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DESTINATION: Venus?

Our toxic twin might be a scientific treasure-trove, but infrequent visits are hindering studies, causing many planetary scientists to grow frustrated.

It was a little after 3 a.m. when Ellen Stofan jumped into her car and raced toward the Jet Propulsion Laboratory. She had just learned that the first radar image of Venus had arrived from the Magellan spacecraft, and she literally could not wait to see it.

Stofan, the mission's deputy project scientist at the time, was one of the first people to peer beneath the clouds using Magellan and inspect our sister planet in unprecedented detail. And that first black-and-white image in August 1990 did not disappoint. It revealed a vast volcanic plain scarred by a giant impact crater. Unlike the Moon, Mars, and Mercury, Venus appeared to have been geologically active in the recent past.

But it was only a hint of what was to come. By the end of its four-year mapping effort, the spacecraft revealed 98% of the planet's surface at a higher resolution than ever before. "We uncovered this amazing, confusing planet," Stofan says.

The most confusing — and compelling — aspect, Stofan says, was that so many images looked like the first. Not only is Venus covered in lava flows, but it also lacks a lot of craters (which build up over time), suggesting that the planet resurfaced much of itself only a few hundred million years ago. And although scientists aren't sure what can cause such a startling global change, they do think the answer might help explain how the planet's runaway greenhouse began — a twist of fate that caused the once-habitable world to turn into a toxic one. Needless to say, Stofan and her colleagues were eager to send more missions to the world in search of an answer.

But while the European and Japanese space agencies have both mounted successful orbital missions to Venus, NASA has not returned there. And the geologic questions that Magellan raised remain a mystery today — nearly 30 years later.

▲ **CLOUDTOPS** Bright and dark bands caused by an unknown chemical absorber mark this ultraviolet view of Venus from the European Venus Express orbiter. The patterns are about 70 km above the surface.

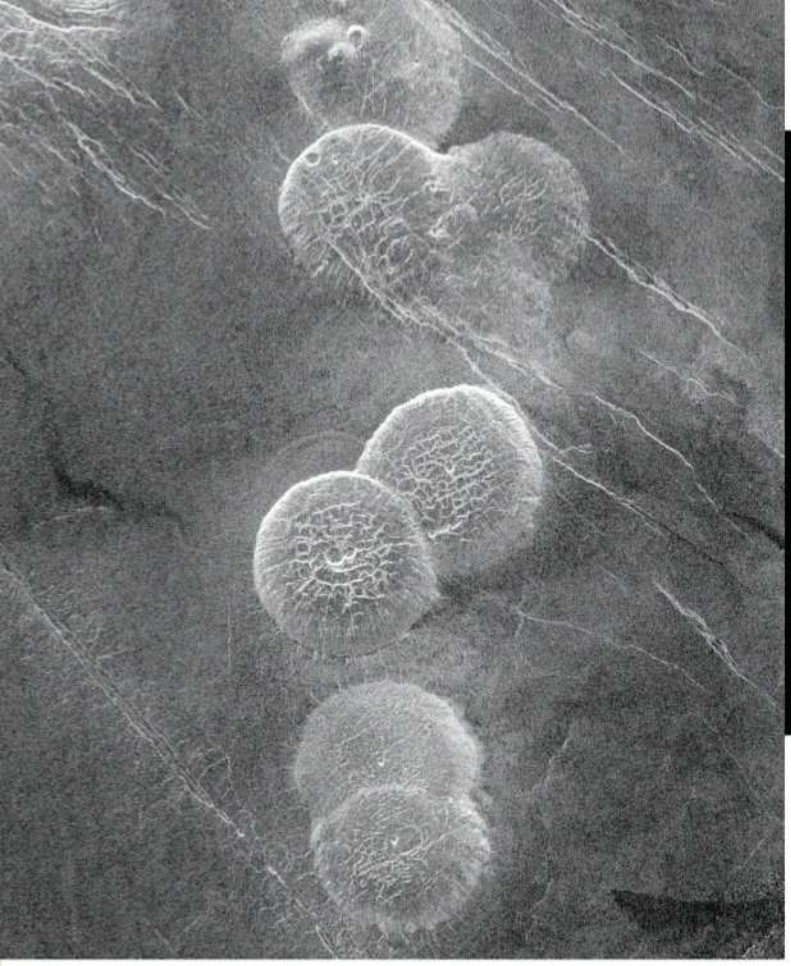
It's a tragedy to many U.S. planetary scientists, some of whom are now up in arms over NASA's shift away from Venus exploration. In the years since Magellan, planning teams have proposed more than 25 new Venus missions. Every single one has been shot down. The latest saga ended in December when Venus researchers received a double dose of bad news: Yet another two mission proposals were rejected.

