

AEROSPACE

A M E R I C A

Ambition: Europa

NASA might find more than life in this moon's ocean. It could find a new strategy for exploring other worlds.

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Ambition Europa

Scientists have known for more than a decade that Jupiter's moon Europa could have life in the ocean under its shell. NASA got to work drafting a cautious, step-by-step plan **to find out, perhaps sometime in the 2020s. Then, along came a congressman from Texas. Debra Werner** spoke to U.S. Rep. John Culberson and scientists about the push for a bolder Europa mission.

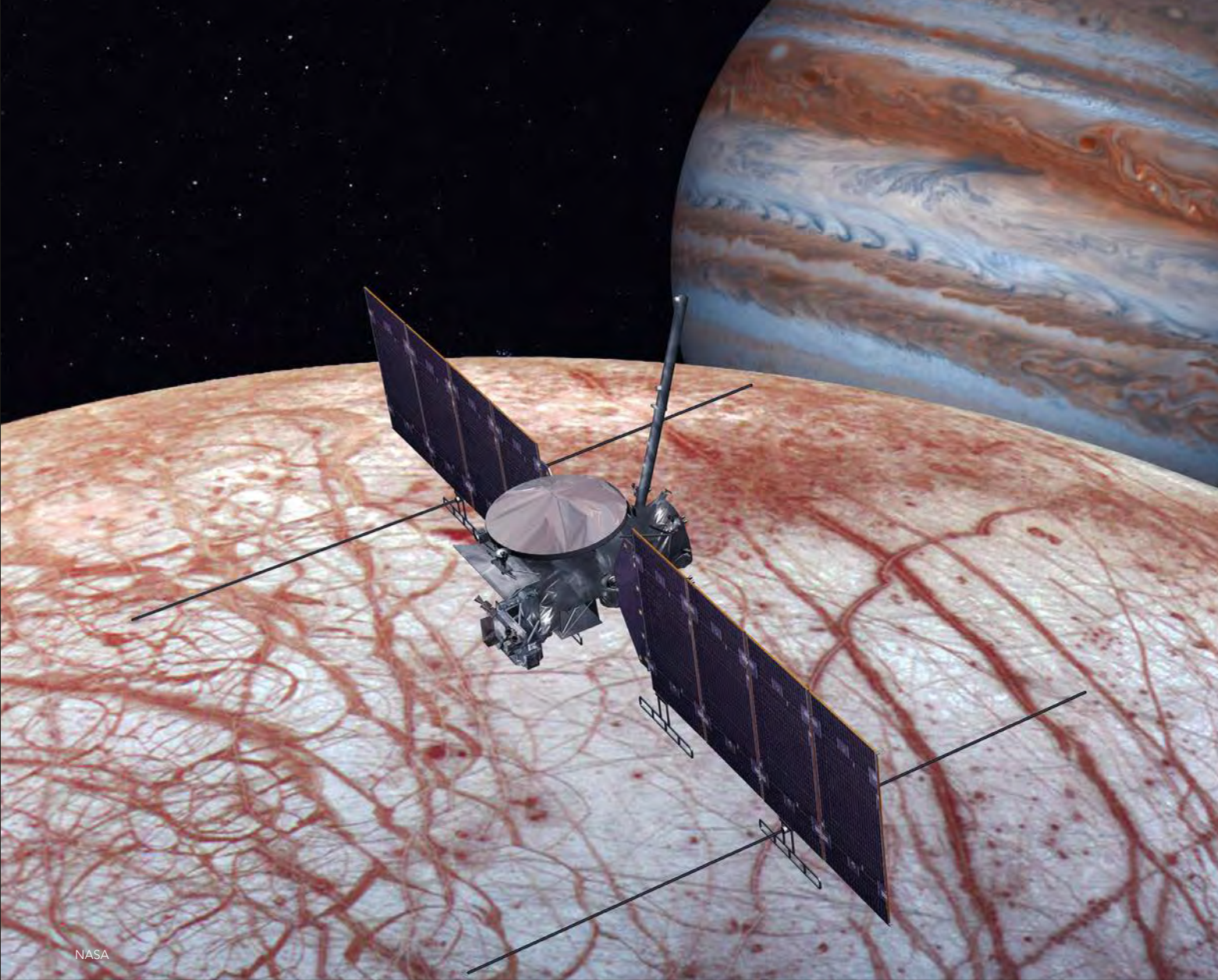
The year was 1972. Scientists at NASA's Langley Research Center were poring over reams of Martian surface photos taken by the Mariner probes, trying to figure out which region would be scientifically interesting but also safe for landing Viking 1 and 2, the first U.S. spacecraft to touch down on Mars. A year earlier, the Soviet Union achieved the first soft landing with its Mars 3 spacecraft after crashing its Mars 2 lander. With the Apollo program winding down, Congress was keeping a tight rein on NASA funding. Viking had been scaled back from one-year to a 90-day mission, and scientists eager to search for signs of

