smrekar: I started here in 1992, but yeah.

Q: So sketch out what you worked on at JPL before InSight got started—well, I mean the proposal process in the mid-2000s, 2010s, really.

Smrekar: Well, initially I worked some on Venus and Magellan data, and I never really stopped being interested in working on Venus research, but this other terrestrial planet, Mars, was very much in the forefront of interest at JPL and elsewhere. One of the things I got interested in in coming to JPL is instrumentation, and I had the inspiration literally in the shower one morning to start trying to work on heat flow instrumentation for Mars, so was involved in a number of—I wrote a number of proposals to develop that kind of instrumentation here in the U.S.

Through that, I started working on a comet mission that didn't last for very long, but it was meant to be a penetrator that would have measured heat flow, and through that, I met people working at the German Space Agency on heat flow instrumentation, so that was kind of my collaboration with them. So really it was through my interest in measuring planetary heat flow and interior evolution, that I got involved in InSight eventually.

Q: You said you were working on other heat flow instruments. So what was interesting about that work?

Smrekar: Well, I mean, in terms of the measurement, it's a fundamental part of understanding the planet's evolution. It gives us both information on the planet formation in terms of its radiogenic elements and how it accreted, as well as it tells us about the present-day energy available to drive geologic processes and habitability and presence of water, etc. So it's a simple concept, but it's very fundamental for a whole host of planetary processes.

In terms of the actual instrumentation, it was a fun project. We worked on penetrators as a means to measure heat flow. In fact, I was the equivalent of a project scientist for Deep Space 2, which was a penetrator technology mission, which, along with a number of other Mars disasters in that time frame, failed, for reasons which are still debated. [laughs]

Q: It was an overdetermined failure. There were too many failures modes to figure out. [laughs]

Smrekar: Right, right, and so that was an introduction to project science leadership, mission disasters, etc. [laughs] So I saw the gambit of—what was that old commercial—the agony of defeat and—what was that Olympics commercial—the thrill of victory. I can't remember how they put it. But, anyway, I saw extremes of success and failure early on. [laughs]

Q: Fantastic. So how did you meet Bruce Banerdt?

Smrekar: Bruce Banerdt actually hired me to work at JPL.

Q: Ah! Okay. So you met him very early on.

Smrekar: Yes, yes. He was my group supervisor initially.

Q: But you do different things primarily, by and large, right? He does seismic stuff, and you're heat flow, but I guess maybe you have some crossover?

Smrekar: Yeah, we certainly have some crossover. We both have looked at gravity data—it's another measure of interior processes—and do modeling of tectonic processes, so we certainly have some overlap, but, yeah, in terms of InSight, I worked more on heat flow and he's been more focused on the seismicity, but we're both interested in the bigger-picture implications of those kind of measurements.

Q: I guess the proposal for InSight was called GEMS. When do you get attached to that?

Smrekar: Yeah, I was certainly attached to GEMS and the early Discovery mission proposals. I'm sure you spoke with Bruce and know the long, long trajectory of arriving at InSight, so I wasn’t involved in all of the early variations on that theme, but since he started proposing it as a Discovery mission, I’ve been involved in that.

Q: So it’s when he decided to go to the Discovery Program is when he recruited you.

Smrekar: Yes. That may have been the point when they added heat flow as well, if I remember correctly. I’m not sure.

Q: Yeah, not quite clear to me yet either when exactly that got added. Bruce and I spent our first hour just getting to the point of starting the proposal because he’d been working on seismicity for so long. [laughter] We haven’t actually got to the mission yet.

Smrekar: Right, right, yes. Well, happily for me, I wasn’t along for all those various incarnations. [laughs]

Q: So once you’re attached to the GEMS proposal, tell me about what your role was.

Smrekar: So I’ve been the deputy PI, I believe throughout that time period, if I remember correctly, starting with the original one.

Q: But what does that involve?

