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Issue 93

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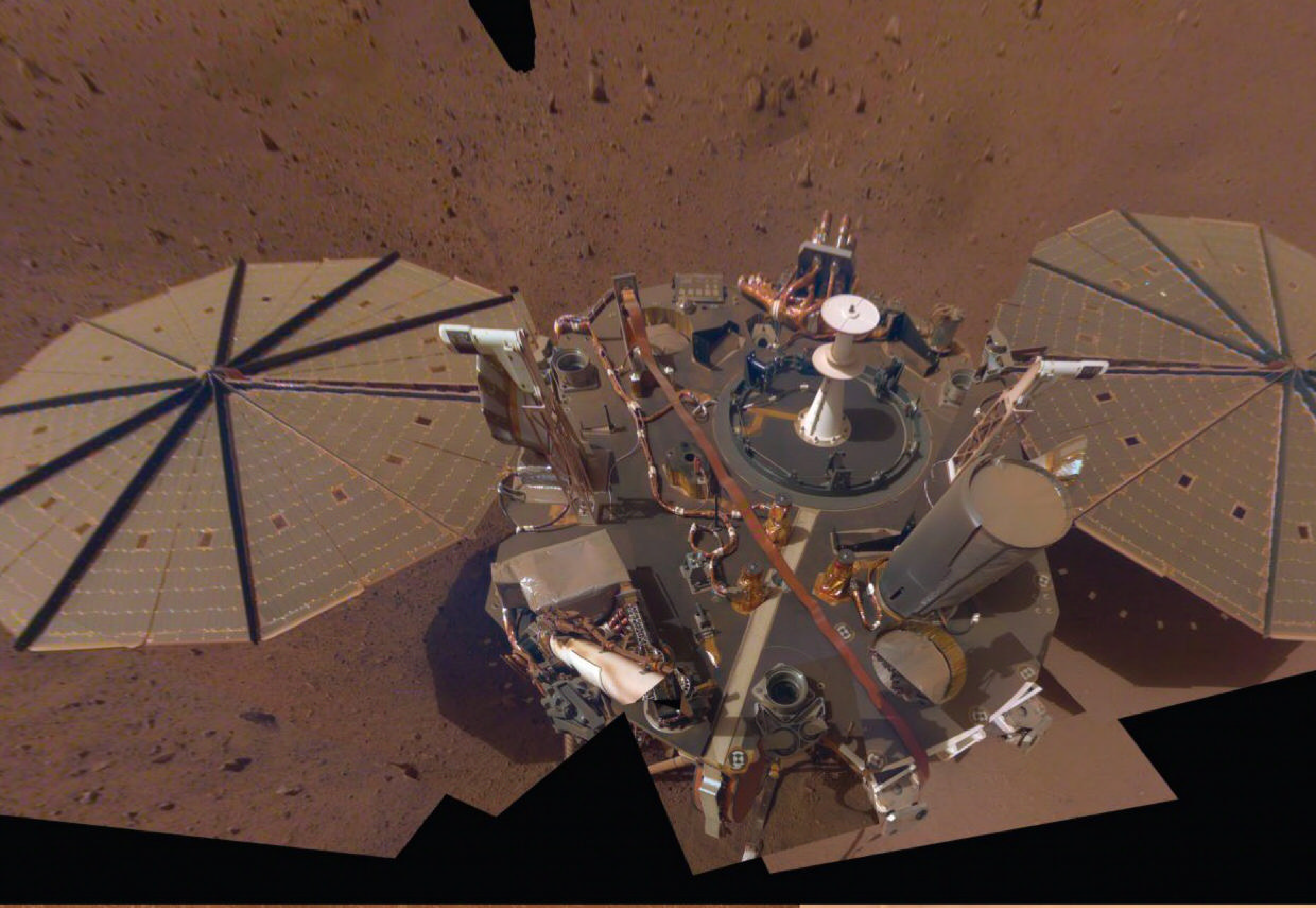
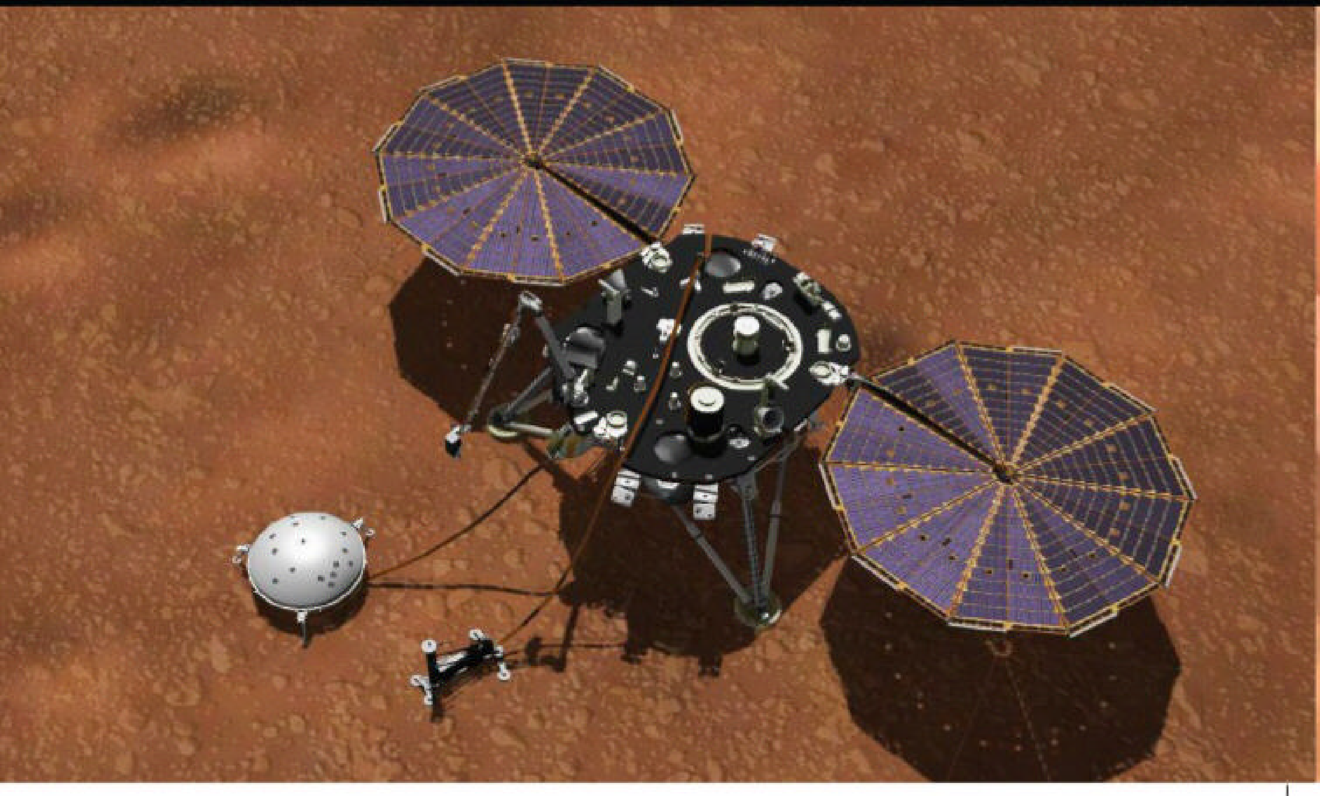