extraterrestrial life did not want either of the \$180 million landers to arrive somewhere boring, tumble over or vanish in a crevice.

This year, a much different dynamic is playing out among Congress, NASA headquarters and the Jet Propulsion Laboratory in California, where scientists are formulating plans to find out whether bacteria or other life could exist in the ocean under the icy crust of Jupiter's moon Europa. Instead of demanding austerity and caution, Congress has directed NASA to break with the tradition of scanning a world for years before deciding whether and where to send a lander.

Specifically, the 2016 appropriations law directs NASA to send "an orbiter with a lander" to Europa and to launch "no later than 2022." Questions linger about the wisdom of launching two expensive spacecraft on one rocket and about the feasibility of launching six years from now. JPL describes 2022 as "the earliest possible launch date," and it is studying multiple options for getting an orbiter and lander to Europa. NASA headquarters has approved studying the design of a Europa lander but has not yet agreed to order construction of it.

by Debra Werner
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NASA

Wanted: Electrifying discovery

Few would question that Europa is among the solar system's most intriguing worlds. Salt water is the Holy Grail in the search for environments capable of supporting extraterrestrial life, and Europa should have lots of salt water. Magnetic field data gathered 16 years ago by the Galileo spacecraft showed that a vast ocean lies under its surface. The findings were so intriguing that in 2011, U.S. planetary scientists and technologists named a Europa mission as their second-highest priority through 2022, behind additional robotic missions to Mars that eventually would culminate in returning a sample to Earth. "Europa has heat and liquid water. If there are organic compounds, we have a chemistry set that is primed for primitive or pre-biotic development," explains geophysicist

Laurence Soderblom. "Some people believe it's even possible there are organisms there. That would be startling."

Soderblom was vice chair of the National Research Council committee that published the planetary decadal survey, "Visions and Voyages for Planetary Science in the Decade 2013-2022."

On Capitol Hill, one lawmaker took special note of the survey's finding. Rep. John Culberson, R-Texas, has emerged as the Europa mission's most ardent supporter.

"We need an event, a discovery that will electrify the public and solidify the already immense support for NASA," Culberson tells me in a phone interview. That discovery could be finding life in Europa's ocean: "It will galvanize the country to take NASA funding even further so NASA can achieve all that's expected of them

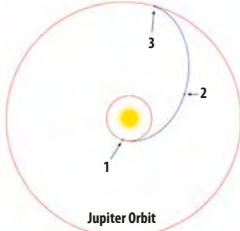
One possible orbiter design for NASA's Europa mission, which Congress has directed should be launched by 2022. NASA considers 2022 the "earliest possible launch date."