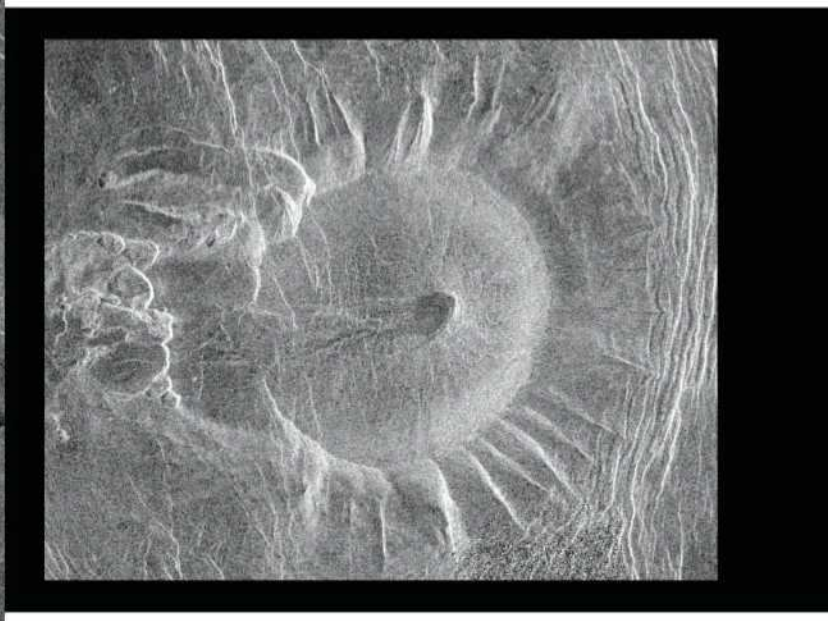
"We jump-started our understanding of Venus with Magellan, and then it was just like we got cut off at the knees," Stofan says.

Yet not only does Venus likely hold the key to understanding open questions about Earth, but it also can address habitability in general — an issue that's crucial now that astronomers have discovered thousands of exoplanets, many of which likely resemble Venus. For that reason, Venus scientists are trudging onward, hopeful that the tides will soon turn and that NASA will one day return to the evening star.

Volcanic World

There's no doubt that Venus is Earth's deadly sibling. The two planets are near-twins in size, density, gravity, and, likely, chemical makeup. Although today Venus doesn't reside in our Sun's life-favoring "Goldilocks zone," it, along with Mars, might have been habitable billions of years ago. (Yes, some astronomers argue that Venus once hosted global oceans and moderate temperatures.) But despite these similarities, something caused the two planets to wander down two very different evolutionary paths.





◀ **PANCAKE DOMES** These seven circular hills in Alpha Regio, on average 25 km wide and 750 m high, appear to be thick lava flows that welled up onto level ground, which allowed them to flow out in an even pattern.

▲ **VENUSIAN TICK** This bizarre volcanic construct is a tick, a caldera surrounded by radiating ridges and valleys. Lava flows breaching the rim created the "head." Ticks sometimes appear near the deformed terrain regions called *tesserae*, but it's unclear if they're related.

Earth, as we know, transformed into a paradise fit for life, while Venus morphed into a hellscape. It boasts clouds of sulfuric acid and an atmosphere that slams down on the surface with 90 times the pressure found in Earth's atmosphere. That surface averages a blistering 460°C (860°F) — hot enough to melt lead. Smooth, gently rolling plains cover about 70% of its surface — the result of past volcanic flows, some of which travel for thousands of kilometers before fanning outward. Recent research even suggests that volcanism continues today. Needless to say: Venus is hot, stifling, and dynamic.

Magellan and its predecessors also revealed terrain studded with mountains, plains, high plateaus, canyons, and ridges. The planet even boasts highlands akin to Earth's continents. The two largest are the sprawling Aphrodite Terra along the equator, nearly as large as Europe and Asia combined, and Ishtar Terra in the northern hemisphere, roughly the size of Antarctica. Those two highlands stand a few kilometers above the plains, roughly similar to the rise of Earth's continents above its seafloor, and they're marred by more than 1,000 large volcanoes and 100 mountains — the tallest of which tower above the landscape at a height greater than that of Mount Everest in the Himalayas.