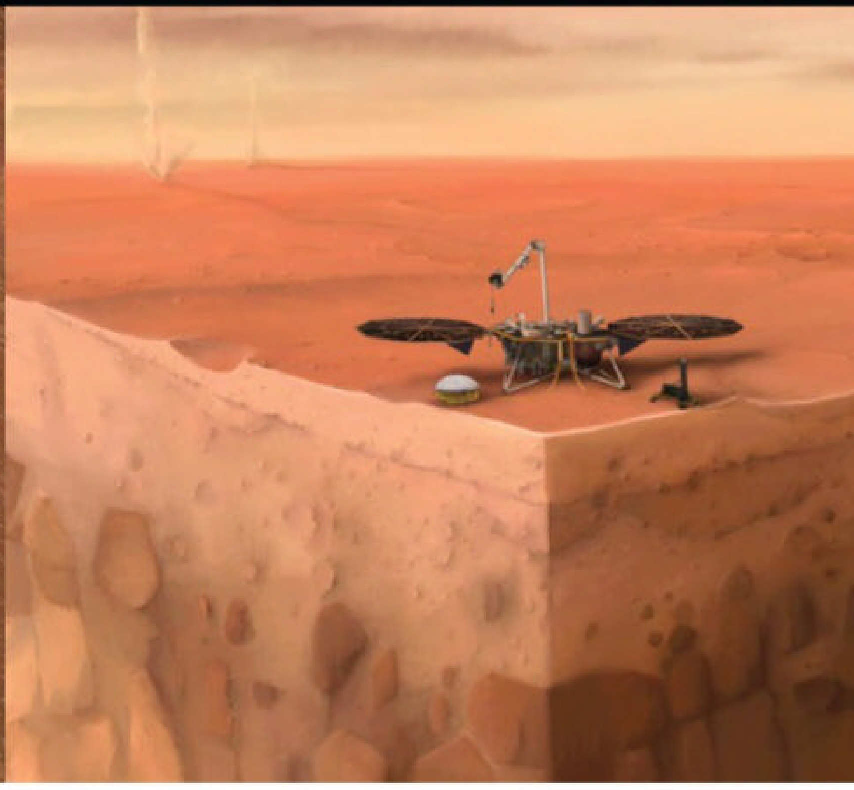
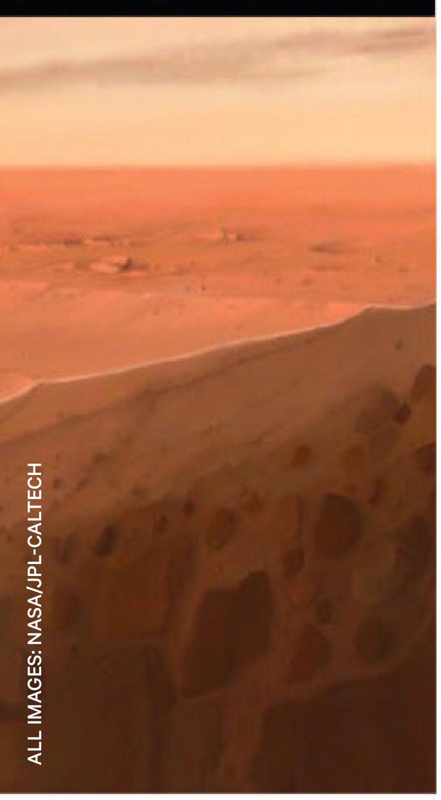