Smrekar: Well, it really is tailored to the particular project and people involved, and so of course Bruce has primarily been the scientific liaison with the seismometer group. He and Philippe, of course, have been tightly intertwined in this endeavor for a long time, and I worked more with the heat flow people, so there's that. For example, I worked to develop a test chamber for the heat flow probe here at JPL, which allowed us to test out the instrumentation at Mars, pressure and temperature. And when I say I developed that, I led the effort, but Troy Hudson, who was also working on InSight, he implemented it in a brilliant way, but I led the effort to get the funding for it and to make sure it happened. I believed it was very important that we be able to really test and calibrate that under Mars conditions, and ended up being extremely valuable for understanding the instrumentation. Of course, in Germany they have tons of test chambers, but they didn't have any that were under Mars pressure, so that was a valuable asset for us. So, doing things like that to help prove to the review panel that we could execute this work.

Worked with others, like Matt Golombek, to make sure we understood to the best of our ability what kind of materials we were going to be trying to hammer through [laughs], the Mars environment, to the best of our understanding, and so those were the kinds of things that were more focused on the heat flow, but, honestly, just whatever it takes to make the science side of things happen, organized science team meetings, organized a team to get their publications organized, their conference abstracts organized, really any of the nitty-gritty management stuff that Bruce and I managed to delegate. The way we set it up, we tried to do different things, rather than just overlapping everything, so Bruce primarily interacted with Headquarters and kind of did the upward management, and I tried to do the downward management more, more of the science team and keeping them informed of what was going on, so, yeah, coordinated.

Q: And so did you already know the German heat flow group before the proposal started?

Smrekar: Some of them, yes. I started working with Tilman Spohn on this comet penetrator heat flow experiment, so that's where I first got introduced to that group. Then over the course of the proposal work, I got to know many of the others. In particular, Mattias Grott was a very key person. Since my Ph.D. proposal, I had worked—one person who was on my Ph.D. committee was Paul Morgan, who is a terrestrial heat flow expert, and he ended up being on Deep Space 2 and then on InSight, so he's been a major mentor and influence in my pursuit of and understanding of heat flow. He's worked with me on all these proposals to develop instrumentation initially for Mars, and we also have pursued that for Venus. So, yeah, he's been another major influence in this development.

Q: So were there other heat flow instrument options when you started, or was it really that you needed that particular instrument?

Smrekar: For InSight, we needed that particular instrument, because obviously we hadn't been very successful with the penetrators. [laughs] And the lack of clear resolution as to what the issue was made it a challenge to want to pursue that, and I think over the course of the development of that mission, I and others kind of came to the conclusion that it probably wasn't the best approach for heat flow. I mean, it has its advantages and disadvantages, but if you have a lander and can piggyback off that, certainly this approach of the mole was very desirable. People have also looked into drilling and so forth for heat flow. It's also extremely challenging, because you have to put your drill bits together, all these things that are done manually on Earth, put your drill bits together and assembling them and go down. Getting down in the ground is just super challenging, and there have been many different approaches that people have pursued for that, but for many reasons, this was the right solution for InSight. In terms of mass, power, heritage, it was the right solution for InSight.

Q: That makes sense. You talked about the heat flow demonstrator. Where was that at JPL?

Smrekar: It was—gosh, what's the name of that building? I can't think of the number of the building, but it was in one of the big hangar test facilities, up at the top of the hill. I can find the number, but I can't recall it right now. Anyway, there's a long flight of stairs there. [laughs]

So, yeah, it was this 3-meter-by-1-meter cylinder vacuum chamber which we filled with dirt, which is kind of a challenge for vacuum chambers, and it had to be highly insulated because we tried to keep it cooled, and we put a thermal gradient across it so that we could see how well we could measure the thermal gradient, which is a key element of the heat flow measurement. So the design of it was very tricky. As I said, Troy Hudson was super instrumental. He actually had started out working with some other people. Troy's been part of InSight. We actually started developing this kind of chamber prior to that when I was working on the proposals for heat flow instrumentation separate from InSight. So it went through many different iterations, but, yeah, it was there.