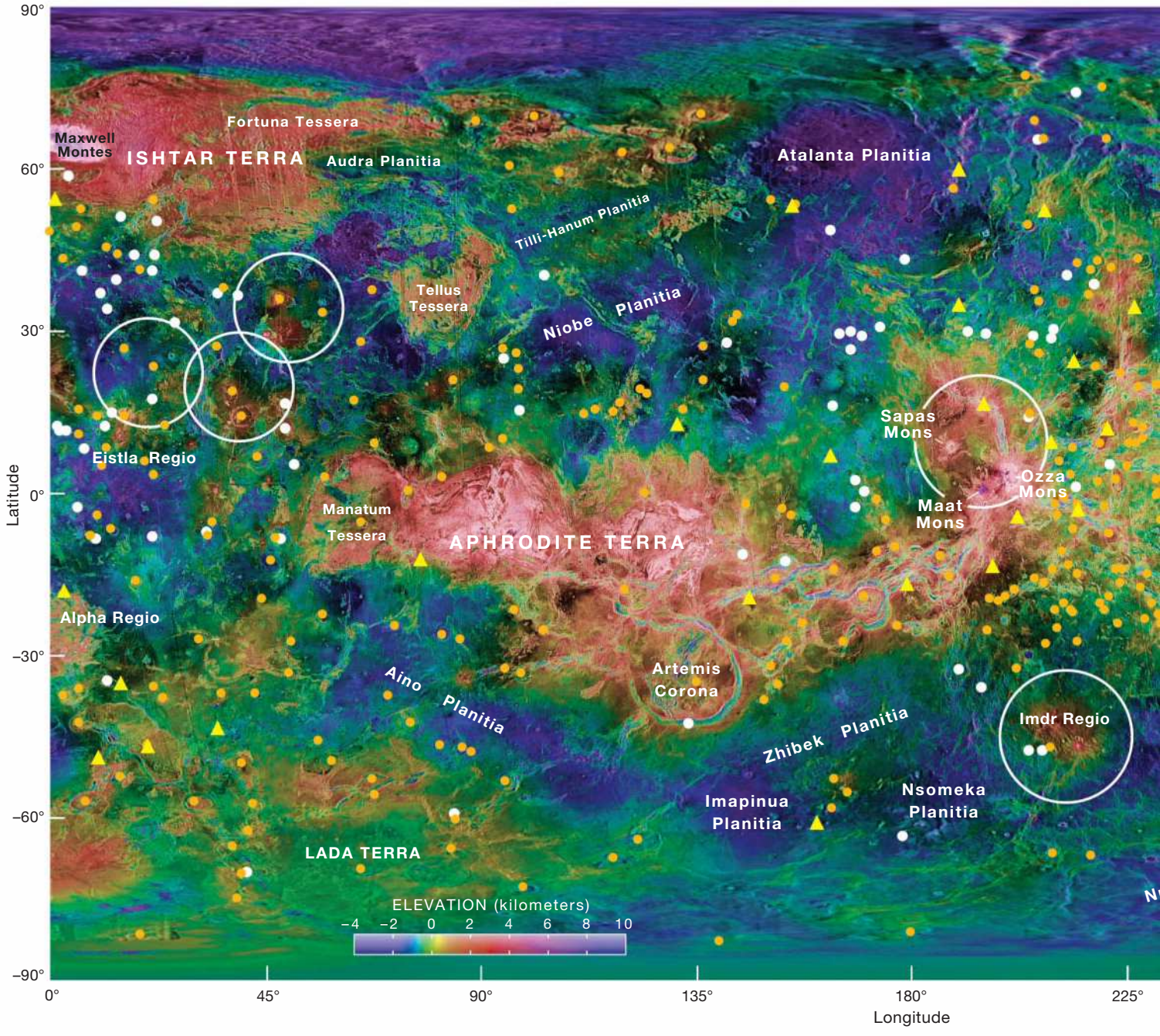
But that range of peaks, Maxwell Montes, built up in a different way than the Himalayas, which were created when two tectonic plates — those large slabs of rock that divide Earth's crust and jostle about — rammed into each other. In fact, Venus does not appear to host plate tectonics at all. That much can be seen from the distribution of volcanoes, which do not create long chains along the boundaries of tectonic plates like they do on Earth, but dot the surface haphazardly. It's a mystery whose answer might explain Venus's young landscape, its stifling atmosphere, and even phenomena on our own world.

Shedding Light on Earth

On Earth, jostling crustal plates help regulate our planet's temperature over tens to hundreds of millions of years as carbon dioxide shifts between the atmosphere and Earth's mantle. So it could be that Venus once had plate tectonics, but over time those plates became thicker and harder to break apart or subduct. As a result, there was no way to pull carbon dioxide out of the atmosphere and into the mantle, forcing the planet down a path that led to extreme temperatures and atmospheric pressures.

▶ **MAGELLAN TEAM** Members of the Magellan team pore over images from the orbiting spacecraft. The map being studied is assembled from the long strips of data from Magellan's pole-to-pole passes. From left to right: Nick Stacy, Ellen Stofan, Barry Parsons (rear), and Don Campbell.

BACKGROUND: USGS ASTROGEOLOGY SCIENCE CENTER; CLOUDTOPS: ESA / MPS / DLR / IDA, M. PÉREZ-AYÚCAR & C. WILSON; PANCAKE DOMES & TICK: NASA / JPL; MAGELLAN TEAM: NASA / JPL; *S&T* ARCHIVES