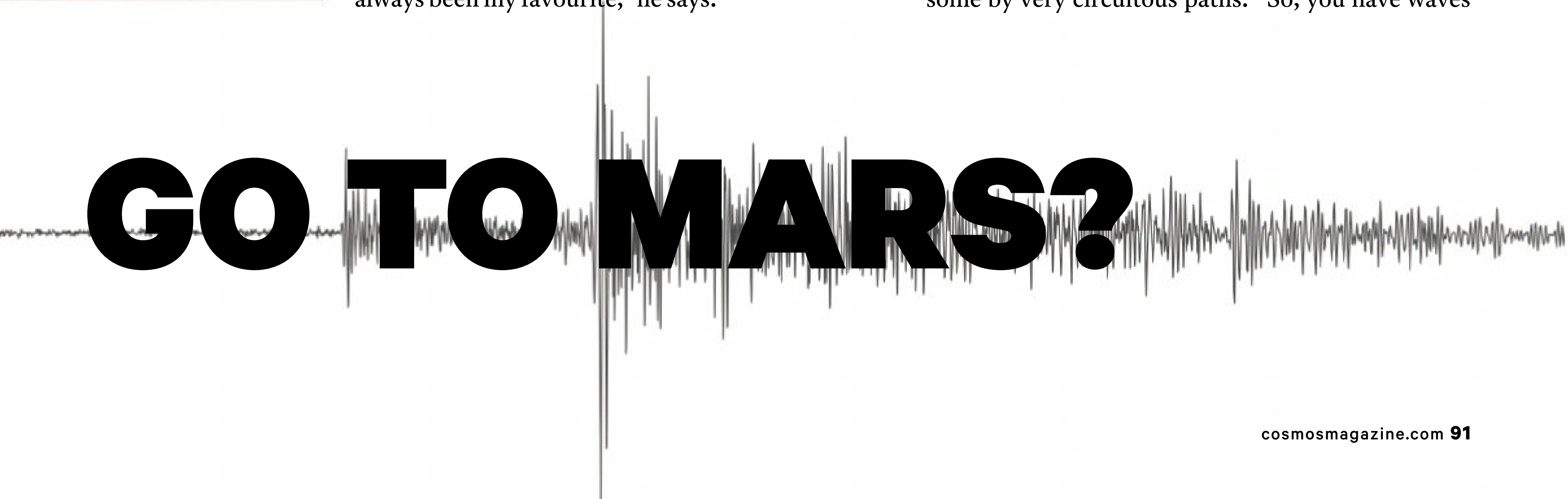


WHAT'S IT LIKE TO

Dreams can come true: from sketches (below) to a selfie taken on Mars' surface (left), InSight has spent more than 1000 sols taking in the sights – and seismographs – of the Red Planet.



ALL IMAGES: NASA/JPL-CALTECH



GO TO MARS?

You start with a puzzle, an idea and some sketches. Then what? **RICHARD A LOVETT** spoke with the principal investigator on NASA's successful InSight mission about what it's like to send a craft to another planet.

Bruce Banerdt has the job he's been dreaming of since he was a child growing up in the California desert, watching Neil Armstrong's "giant leap for mankind" on TV. "I always wanted to go to space," he says.

Not that Banerdt is an astronaut. He's principal investigator (PI) for a Mars mission. Astronauts, he realised growing up, spend a lot of time running other people's experiments. Banerdt wanted to go to space, but he also wanted to run experiments he himself helped concoct, even if that meant managing them robotically from Earth. "I got to feeling that would be one of the best ways of going to space," he says.

> InSight recently detected its three largest marsquakes. One shook the lander's seismometer for an hour and a half.

So he majored in physics, then got a PhD in geophysics. In the process, he landed the job that put him on track to his dream: an internship at NASA's Jet Propulsion Laboratory in Pasadena, California.

That was 1976. The internship turned into a part-time job, which became full-time after he completed his PhD at the neighbouring University of Southern California.

He's been there ever since. "I only ever did one job interview in my life," he says with a laugh.

Along the way, he developed an interest in using remote sensing methods such as seismology and variations in gravitational and magnetic fields to peer into the cores of terrestrial-type worlds, including Venus, Mercury and the Moon. "But Mars has always been my favourite," he says.

Mars is where he's working right now, via NASA's InSight Mars Lander.

InSight was conceived as a billion-dollar project to put a seismometer on the surface of Mars in the hope of using the Red Planet's occasional marsquakes to probe its interior.

Launched in 2018, it's now been there for more than 1000 sols (Mars days, slightly longer than Earth's) and recently detected its three largest marsquakes, ranging from magnitude 4.1 to 4.2. By Earthly standards, those aren't huge, but they are big enough to make Banerdt very happy, because the bigger the quake, the easier it is to study how its seismic waves were altered as they bounced around the Martian interior en route to InSight's seismometer.

These quakes weren't just big. One shook the lander's seismometer for an hour and a half. On Earth, such a thing would be unthinkable, other than for giant temblors that can make the entire Earth ring like a bell for a day or longer. For smaller earthquakes, he says, 20 minutes of shaking is probably the maximum.

What caused it, he thinks, is that the marsquake set off seismic waves that initially went off in all directions. Some headed quickly toward InSight and its seismometer. Others went in different directions, then hit discontinuities in the Martian interior that reflected them back toward InSight sometime later, some by very circuitous paths. "So, you have waves that have travelled this drunken walk to get to your seismometer," Banerdt says. "That's our theory."

These marsquakes probably wouldn't have been seen, if Banerdt and his team had not made a daring decision.