Then JPL doesn't let you hang on to hardware because they just don't have a lot of space, so we managed to put it basically on the government eBay site when we were told to get rid of it. I'm using that phrase loosely, but basically a government auction site. And told our colleagues at Honeybee instrumentation, Honeybee Robotics, which they're also interested in heat flow, and so they picked up our chamber. [laughs] I hope they still have it somewhere. I hope they've made good use of it. But, yeah, we had to get rid of it, sadly.

Q: So they put it through the excess process, but told Honeybee to try to get it. I wonder if it's in the Altadena facility they've opened.

Smrekar: Yes, that was where it went originally, yeah.

Q: Great. So it was already excessed. That's too bad. I know you had a site visit. Was it used during that?

Smrekar: Yes, yes, that was part of our site visit tour, and so we took people up and showed them the facility, showed them data from it. We had a demonstration of the mole hammering into the soil during that. So, yeah, obviously it was pretty convincing [laughs], both that the mole would work and that we would be able to demonstrate its use for measuring heat flow.

Q: I was interested in making sure we documented that, because I don't know how well-documented it will be otherwise. What else went on during the site visit for the proposal evaluation?

Smrekar: Let's see. That was the aspect of the site visit that I was most involved in, working with the HP3 team and this demo. I'm trying to remember if we had any other demos for the seismometer and so forth, and we probably had a model there, but, honestly, I don't remember the other aspects of the site visit that much, it was so intense. [laughs] That's all I could focus on, I think.

Q: Understandable.

Smrekar: I've been through so many site visits, it's kind of a PTSD experience. [laughs]

Q: Right, because you must have had one for Veritas, right?

Smrekar: Two for Veritas. [laughter]

Q: Two? Oh, because Veritas was proposed three times, wasn't it?

Smrekar: Yes. [laughs]

Q: So you had to go through it twice at least.

Smrekar: Yes, and during the pandemic. [laughs]

Q: Yeah, during the pandemic. Those must have been especially interesting.

Smrekar: Mm-hmm.

Q: Where were you when you were notified by NASA that you'd succeeded, that you'd won the proposal?

Smrekar: Oh, gosh, that's so long ago for InSight. [laughs] Like I said, so many things have gone on since then. I believe at JPL. Yeah, I think I got a call from Bruce, and, yeah, we were tremendously excited. I apologize. I'm not able to dredge up the exact details, but, yeah, I got a call from Bruce and was very excited that we were going to be moving forward.

Q: And so your role doesn't really change, but the work you have to do changes, I think, right, once you're PI of a full project instead of a proposal. So talk about that. Or deputy PI, sorry.

Smrekar: Sure. Right. Well, before that, it was just very intermittent work, you know. It was a big scramble for proposal, big scramble for the site visit, but, yeah, once we were fully selected, it was a matter of spinning up the project and starting the work with all the engineers and fully staffing up.

I think for scientists, the science team was already in place, and that remains very stable because scientists are kind of used to having intermittent funding from one proposal to the next, and working in that manner, but engineers can't just wait around. Some of the people that were originally involved continued forward, but we had to bring on many new people, so that was certainly part of the work. And, yeah, just trying to get the science team spun up and focused on the initial tasks and really laying out those tasks, and figuring out how to work with Bruce, how to distribute the labor.

So it became much more of a full-time focus, and I had to let go of some of the other things that were happening and really move forward. I had been working on Mars Reconnaissance Orbiter as a deputy project scientist, so I moved off that and started working close to full-time on InSight, still doing research on the side, but started working on that. I started meeting all the new partners for our contributions, the science team and all the various distributed elements of that, and with the team in Berlin, worked with them to start spinning up their group and laying out our path to getting through all of our reviews and building our hardware and planning out our testing schedule and so forth. So, yeah, just started making that my focus.