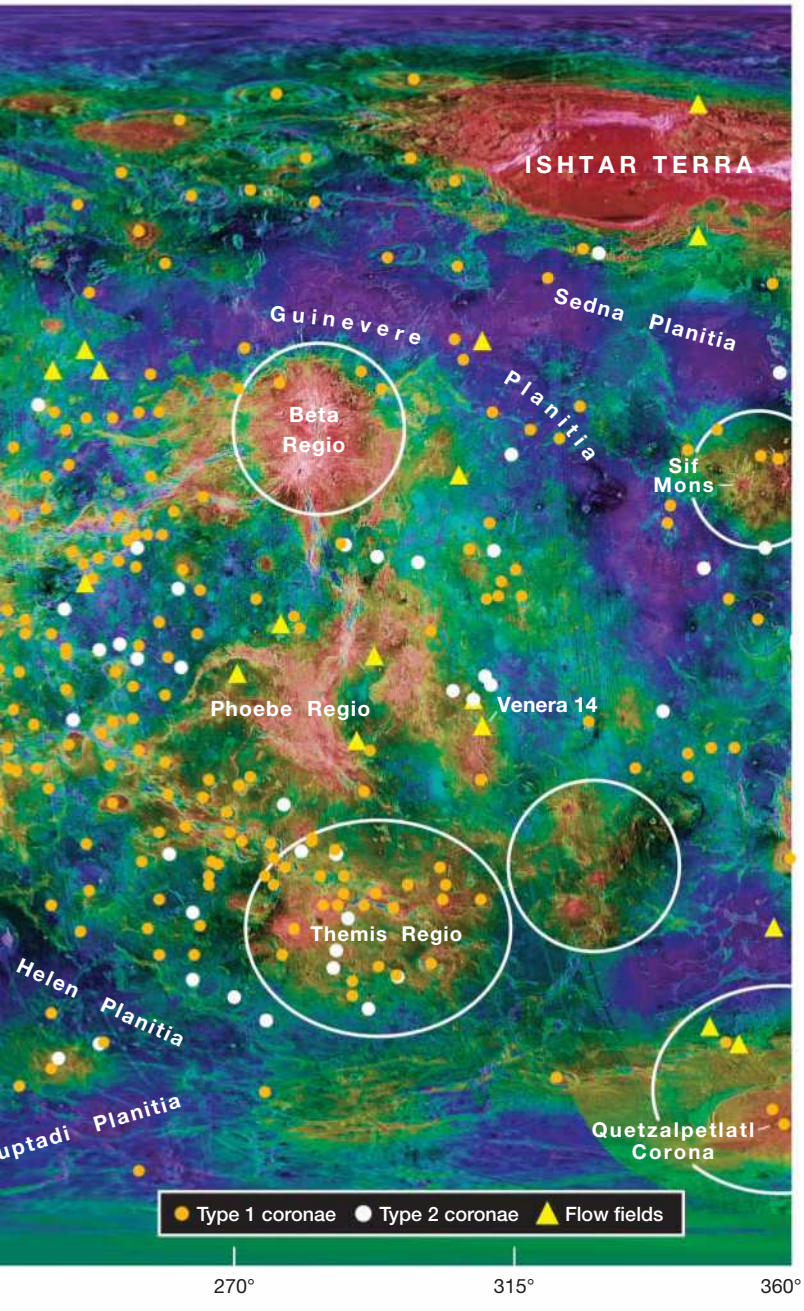
Or it might be that Venus never had plate tectonics in the traditional sense. Instead, as the crust piles up with lava, it thickens and grows more massive, pushing the crust beneath it back down into Venus's interior. That process would also create compressional crumpling that, together with the lava flows, would wipe away craters, thus explaining why the surface looks so young.

Some scientists argue that a similar process could have provided the initial force that kick-started plate tectonics on Earth. That's important because plate tectonics just might be a crucial ingredient for sustaining life (given that it keeps our planet's temperature in check), and yet scientists can't yet pin down just how and when it began here.

As such, Venus harbors secrets that might bear on our pale blue dot. Take its stifling atmosphere as a second example. It's a department store of climate puzzles, says David Grinspoon (Planetary Science Institute), including the circulation of the atmosphere, the balance of radiation, the function of clouds, and the role of trace greenhouse gases. Although scientists have a fairly good understanding of how those processes work on Earth, seeing them in an altered way on a new world will help them better understand the underlying physics and thus improve their models for Earth overall.

Grinspoon even argues that Venus might reveal hidden fine-tunings that could help climate scientists better forecast our own future in a warming world and better understand

MAP: USGS ASTROGEOLOGY SCIENCE CENTER, DATA: E. R. STOFAN AND S. E. SMREKAR / *PLATES, PLUMES, AND PARADIGMS* 2005 AND DARBY DYAR



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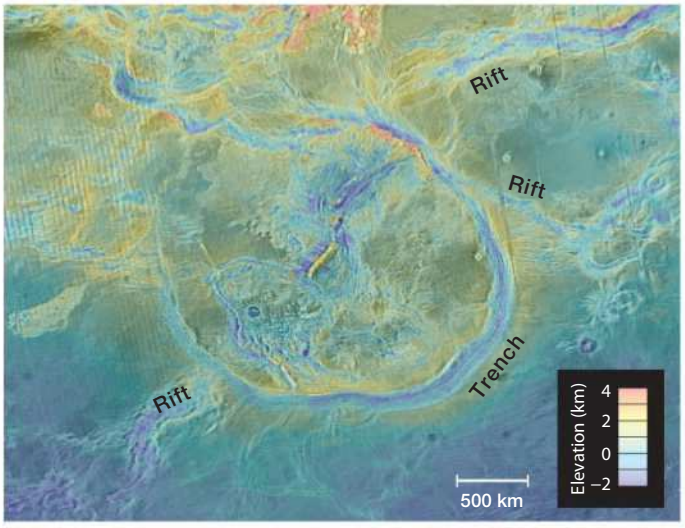


◀ **VOLCANISM** Venus has widespread signs of recent (perhaps active) volcanic activity. Expansive lava flows cover its surface, and giant hotspots (circled) are the surface manifestations of upwelling mantle plumes. These can span more than 1,000 km and likely underlie the roughly 500 circular features called coronae. (Type 1 coronae have concentric rings of cracks.) Representative features and those mentioned in the article are labeled.

▲ **ARTEMIS CORONA** This image combines radar (gray) and topographic (color scale) views of Artemis Corona, a 2,600-km-wide hotspot in Venus's southern hemisphere. Scientists think coronae form when a large molten plume wells up from the mantle, fracturing the crust above it and exuding onto the surface. The weight from the spreading lava bends the underlying crust, forcing it to subduct back into the mantle. This process would explain the rifts radiating out from the corona and its encircling trench and buckled terrain. In Artemis's case, there also appear to be several smaller corona-like features inside the large one.

the role we play in those changes. "It's not just an academic question," Grinspoon says. "Understanding how climate works on Earth-like planets is now a matter of survival."