InSight's solar panels had been getting dusty, and no handy dust devils had come along to scrub them clean, as had happened for the solar-powered Spirit and Opportunity rovers. With power down by nearly 80%, it was a mounting crisis in which Banerdt says the most likely outcome would have been having to shut down the seismometer.

But there was another way to get rid of the dust: use the materials at hand to create a whisk broom. And what material does Mars have a lot of that might do this? Sand.

The team made the bold call to use the lander's robotic arm to sprinkle sand on the upwind edges of the solar panels and let the wind blow it across the solar panels, in the hope it would brush away enough dust to keep the lander functional.

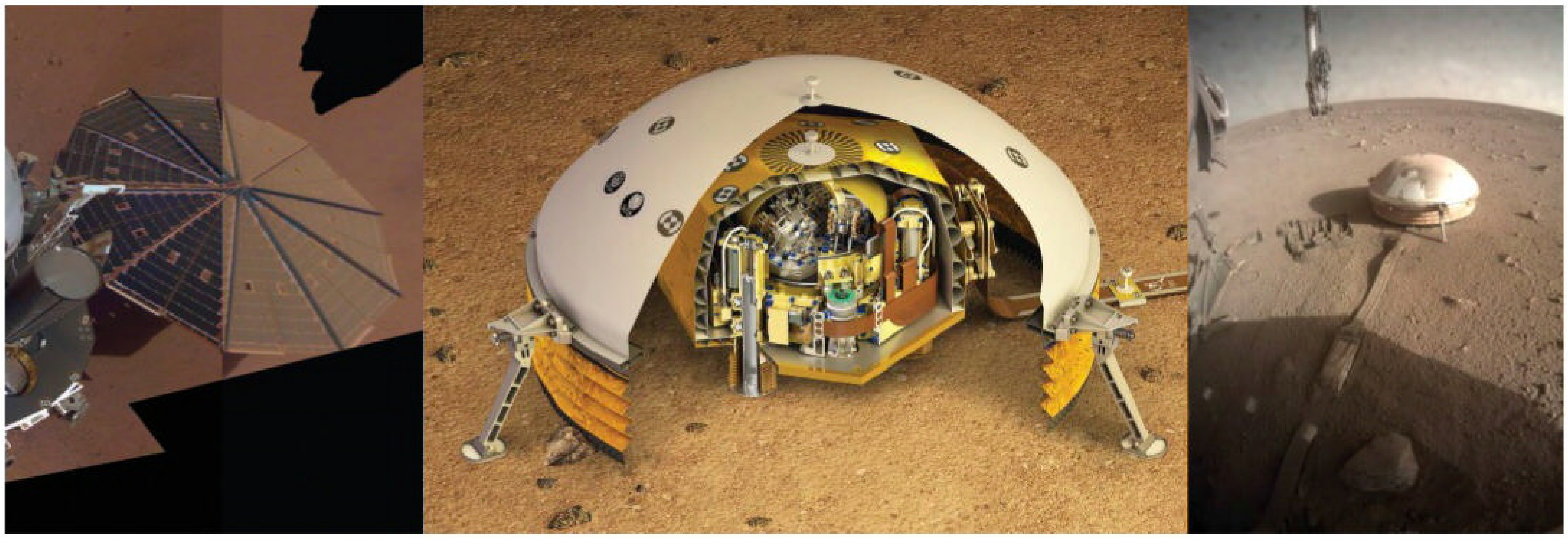
InSight's principal investigator Bruce Banerdt (opposite) gets to explore the inner space of Mars from his NASA office. The greatest threat to InSight's mission is the Martian dust covering the solar panels (below left split image: at left from 2018, at right 2019). The seismometer's also dealing with dust; the illustration below shows the delicate measurement device hidden under a protective cover. Below right: so far, grubby but still going.

Instead, the role is more like being a CEO. "The job definition is being responsible to NASA for the overall success of the mission," he says.

How to do this is up to the individual PI. Some prefer to direct from the metaphorical equivalent of 30,000 metres, delegating many of the details to the engineering team. Others are more proactive, working with the engineers to make sure that decisions made early on don't interfere with the scientific goals.