Q: You must have spent a lot of time in Berlin?

Smrekar: A fair amount, yeah. It's a great place to have to spend time. [laughs] It's fantastic. And the HP3 team was a comparatively small team, and they really bonded and became a very tight-knit and enjoyable group to work with, so that was a real pleasure.

Q: Were there other international partners in HP3?

Smrekar: Yes. One of their main partners was a Polish group that developed aspects of the actual hammer mechanism, so that was one of their main partners. I'm not sure if I understand all of the reasons, but in general, their group was quite international as well, in terms of the engineers that they had onboard, really from all over the world but working there in Berlin, as well as in other DLR facilities around Germany.

Q: So one of the things that's interesting about InSight is that it is so international at the project level, but even the instruments were, it looks to me, so it has to have been an interesting management problem.

Smrekar: Yes, yes. I mean, I think that HP3, just by nature of it being a smaller group of people, perhaps with more long-term working relationships, it was comparatively straightforward. I think one of the challenges was this new group in Bremen. They had a lot of young engineers, and it took a while to sort of get them in the mindset of building flight hardware and the nature of the reliability that was required in order to really ensure that this would work, but they were extremely enthusiastic and really bright and came along, but that was an initial challenge.

Everyone has a different management philosophy. Tilman Spohn is a brilliant theorist and kind of took that theoretical approach to building hardware, so that has a tremendous value as well as limitations. We had to work to really try to do as much testing as possible, because you can have as much theory as you want, but soil is super challenging. There's so many unknowns about Mars. I don't know if you're interviewing Troy Hudson or not, but he had a great science cartoon that talked about, I don't know, the Big Bang, relativity, and then there's soil. [laughter] Of course, there's a lot of theoretical development about understanding soils. But in a real planet, if you go out and try to dig a hole in your backyard, you begin to appreciate that there's just a lot of things that you don't always anticipate that are variables.

So it just involved a ton of testing, and it's a tradeoff between trying to test the materials where you understand the properties versus materials where they're more realistic, and what does even "more realistic" mean? So in developing these simulants, where you understand what you're testing into, was a big aspect of this whole work. We tested a range of things. There's been a lot of work to develop lunar simulants, fortunately, because, of course, of all of the institute programs that have been investigated for the Moon, so people had developed all this lunar simulants, which is extremely precise in terms of trying to mimic what we know about the Moon, because the material's very fragmented, you have little glass beads from the tiny impacts, and so, fortunately, I had kind of acquired some of this, a large amount of this [laughs] through the earlier work in instrumentation development. So that was kind of one simulant—and we tested it in and then we got all these other materials and we tested in and we had to send these back and forth between Germany and the U.S., which was no small effort.

So there were a lot of challenges just in terms of working with people so far away and with different schedules and approaches and methods. That's always a challenge and a reward, because, you know, having more than one approach is always valuable.

Q: So you tried a wide variety of simulants to test in. That's interesting. I can't imagine, because the soil is so variable, how you would even constrain that problem. I always think of Mars as kind of desert pavement, not much like the Moon at all.

Smrekar: Well that's a challenge, an end member and known to be extremely challenging. It was meant to be sort of a "Well, if we can actually drill down in this material, then probably we're going to be able to go through a lot of other things." So it was a convenient and very well-characterized challenging end member.

In fact, the way you put that reminds me we talked a lot about the wording, what we would say at the site visit. [laughs] I remember joking with some of the people—it was actually

Mattias, Matthias Grott, who presented on behalf of HP3 at the site visit. We were going to say, "Okay, this reasonably bounds our understanding of Mars, and that's all we can do." We kind of broke down how are we going to put this—what phrase shall we use. "Reasonably bound." That's what we believed we were doing, and based on all our knowledge at the time, that's what we were doing.