If scientists could pinpoint the factors that tipped Venus away from becoming a habitable world and toward a noxious one, then they would also be able to pinpoint the factors that kept Earth on the other course. "We want to know when in the 4.5 billion years of the history of the solar system, the destiny of the two planets was written — and when did it diverge," says Thomas Widemann (Paris Observatory).

Only then can we understand what truly makes a world habitable. Or as Lori Glaze (NASA Goddard) says: "If we don't understand that, we don't know what makes Earth *Earth*."

At the end of the day, our toxic twin — which is eerily similar to our planet in some regards and yet worlds apart in others — could easily help explain our changing climate, the initiation of plate tectonics, and what made our world habitable. "Venus is uniquely positioned and equipped to give us answers in a way that no other planet that we can explore can," Grinspoon says. "And yet we've been completely neglecting it. It's criminal."

A Planet Left in the Dust

With so much to learn from our neighboring planet, many planetary geologists find it inconceivable that NASA hasn't sent a dedicated mission there since the 1990s. And it's not like Venus was a one-hit wonder back then. When scientists first started to explore the solar system, they set their eyes on Venus. Not only was it the target of our first successful encounter beyond Earth, but it also was frequently visited throughout the 1960s and '70s.

But after Magellan, no new probe embraced its skies for more than 10 years, until European and Japanese orbiters launched in 2005 and 2010, respectively. So, James Green, NASA's new Chief Scientist, argues that there are more Venus missions happening than disgruntled researchers let on. "You don't have to lead the mission to do Venus science," he says.

Venus was the first target for planetary exploration in the Space Age. Nearly twice as many spacecraft visited it as went to Mars in the 1960s — and four times as many in the 1980s. But after Magellan's mission ended in 1994, interest waned.

- – – Failed mission
—— Successful mission (includes partially)

[B] = balloon
[F] = flyby
[L] = lander
[O] = orbiter
[Pe] = penetrator
[Pr] = probe
[R] = rover
[S] = sample return
[U] = unclear

DID YOU KNOW?
All Venusian landers so far have incorporated spherical structures, because that shape best withstands collapse under the tremendous atmospheric pressure. In fact, the pressure is similar to what you'd experience nearly 1 km beneath the ocean's surface on Earth.

MARS	Launch	VENUS
Marsnik 1 | *USSR* [F]	1960	
Marsnik 2 | *USSR* [F]	1960	
	1961	Sputnik 7 | *USSR* [Pr]
	1961	Venera 1 | *USSR* [F]
Sputnik 22 | *USSR* [F]	1962	
Mars 1 | *USSR* [F]	1962	
Sputnik 24 | *USSR* [L]	1962	
	1962	Mariner 1 | *NASA* [F]
	1962	Sputnik 19 | *USSR* [F]
	1962	Mariner 2 | *NASA* [F]
	1962	Sputnik 20 | *USSR* [F]
	1962	Sputnik 21 | *USSR* [F]
	1963	Cosmos 21 | *USSR* [U]
Mariner 3 | *NASA* [F]	1964	
Mariner 4 | *NASA* [F]	1964	
Zond 2 | *USSR* [F]	1964	
	1964	Venera 1964A | *USSR* [F]
	1964	Venera 1964B | *USSR* [F]
	1964	Cosmos 27 | *USSR* [F]
	1964	Zond 1 | *USSR* [F]
	1965	Venera 2 | *USSR* [F]
	1965	Venera 3 | *USSR* [L]
	1965	Cosmos 96 | *USSR* [L]
	1965	Venera 1965A | *USSR* [F]
	1967	Venera 4 | *USSR* [Pr]
	1967	Mariner 5 | *NASA* [F]
	1967	Cosmos 167 | *USSR* [Pr]
Mariner 6 | *NASA* [F]	1969	
Mariner 7 | *NASA* [F]	1969	
Mars 1969A | *USSR* [O]	1969	
Mars 1969B | *USSR* [O]	1969	
	1969	Venera 5 | *USSR* [Pr]
	1969	Venera 6 | *USSR* [Pr]
	1970	Venera 7 | *USSR* [L]
	1970	Cosmos 359 | *USSR* [Pr]
Mariner 8 | *NASA* [O]	1971	
Cosmos 419 | *USSR* [O]	1971	
Mars 2 | *USSR* [O+L]	1971	
Mars 3 | *USSR* [O+L]	1971	
Mariner 9 | *NASA* [O]	1971	
	1972	Venera 8 | *USSR* [Pr]
	1972	Cosmos 482 | *USSR* [Pr]
Mars 4 | *USSR* [O]	1973	
Mars 5 | *USSR* [O]	1973	
Mars 6 | *USSR* [F+L]	1973	
Mars 7 | *USSR* [F+L]	1973	
	1973	Mariner 10 | *NASA* [F]
Viking 1 | *NASA* [O+L]	1975	
Viking 2 | *NASA* [O+L]	1975	
	1975	Venera 9 | *USSR* [O+L]
	1975	Venera 10 | *USSR* [O+L]
	1978	Pioneer Venus 1 | *NASA* [O]
	1978	Pioneer Venus 2 | *NASA* [Pr]
	1978	Venera 11 | *USSR* [F+L]
	1978	Venera 12 | *USSR* [F+L]
	1981	Venera 13 | *USSR* [F+L]
	1981	Venera 14 | *USSR* [F+L]
	1983	Venera 15 | *USSR* [O]
	1983	Venera 16 | *USSR* [O]
	1984	Vega 1 | *USSR* [L+B]
	1984	Vega 2 | *USSR* [L+B]
Phobos 1 | *USSR* [O+L]	1988	
Phobos 2 | *USSR* [O+L]	1988	
	1989	Magellan | *NASA* [O]
	1989	Galileo | *NASA* [F]
Mars Observer | *NASA* [O]	1992	
Mars Global Surveyor | *NASA* [O]	1996	
Mars 96 | *Roscosmos* [O+L+Pe]	1996	
Mars Pathfinder and Sojourner | *NASA* [L+R]	1996	
	1997	Cassini | *NASA* [Fx2]
Nozomi | *JAXA* [O]	1998	
Mars Climate Orbiter | *NASA* [O]	1998	
Mars Polar Lander/Deep Space 2 | *NASA* [L+Pe]	1999	
Mars Odyssey | *NASA* [O]	2001	
Mars Express/Beagle 2 | *ESA* [O+L]	2003	
Mars Exploration Rover Spirit | *NASA* [R]	2003	
Mars Exploration Rover Opportunity | *NASA* [R]	2003	
	2004	Messenger | *NASA* [Fx2]
Mars Reconnaissance Orbiter | *NASA* [O]	2005	
	2005	Venus Express | *ESA* [O]
Phoenix Mars | *NASA* [L]	2007	
	2010	Akatsuki | *JAXA* [O]
Phobos-Grunt/Yinghuo-1 | *Roscosmos and CNSA* [O+S]	2011	
Curiosity | *NASA* [R]	2011	
Mars Orbiter Mission/Mangalyaan | *ISRO* [O]	2013	
MAVEN | *NASA* [O]	2013	
ExoMars Trace Gas Orbiter/Schiaparelli | *ESA and Roscosmos* [O+L]	2016	