Reaching Europa

NASA wants to find out if Jupiter's moon Europa could support life. The agency is weighing different trajectories that would send an orbiter and possibly a lander into a looping orbit around Jupiter and by Europa. Here are some options:

FLY DIRECT

Arrive in 2.9 years



EVENTS

1. **Launch:** June 17, 2022
2. **Deep space maneuver:** March 22, 2023
3. **Jupiter orbital insertion:** May 1, 2025

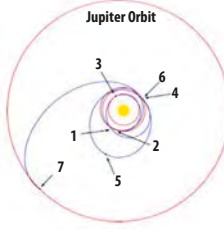
Tradeoffs: Requires NASA's Space Launch System rocket, which is still being developed. Can't launch orbiter and lander together.

Source: NASA Jet Propulsion Laboratory

GRAVITY-ASSIST OPTIONS

EVEEGA (Earth Venus Earth Earth Gravity Assist):

Arrive in 7.6 years



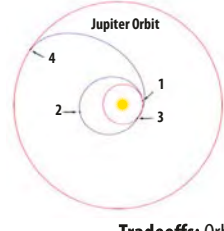
EVENTS

1. **Launch:** May 25, 2022
2. **First Earth gravity assist:** May 24, 2023
3. **Venus gravity assist:** Nov. 22, 2023
4. **Second Earth gravity assist:** Oct. 21, 2024
5. **Deep space maneuver:** Oct. 22, 2025
6. **Third Earth gravity assist:** Oct. 22, 2026
7. **Jupiter orbital insertion:** Jan. 15, 2030

Tradeoffs: Does not require still-to-be flown Space Launch System rocket, but if SLS is chosen, orbiter and lander could be launched together.

Delta-V EGA (Delta-Velocity Earth Gravity Assist):

Arrive in 4.7 years



EVENTS

1. **Launch:** Sept. 22, 2022
2. **Deep space maneuver:** Oct. 28, 2023
3. **Earth gravity assist:** Aug. 7, 2024
4. **Jupiter orbital insertion:** May 24, 2027

Tradeoffs: Orbiter and lander could "most likely" be launched together, if Space Launch System rocket is ready, NASA says. Avoids hotter environment of Venus, but requires more propellant for deep space maneuver.

and maintain our world leadership in space exploration, both manned and unmanned," he predicts.

Fortunes began to turn toward a more ambitious Europa mission and schedule in 2014 when Culberson became chairman of the House subcommittee that recommends appropriations for NASA. The agency asked for \$15 million in fiscal 2015 to continue planning for construction of a probe to be called Europa Clipper that would have sailed repeatedly by Europa from an orbit around Jupiter. Culberson proposed septupling that figure to \$100 million; the Senate signed on, possibly because the launch looked like a job for NASA's yet-to-fly Space Launch System rocket and its Exploration Upper Stage. President Barack Obama signed the \$100 million into law as part of the \$18 billion for NASA in the omnibus spending bill for 2015. Congress went further in the Consolidated Appropriations Act that Obama signed in December, specifying the launch date of 2022 and requiring NASA to use SLS. NASA's \$30 million request was boosted to \$175

million. Thus was born the Europa Multiple Flyby mission.

Of the lander, Culberson jokes: "There might be some frozen shrimp or frozen krill or who knows what else in that frozen snow." What he's not joking about is his hope that NASA will find something beyond organic molecules on Europa.

Unique strategy

The congressionally directed Europa plan stands in stark contrast to NASA's traditional, methodical approach for exploring new worlds. First, a spacecraft gathers imagery as it flies by an unexplored world, as NASA's Galileo spacecraft did with Europa in the 1990s from its orbit around Jupiter. Years later, another spacecraft might be sent specifically to map the surface and study its geology, as NASA planned to do with the Europa Clipper. Only after all that would scientists dare to launch a robotic lander packed with scientific instruments.

Culberson is determined to compress that process for Europa. Scientists would

scan images sent home by the orbiter and then direct the lander, which may already be orbiting Jupiter, where to touch down. The congressional directive tells NASA to launch “an orbiter with a lander,” which sounds like two spacecraft on one rocket. In reality, there has been lots of discussion this year about whether that is the best approach. NASA sent a statement when Aerospace America asked if the agency saw wiggle room in the congressional language: “NASA has directed JPL to study options on how best to send a lander to Europa. These studies will be used by NASA, the Administration, and Congress to determine what is the best approach to getting a lander safely to Europa.”