Q: What else? So we've kind of talked about the challenge of the heat flow instrument, but what were your other challenges during development?

Smrekar: Well, I'm sure you'll talk at length with Bruce about all the SEIS challenges, so I think he's better able to portray that than I am, but other challenges that we had were trying to add additional instrumentation. These additional instruments are referred to as the APSS [phonetic], (Auxiliary Payload Sensor Suite). Anyway, we wanted to add other instrumentation to make sure that when we see a seismic signature, that it was really coming from the ground and not from the magnetic field variations or electric field variations or an atmospheric dust devil or pressure variation, so we really had to refine that instrument suite after selection. Getting the pressure sensor to a level that was adequate to represent variations that the seismometer was sensitive to was a real challenge. That level of precision had never been done for an atmospheric pressure sensor for Mars, and there were a lot of trips to the facility where it was built, actually somewhere in Northern California, to really make sure that they were going to be able to deliver on that. So that was kind of a down-to-the-wire to see exact—which was really going to come through in the way that we needed.

We had to get a wind sensor from the Spanish Space Agency. They've been involved in a number of Mars missions, and so again we had to kind of work with them. It was a very mature design, but they were trying to improve on it based on their previous experience with it, with the Mars missions, to make it more robust to landing. So that was another part of the instrumentation. And we had a magnetometer as well. Again, there was a lot of high heritage on that, but we had to sort of add some of these things in and do work on them beyond what we had originally envisioned. The magnetometer itself was not so complicated, but understanding the response of the lander is always a challenge, so you add a bunch of tests to characterize the magnetic field of the lander. There was a lot of other challenges with just getting the additional instrumentation up to the standards that we needed to support that half-of-a-hydrogen-atom sensitivity over a seismometer. [laughs]

Q: Half of a hydrogen atom. What a way of putting that. Jeez. [laughs] Okay, so that's challenges. Of course, you had a big launch delay ultimately, and I'll talk to Bruce about that from the whole seismometer thing. How did that affect your portion of the project, the heat flow folks and so on?

Smrekar: Well, we were fortunate in that the various agencies, the German Space Agency and so forth, stepped up to support that delay and kept supporting all their people and so forth. I think a challenge was that there was so much focus on the seismometer, as it needed to be, that there wasn't as much focus and energy on the heat flow probe as there could have been had the seismometer not been having issues. Of course we had to make that seismometer work, and the heat flow probe had always been not part of our Level 1 science requirements, for the reason that we knew in advance it was going to be super challenging. We knew that going under the soil was going to be challenging, so therefore we never promised NASA that we absolutely we will deliver this data, because we knew it was going to be hard. [laughs] So for those reasons, it never had as much focus from the JPL team.

You know, we knew that there were some challenges. This backwards motion, we saw that first in this chamber that we developed here at JPL, the Mars pressure chamber, and that was basically inside the cylinder that comprises the mole, there's a hammer and a counterweight, and that is affected by the atmospheric pressure, so when we first hammered it under Mars pressure, we saw this backward motion, but it came kind of late, and we considered various—so there was a redesign to counteract that change in resistance to pressure inside the tube, but there were other possibilities considered as well, such as putting little barbs on the front of the mole, and those options were never fully explored. I can't say that that would have been the right answer, because they weren't fully explored. That might have caused more problems. I don't know. But it might have saved us. There was so much focus on making the seismometer work, that there wasn't as much attention and funding and focus on trying to fully explore options for improved performance of the mole.

Q: So then you say this came to light. Did it come to light before the delay already—

Smrekar: Yes.

Q: —or was it later?