But while NASA's planetary-science community is thankful that its international partners have picked up the baton, many say it is not enough. They want to send orbiters that will map the world in closer detail. They want to send balloons that will fly into those acidic clouds to test for stable isotopes and noble gases, which bear the fingerprints of Venus's origin and evolution. And they want to drop probes onto its surface, landing on some fresh lava flows or the *tesserae* — regions of crumpled terrain with unknown origins — in order to better assess the past habitability of our sister planet.

▲ **IN ULTRAVIOLET** This two-image composite from Akatsuki data shows clouds and hazes (65 to 75 km altitude). Colors track changes in sulfur dioxide and an unknown UV absorber.

With such lofty goals, scientists have written one mission proposal after the next, only to watch NASA reject them time and time again. "It's like Lucy holding the football for Charlie Brown," says Darby Dyar (Mount Holyoke College). "We run and we run and we try to kick the damn ball and it gets pulled out from under us."

That isn't to say that Venus scientists don't recognize the merit of other missions. "I look at the missions that have been selected over the last couple of rounds, and they're all outstanding," Glaze says. "They have great science ideas. They're all going to produce compelling discoveries." But she admits she's also a bit frustrated. "I do feel that it's time for Venus to play a role in this whole planetary evolution story."

Others are more dismal. Without a dedicated mission, some argue, the group of Venus scientists will shrink. And that will mean that there are even fewer scientists who will advocate for new missions. It will also mean that NASA might soon find itself devoid of anyone who has actually sent a probe to Venus. There is simply so much to gain from a Venus mission and so much to lose without one.

The Martian Allure

So what's behind NASA's long hiatus? The one to ask is Thomas Zurbuchen, NASA's Associate Administrator for the Science Mission Directorate. He's guided by a once-per-decade survey of planetary scientists that ranks funding priorities and future exploration candidates — and which, notably, ranked placing a spacecraft on Venus's surface below a Mars sample-return effort and a mission to the subsurface-ocean-bearing Europa. But ultimately, he's the person who chooses the interplanetary missions that fly and those that won't. And he does so based on three criteria: "The science is excellent, the technology is ready to go, and sometimes you need a little bit of luck, too," he says. Not that it's an easy decision. "It's one of the hardest things you'll ever do," he adds.

Zurbuchen has profound empathy for those who don't see their projects accepted. "Every time I lost a proposal I took it personally — deeply personally," he says. "I think that's what we're seeing. It's just researchers who really care about what they do, and they bring passion to the table every day."

Green agrees. Several years ago, NASA rejected his own mission proposal, causing his sunny demeanor to take a downward swing. "I was depressed for six months," he says. "That's what happens in this field. It's not easy."