"I've been very hands-on," Banerdt says. "To me, the secret is you need to know a little about everything. There are a lot of people who make great decisions in their own field. But you have to have someone in the middle who knows the trade-offs – someone who understands the science, who knows the engineering, who knows the politics. To me, that's the secret of being a principal investigator: being able to balance the expert decisions and come up with the best decision overall."

It's also a major time commitment. NASA generates some missions on its own, but for the majority



The idea, Banerdt admits, sounded so preposterous that when it was first suggested it was pretty much laughed out of the room. "The last thing you want to do is put more dirt on the panels when they're getting dirty," he says.

But geologists on the team had seen images of how blowing sand had removed dust on the Martian surface. So, with no better option, that's what InSight eventually did – and as principal investigator, it was Banerdt who made the decision. "I feel very strongly that we would not have seen these [big] quakes if we had not been able to clean these panels the way we did," he says.

The title "principal investigator" makes it sound like Banerdt's job is primarily science: investigating, researching, writing journal articles. And while principal investigators do get their names on journal articles, that isn't their primary job. "My [traditional] science career kind of ended when I became a principal investigator," Banerdt says.

INSIGHT'S GREATEST HITS...

So far, InSight has made five major findings.

1. The Martian core is larger than expected. "It's about half the radius of the planet," Banerdt says. That means it must also be less dense than expected, given what is known of Mars' total mass. That means that as the core formed, the molten iron and nickel droplets falling toward its centre swept up substantial amounts of lighter elements, like sulphur, carbon, and oxygen. That's an important clue to how the core formed.

2. The crust is relatively thin. Various theories, Banerdt says, had predicted thickness up to 60-80km, but it turns out to be about half that, probably 37km, though there is some ambiguity in the data that might make it even thinner yet. This, too, is an important clue to the early history of the planet. "It goes back to the degree of melting of the early planet and how much was able to float to the top," he says.

3. The upper mantle isn't homogeneous: its seismic properties vary with depth in a way that indicates a temperature gradient between its upper and lower layers. It's an important clue to how heat from the Martian depths escapes to the surface.

4. Marsquakes tend to be concentrated in one region, called Cerberus Fossae, which, probably not by coincidence, appears to be one of the planet's most recent sites of volcanic activity.

5. Big marsquakes appear to be "too" rare. On Earth

FROM LEFT: NASA/JPL-CALTECH X3

> These marsquakes probably wouldn't have been seen if Banerdt and his team had not made a daring decision.

of them, it has a lengthy process in which prospective principal investigators compete to convince the agency that their projects are the ones it should fund.

"I first got involved in looking at building a seismometer to go to Mars in the late 1980s," Banerdt says.

At first, it was a sideline interest, but as time passed, he found himself more involved, making presentations at scientific meetings, meeting with people at lunches, and talking with colleagues about the science such a mission would gather, and how important it was. "The first thing a principal investigator has to do is sell the mission," he says. "For two decades, I was in sales mode."

In interviews, Banerdt appears to have the gift of gab. He has the rare ability to talk not just in complete sentences but complete paragraphs. But, he says, that wasn't a skill he was born with.