Smrekar: It was before the delay, but kind of late in the game. So if it had been a Level 1 science instrument, it might have gotten that same focus and level of funding and, "Look, we have this extra time. How can we change things?" But that was not the path we went down. And it wasn't like we knew "Okay, this is broken. It's not going to work." It wasn't like that, because they had redesigned it such that given our best understanding—and in Mars chamber, it was no longer moving backwards, but we knew that that was a sensitivity that could be an issue, but we had to redesign it so that it was progressing forward, downward, [laughs] under Mars pressure, so we thought it had been addressed, but obviously, in hindsight now, we see that there were further issues. But, I mean, that was not a result of the Mars pressure as we originally saw in the tests, but as a result of the unanticipated soil characteristics.

Q: So it's interesting that it wasn't part of the Level 1 requirements, so it must have been a difficult negotiation with NASA, because usually they want to rope stuff in, not kick stuff out.

Smrekar: No, honestly, my sense is that they like to have stuff that they can descope if there's issues or just, you know, not have to sort of take demerits off the success of the mission if something doesn't work, and because we knew that getting this thing down to 3 meters was going to be challenging, that's the way we agreed to put in, and I think NASA appreciated that.

Q: Okay. So I guess it sounds like they appreciated the honesty and weren't really pressuring you.

Smrekar: Yeah, and, you know, if you look at our science objectives, the majority of them come from the seismometer, so the strategy made sense from a science as well as risk standpoint.

Q: Fair enough. Talk about landing day, then. What's that like for a scientist? [laughs]

Smrekar: Traumatic. [laughs] I think especially for me, seeing landing day go up in smoke previously, you know, I knew all too well that potentially things might not go well. Of course, landing a penetrator is different than a lander, but it [the lander design] had seen success before, so, you know, intellectually I fully expected it to work, but emotionally [laughs] there is still the anxiety and uncertainty. And, you know, even things that we have excellent reason to believe will work can see unexpected things happen. So it's just incredibly exciting to see the fruition of so many years of effort, but it's just kind of hard to encompass all of the things that are going on in your head, in your heart, at the same day.

Q: I forgot to ask about landing site selection. Talk about the process of figuring out where you were going to land and do your science.

Smrekar: If you really want the full story, you should talk to the "landing site dude." [laughs]

Q: Matt Golombek? Fair enough.

Smrekar: He had a number of successful landings in his notches on his belt, so he's been through many of these, and we had the good fortune that our original position was that we could land anywhere on Mars from the standpoint of doing our science. Now, of course, in hindsight, we're very fortunate to be pretty close to this source of active seismicity. That's been a huge benefit and boon, but it wasn't part of our selection process at all. Really our goal was just to measure Mars seismicity wherever it should be.

So from the science standpoint, anywhere was fine, but because we were a Discovery mission with a constrained budget and we were using a largely designed spacecraft from Lockheed Martin, we had pretty tight constraints on how close to the equator we had to be to have adequate solar power, the altitude that we could land at to reuse the whole entry system, and on the ground, we tried very hard to—obviously we can't have too many rocks or we might crash on a rock, so that's the number one constraint. And then Matt and colleagues also did a very clever way of trying to get at subsurface rocks, because, of course, that would be a problem for HP3. Fortunately, we have the HiRISE camera asset to be able to see pretty small stuff on the surface, and so what they did was look at the ejecta or impact craters, because that samples the subsurface, so they looked at the rock distribution around impact craters to assess what the distribution of bedrock, of solid rock, is in the subsurface. The site that we selected had relatively low counts of subsurface rocks in the surrounding ejecta blankets, so that was something that had never been relevant or tried before. We couldn't fully validate that aspect of our landing site selection, but it was an important element.

We also tried to think about things like the atmospheric effects on the seismometer, so we didn't want to be too close to the dichotomy or some topographic feature that would induce a lot of extra wind. Were there other aspects of it? Oh, yeah, I guess just in terms of the subsurface rocks, we also had validation of that from a fault scarp that we could see in the imaging, which showed the bedrock at depths greater than we would access through HP3.