Earlier this year, NASA Administrator Charles Bolden told a House subcommittee that his “strong recommendation” would be to “separate the orbiter and lander to optimize the chances of being successful with both.”

Charles Elachi, director of NASA’s Jet Propulsion Laboratory, told the subcommittee two weeks earlier that the decision did not need to be rushed. “Three years from now, we can decide to launch them together or separately,” he said. For sure, NASA will develop them separately.

Of that discussion, Culbertson, who presided over those hearings, says it’s important to adequately fund the Europa mission while leaving the details to NASA planners. “The orbiter may go first. There may be a second launch of the lander,” he tells me. But technology-wise, NASA “could certainly handle both on the same launch. I’ve already had multiple detailed briefings on the technology. But I’ll follow the best advice of the engineers and the scientists. It’s up to them to figure it out,” he adds.

If NASA engineers and scientists are feeling micromanaged, they are giving no hint of that in public. The agency is forming a team to establish scientific goals and select instruments for the Europa lander, which will draw heavily on technology NASA developed for recent Mars landers. “It will look very much like some of the technology we have developed before,” Elachi told the subcommittee. “We are very confident technologically that with appropriate funding that mission could be done at an acceptable risk,” he said.



NASA/European Space Agency/Southwest Research Institute

Cost worries

Some scientists worry that an ambitious Europa mission could siphon funding from other worthwhile exploration goals. That was the concern with a failed 2008 proposal to build a Jupiter Europa Orbiter that would have made multiple flybys of Jupiter’s four moons before spending nine months in Europa’s orbit. When the decadal survey members saw that project’s \$4.5 billion to \$5 billion price tag, they urged NASA to come up with a way to study Europa for half the cost.

That’s when NASA devised the Europa Clipper plan. By making looping orbits far

Rendering of plume of water vapor arising from Europa’s frigid surface. Magnetic field data gathered 16 years ago by the Galileo spacecraft showed that a vast ocean lies beneath.

out into space during each trip around Jupiter, the clipper would spend relatively little time in the planet's intense radiation environment. That would reduce the shielding required for its electronics and science instruments. Shielding adds weight, and additional weight means higher launch costs. The probe would fly close enough to Europa every two to three weeks to gather data on its chemical composition, topography, magnetic field and the thickness of its crust of water ice.

Scientists were happy with the clipper plan. The mission offered "way above 90 percent of what the Jupiter Europa Orbiter could have delivered for half the cost," says Soderblom, the vice chair of the decadal survey committee.

The congressionally directed Europa Multiple Flyby Mission will be more ambitious. It adopts a similar approach of long, looping orbits that take the clipper by Europa, but adds the lander and aims for an earlier launch date. NASA hasn't decided exactly how to get the lander and orbiter into space, despite the congressional direction to launch "an orbiter with a lander." Under the old plan, the clipper would have spent 6.5 years traveling to Jupiter after launching on an existing rocket. The SLS creates the option of putting the orbiter alone on a direct trajectory with an arrival date in 2024 or 2025. A lander sent sepa-

rately could follow that same path. If both were launched on one SLS rocket, their weight would rule out a direct route. The two spacecraft would arrive in 2027 or 2030, depending on the chosen trajectory.

A question is whether SLS will be ready and proven by 2022. The first SLS launch will be unmanned and it is scheduled for 2018; a second flight and the first with an astronaut crew, is schedule for 2023.

The Government Accountability Office estimated in March that even without a lander, the Europa Multiple Flyby mission would cost \$3 billion to \$4 billion over its lifespan, including the rocket to launch it but not including the lander. NASA has not yet projected what a Europa lander would cost because the agency has not yet approved plans to build it or decided exactly which instruments to send to Europa's surface.