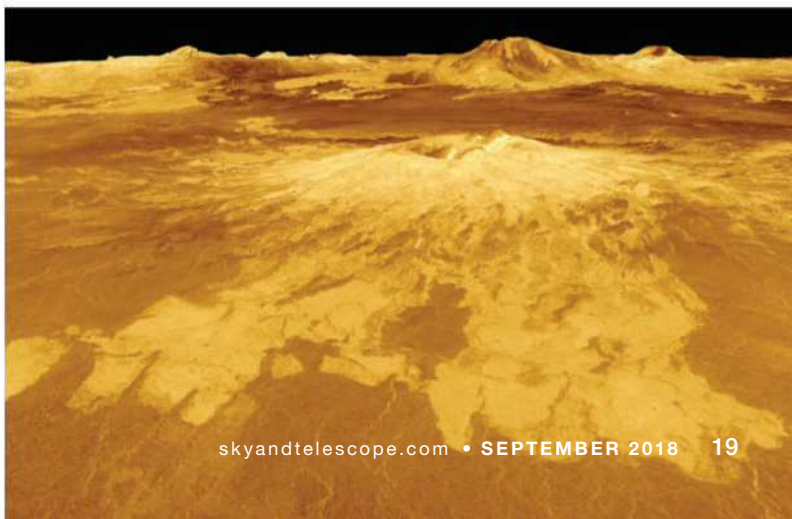
But most Venus researchers argue there are deeper issues at work. Although every planetary scientist has a pet theory — which together shed more light on human nature than on our sister planet — all agree that the dogged search for extraterrestrial life helped shift NASA's gaze away from Venus and toward Mars. In fact, Magellan's discovery just might be what sealed Venus's exploratory fate: Once NASA managers realized that Venus's young lava flows likely covered any evidence of past life or liquid water, they left the toxic world behind and turned their focus toward the Red Planet.

"Mars has this glitter to it," says Mark Marley (NASA Ames). That much could be seen in 1996 when scientists announced the discovery of what looked like bacteria fossilized within the Allan Hills 84001 meteorite — a rock that blasted off Mars and landed on Earth. Although scientists now almost universally dismiss a biologic origin for the meteorite's microscopic structures, the excitement it helped feed persisted. Exploring Mars's dusty red surface could help scientists answer one of the greatest questions they have ever asked: Is there life beyond Earth? The temptation was impossible to resist.

"It's quite possible that Venus is actually the end-state of all terrestrial planets." —Stephen Kane

And it remains impossible to resist. Even as NASA pushes outward to other bodies in the solar system (and beyond), the

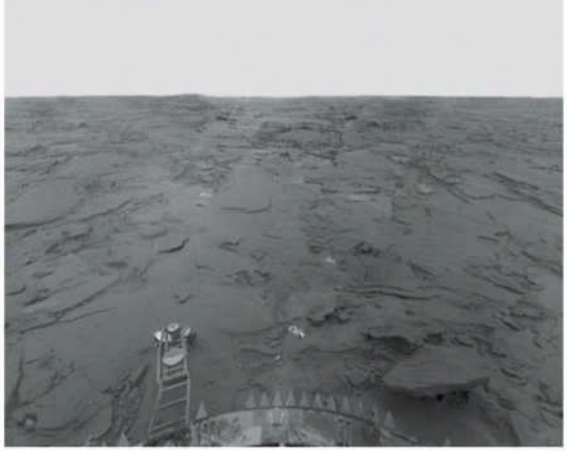
▼ **VENUS IN 3D** Colored based on images from the Soviet Venera 13 and 14 landers, this simulated perspective of Magellan data looks down on Sapas Mons, an equatorial shield volcano on the western edge of Atla Regio. The volcano is 1.5 km tall. Lava flows extend for hundreds of kilometers across the foreground plains, and Maat Mons lies on the horizon. The vertical scale in this perspective is exaggerated by a factor of 10.



search for life is still a high priority. Take the two mission proposals that were accepted last December for the final assessment round. Instead of exploring lifeless Venus, Zurbuchen opted for studying a flying rotorcraft that would investigate the geology and prebiotic chemistry on Saturn's largest moon, Titan — which is thought to be a great place for testing ideas on how life arose on Earth — and a craft to return samples from the nucleus of Comet 67P/Churyumov-Gerasimenko (*S&T:* May 2017, p. 14), whose primordial cousins might have delivered the essential building blocks of life to Earth. There's no doubt that NASA has stayed true to its mantra.

Additionally, many Venusian critics argue that the current technology favors visits to Mars over infernal Venus. The Red Planet won't melt lead, so rovers and landers placed there have lifespans measured not in hours but in years. Grinspoon thinks that could be a factor in the slew of Venus mission rejections. "I believe there's a psychological bias that we're not going to select a mission that essentially takes an hour's worth of science data — no matter how important that data is, no matter how vital the questions are that could be addressed," he says. The other missions will seem like they give a bigger bang for one's buck.

To be clear, no one is saying that NASA should stop going to Mars. "One thing you'll never hear me do is put down the cause of Mars exploration," Grinspoon adds. "It's just fantastic what we've learned."



◀ **GROUND TRUTH** Donald Mitchell remapped and combined a spherically projected Venera 14 panorama to create this more intuitive view of the Venusian surface. The spacecraft landed just south of the equator, near the border of Phoebe Regio and Navka Planitia.

But it doesn't have to be an either-or endeavor. Many Venus researchers say that there are fundamental questions about our neighboring planet that could be answered with the technology available today — even if those missions might not survive for long. "To say that we can't get to the surface of Venus is just hogwash," Dyar says.

Finally, many planetary scientists argue that Mars has a romantic appeal that Venus will never possess (despite the fact that it's named after the Roman goddess of love and beauty). Not only is Mars a world that might host evidence of past life, but it also might host humans in the future, as we settle on the Red Planet or use it as a stepping stone as we venture outward beyond Earth. The same cannot be said of Venus.

All Hope Is Not Lost

But the tides might be turning. Despite the shrinking constituency of Venus scientists, a counter-trend seems to be building within the ballooning field of exoplanet astronomy.