So those are the considerations that went into it, and so fairly soon, we came to a few sites that were good candidates, and then there was a very detailed characterization campaign that Matt led, to really look at the whole landing site and make sure—it's a big ellipse, and a lot of HiRISE images, so there's been a lot of summer interns that have counted rocks and assured our safety in landing. [laughs]

Q: But it sounds like most of your constraints actually came from the landing system and not from your scientific instruments.

Smrekar: Yeah, yeah, but, of course, being close to Cerberus Fossae as a source of much of our seismicity has been a very fortunate occurrence.

Q: Serendipity.

Smrekar: Yeah. [laughs]

Q: Let's see. We talked about challenges, we talked about site selection. So after landing, you have to deploy the instruments, and I know there's a JPL-built arm from a prior mission. I guess it was probably built for the 2001 Mars lander that didn't fly. You have to deploy the instruments, and you have some, I don't know, envelope around the spacecraft, so how did you decide where to put them?

Smrekar: So, again, Matt ran that process.

Q: Matt did that. Okay.

Smrekar: Much like a site selection process. [laughs] And we had constraints, desires, in terms of keeping HP3 and SEIS fairly far from each other, because SEIS didn't want to hear the HP3 hammering any more than it needed to, and we didn't want them casting shadows on each other because that would have a thermal effect, which is a real issue for the seismometer. So, yeah, we had our kind of nominal scenario of where we'd put them, just based on where the arm could reach and those other constraints, and, yeah, I mean, HP3 didn't want to have any shadows either because it affects the subsurface temperature variations that it would be recording. And it worked out pretty well that we could essentially go to those pre-landing-site positions. There were some rocks in there that we had to adjust for, but this is something we practiced in advance, set up some operations training runs where we determined what data were needed to be acquired, how it was going to be analyzed, what sort of the decision tree would look like, where instruments were going to go.

So, yeah, it ran very smoothly, thanks to Matt and all the colleagues that worked on that, and so we were able to choose those sites fairly rapidly, based on that pre-landing effort and the site cooperating with us, not giving us too many obstacles.

Q: Right. You had a fairly clean site, at least as far as the surface was concerned.

Smrekar: Mm-hmm.

Q: Did you try to impose scenarios in which you landed in a rock field anyway?

Smrekar: Yeah, yeah, there were some scenarios like that. [laughs]

Q: What would you have done?

Smrekar: Well, we would have tried our best to squeeze things in, and again for the reasons I've outlined, the seismometer would have had the priority to pick a site. It was interesting in terms of how the evolution of our use of the arm evolved. As you said, it was an arm from another mission, and we were very cautious with it initially, but then after the seismometer was deployed the wind shield was deployed, HP3 was deployed, then we started having all these issues with the HP3. We started doing all kinds of things with it that people never would have done initially, you know, like scoop soil and move rocks and dump soil here and there, you know, push on the ground. The arm team was very hesitant to do things that they feared could cause damage to the arm, but once we had our main tasks accomplished, then we started trying all these crazy things. [laughs] We had to twist the arm people's arm a little bit. They did eventually concede that, yes, we could try these things. So, yeah, that was a kind of interesting aspect of the whole deployment and HP3 recovery work.

Q: How did the HP3 problem play out after you put it on the surface. Tell me that story.

Smrekar: So the first attempts at hammering went fantastically. [laughs] It started going in at a speedy clip, and then progress really slowed, and there was a lot of work to diagnose what could happening, and part of that is that we couldn't visually see what was happening with the hammer because it's inside a tube, a deployment tube that keeps it upright until it gets beneath the ground, and so there was a lot of work to diagnose what was going on. Essentially, within that tube, that deployment tube, there are spring guides that hold it in place, and so what we eventually realized is that once it got past those guides, it was no longer making progress. So those springs inside the tube were enough to counteract the hammer kick, essentially, but after it got that far in and it kept hammering, it kind of made a larger hole around it and there wasn't much friction around the side of the hole, which was what the hammer mechanism relies on, having friction on the sides, to counterbalance the recoil.