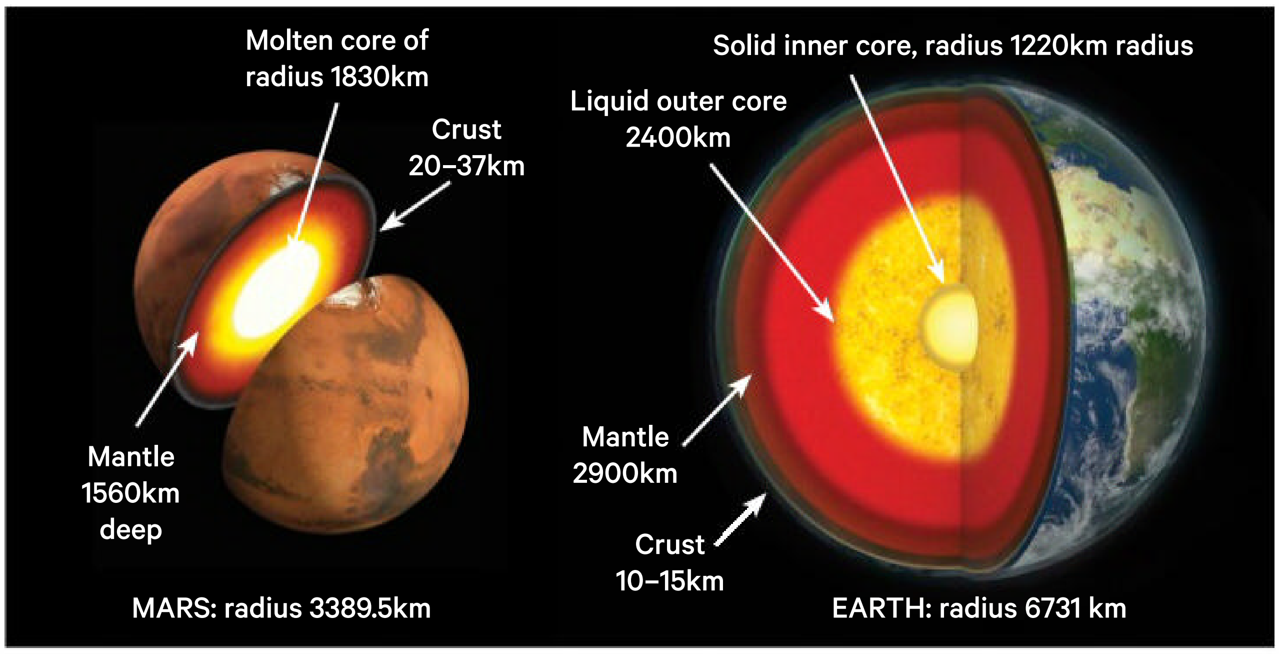
"I'm not a natural schmoozer," he says. "I'm a very shy person by nature." Left to his own devices, he says, he'd have locked himself in his office and written "massive amounts of code that would simulate the physics of planets".

When the mission was approved, the job turned to oversight and administration, including sifting out priorities in order to fit the budget. "If you had an unlimited pot of money," he says, "you could solve all your problems." But in the real world, "you have to pick and choose – where you're going to take risks, and where you're not going to take risks. That's a lot of what I end up doing. 'This is a problem we'll spend time and money solving; this other we'll spend less on.' I get lots of advice, but I'm the one who has to make the decisions."

But with that came the ultimate reward, when he got to be in the control room at launch and, at the right moment, give his go-ahead.

"I got to say, 'The principal investigator is go for launch'," he says. "That's an incredible experience for a kid who grew up dreaming of space."

RICHARD A LOVETT's last story for the magazine, on the telescope Gaia, appeared in Issue 91.



TOP: NASA/JPL-CALTECH / BILL INGALLS. BOTTOM: STOCKTREK, TUMEGGY / GETTY IMAGES

and the Moon, there are simple mathematical relationships between the number of big and small temblors. On Earth, for example, each 1-point increase in magnitude is accompanied by a 10-fold drop in frequency. Something similar occurs on Mars, but only for small earthquakes.

"There's a fall-off in the higher magnitudes," Banerdt says. "There are tons of 2.0s, and lots of 2.5s, and a fair number of 3.0s, but when you get above 3.0s, there seems to be a fall off." Why? Nobody knows. "That's puzzling," he says.

...AND ONE MISS

In addition to the seismometer, InSight carried an instrument onboard called the mole, which Banerdt describes as akin to a "self-hammering nail" that was supposed to pound itself 3-5 metres into the ground. Others have compared it to a pile driver. Its goal was to measure the temperature gradient in the upper level of the Martian crust, from which scientists hoped to learn about how heat is escaping from the planet's interior.

It didn't work.

The instrument was designed for the type of sand/rock mix seen by rovers and in satellite images. Instead, it hit something else, a layer of rock that crumbled in a way it wasn't designed to deal with.

"It's one of those things where you design your instrument the best you know, but you can still run into things that are unexpected," Banerdt says. "Now we know more."