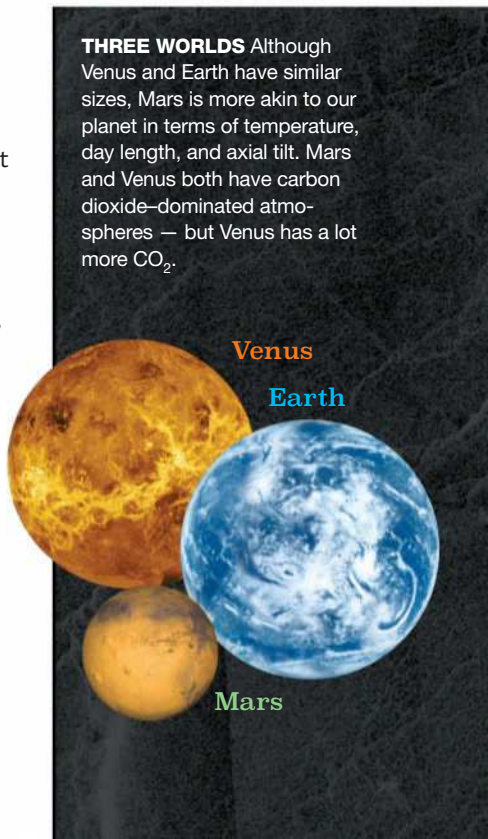
There, researchers have uncovered thousands of planets around other stars, dozens of which are Earth-size and in their star's habitable zone. But because most observations often only reveal a planet's size and distance from its host star — and Venus and Earth are essentially twins in these respects — there is no way to determine whether these planets are true Earth analogs or if they're more akin to our hellish sister.

As such, many argue that we must better understand Venus if we wish to better interpret exoplanets. "If we really are interested in studying Earth-size planets, then we need to go to the exoplanet laboratory right next door, which is Venus," says exoplanet astronomer Stephen Kane (University of California, Riverside).

To boot, there might simply be far more Venus analogs than Earths. "It's quite possible that Venus is actually the end-state of all terrestrial planets," Kane

VENERA 14: DONALD MITCHELL AND YURI GEKTIN; TESSERAE: NASA / JPL / MAPAPLANET.ORG / EMILY LAKDAWALLA

▼ **TESSERA TERRAIN** Radar-bright and roughly textured, Fortuna Tessera and other tesserae have strange cracks and wrinkle-ridge folds. Lava plains infiltrating the tessera's cracks indicate the fractured terrain is older. Scientists aren't sure how tessera terrain formed.



THREE WORLDS Although Venus and Earth have similar sizes, Mars is more akin to our planet in terms of temperature, day length, and axial tilt. Mars and Venus both have carbon dioxide–dominated atmospheres — but Venus has a lot more CO_2.

says. "You can go from a habitable environment to a runaway greenhouse. But you can't go from a runaway greenhouse back to a habitable environment. It's a one-way street."

But scientists won't know the exact ratio of Venus-like to Earth-like worlds until they uncover Venus's evolutionary path. "We have no hope of making sense of those observations without getting a handle on the Venus-Earth dichotomy," Grinspoon says. Nor will scientists know if there are other key characteristics that might hint at a planet's current status, allowing them to pour their precious resources into worlds that are more likely to harbor life.

"The exoplanet community is having a very slow and gradual realization that we can't do this on our own — we need the planetary-science community," says Kane. And that has caused some Venus proponents to regain hope. "I think that constituency is already starting to gather, it may help come to the rescue of the small-but-determined Venus community," Grinspoon says. "I'm still cautiously — perhaps foolishly — hopeful that NASA will come around."

And he is not alone. "I think it's inevitable that we'll go back there eventually," Kane says. "But I certainly do hope that people will see the immense importance of it so that it can be sooner rather than later."

Until that time comes, U.S. scientists will keep kicking at Lucy's ball by writing one mission proposal after the next. And there is some cause for optimism: NASA recently selected a mission concept called Venus In Situ Composition Investigations (VICI) for further technology development. Meanwhile, the European Space Agency, Russia, and India are all researching future missions to send to our sister planet.

"Look at the history of Magellan — that didn't get handed to us at all," says James Head (Brown University), who fought hard to include the orbiter in Jimmy Carter's campaign and later in President Reagan's budget. "It was a long, hard slog to get that mission funded. We just have to keep fighting because it's the right thing to do."

■ Freelance science journalist **SHANNON HALL** was watching Venus's dark shadow dance across the surface of the Sun six years ago when her niece was born. So, when she later taught her niece the names of the planets, Venus was first on the list.

Dive into historic exploration images of Venus's surface: https://is.gd/venusgallery.

Venus on Earth

NASA's Glenn Extreme Environments Rig (GEER) enables researchers to simulate various planetary conditions in a chamber a little smaller than a refrigerator. Last year, they exposed various mineral, rock, and glass samples to Venusian conditions for 80 days to see what reactions would take place. Researchers have also exposed different kinds of high-temperature electronics, some of which survived, says NASA's Jim Green. That success might open the door to small, long-lived landers.

▲ **TO HELL AND BACK** NASA Glenn engineer Kyle Phillips removes samples from GEER after they were exposed to Venus surface conditions for 80 days.

GEER: NASA; INFOGRAPHIC: TERRI DUBÉ / S&T; VENUS: NASA / JPL-CALTECH; EARTH: S&T ILLUSTRATION; MARS: NASA / GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO; PANCAKE DOME BACKGROUND: NASA / JPL