So we tried various things. I mean, there's not a lot of flexibility in how to hammer. Basically, it's on and it hammers or it isn't. It isn't like changing speed or anything. It has one task: hammers or it doesn't. [laughs] So it took a while to understand what was going on and to try to do our best job in estimating how much it had deployed. There are different ways to measure that progress. Basically, you have to get the tether to go through a small reading device at the top of this tube in order to be able to measure how much of the tether's been deployed. In this early phase, we hadn't yet gotten there. That's why it took a while to infer that it was past the springs inside and that was part of why it had stopped moving forward.

So it took quite a while to decide that what we would decide to do is lift the support structure off of the mole so we could see what was going on, because we didn't have any other way to better understand what the issue was until we do that. That took a long time to make that call, because there was a lot of risk involved. We could knock the mole over or do something that would end our ability to keep trying. So we did that. We tried different—tried hammering again, and there was a lot of challenge to say, "Should we just keep trying to hammer? When do we call off that process?" So eventually we got to the point where we had tried enough hammering and decided it's just not going to go anywhere without us doing something different.

That was the point where we really tried to assess what we could do with the arm, and the first thing we did was try to just place the—it has a little shovel, so we tried to place the front of the shovel on the ground to try to cause more pressure around the mole to counteract the hammer recoil. That seemed to have some progress. We made some further progress, and then at some point it just really backed out very dramatically. So that caused us to try something else again, and at that point we tried to fill the hole. All this took a lot of additional imaging to try to see into the hole, to try to figure out why it is behaving so differently. We realized that it had this very thick crust on the surface which was bigger than we had seen anywhere else on Mars. That was part of why the hole was enlarged and not filling with soil. We were able to see that the soil had, like, drained away into the soil. There seemed to be some ability for the soil to just kind of sift down into a deeper depth, which was completely unexpected.

So it was clear that it wasn't getting adequate friction to progress, and that's when the whole process of trying to dump soil down the hole and basically pack around it began, and that was a very challenging process. Everything you do on Mars, of course, we have to take images, assess them, make a sequence, test the sequence, try it out, look at the images, so it's a very slow and painstaking process. It was just really super challenging for everyone to stay optimistic and keep moving forward with trying to solve this engineering challenge remotely.

It was a hard, hard moment when we finally had to pull the plug and concede defeat.

Q: It took months of painful work to get to that point, it sounds like.

Smrekar: Yes, yes, a very long time.

Q: Too bad. I remember reading that and being disappointed, because I wanted to know about the heat flow too. [laughs]

Smrekar: Yeah, it's a fantastically useful measure of what's going on inside the planet. [laughs]

Q: Yeah, if we can ever get it.

So let's see. We're out of time, but I wanted to ask you who you thought the key players were for my next set of interviews, whom you haven't already mentioned.

Smrekar: Oh, yes. Are you going to talk to people on the DLR side for HP3 or—

Q: I'll try to talk to Tilman Spohn, yeah, and then whoever he suggests.

Smrekar: And certainly Troy Hudson has been extremely instrumental in leading that whole effort to recover the mole, so, yeah, he would be an important perspective. And like I said, he's been around since the development of this heat flow chamber.

And Matt, certainly. You might be interested in talking to some of the atmospheric scientists, because that these auxiliary payloads have been very scientifically rich in terms of what we've learned. In the U.S., there's Don Banfield. In Europe, there's Aymeric Spiga. Sorry, Claire Newman in the U.S. and Aymeric Spiga in France. So some of those people might be interested. And Catherine Johnson for the magnetometer, we also had some very exciting discoveries there. Yeah, I think those are some other people.

Q: Great, great. Well, thank you for your time. I'm sorry we've run a teeny bit over.

Smrekar: No worries.

Q: Thank you so much for your time. Have a great day. Bye.

Smrekar: You too. Bye.

[End of interview]