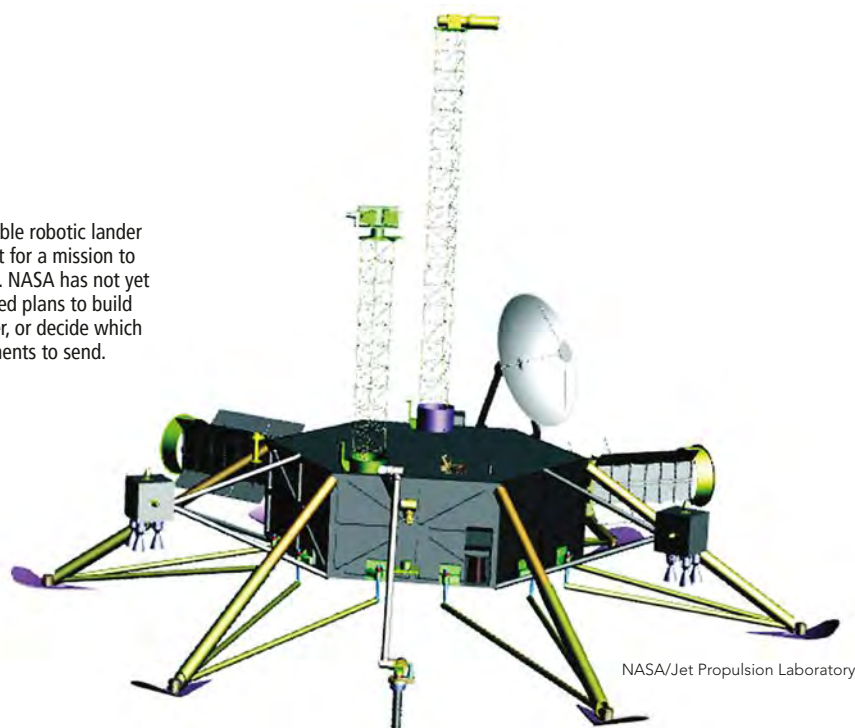
"I worry that we are right back where we were with an unaffordable mission," says a scientist who, like many people I spoke with, asked not to be named.

NASA finds itself caught between enthusiastic supporters in Congress and the White House Office of Management and Budget. During deliberations over the fiscal 2016 budget, OMB Director Shaun Donovan complained in a letter to Rep. Hal Rogers, R-Kentucky, that Congress

was directing "an impractical level of funding toward the Jupiter Europa mission." Rogers is chairman of the House Appropriations Committee. The bill, which Obama signed in December, also cut \$200 million from other NASA science programs and \$100 million from space technology.

Bolden, at the hearing in March, cited NASA's approach to Mars exploration as a more sensible template for Europa. NASA's

A possible robotic lander concept for a mission to Europa. NASA has not yet approved plans to build a lander, or decide which instruments to send.



NASA/Jet Propulsion Laboratory



NASA

NASA hasn't decided how to get an orbiter and possibly a lander to Europa. An orbiter launched alone could reach Europa in as little as 2.5 years following a direct trajectory.

Mariner 4 spacecraft gathered the first images of Mars in 1965. Eleven years later, NASA's Viking 1 and 2 spacecraft obtained photographs of the surface that allowed mission managers to pick the specific sites where the Viking landers touched down in 1976. The Mariner images narrowed the options to certain regions. "We made sure we understood it fully before deciding on a place for a lander," he said.

An unfamiliar moon

NASA's best images of Europa come from 11 trips Galileo made past it in the 1990s. The best of those images show a small portion of Europa's surface with a resolution of 10 to 20 meters per pixel. NASA captured additional lower resolution images of Europa with cameras on its New Horizons mission to Pluto in 2007; the Cassini Saturn mission in 2001 and Voyager 2's 1979 journey past Jupiter, Saturn, Uranus and Neptune.

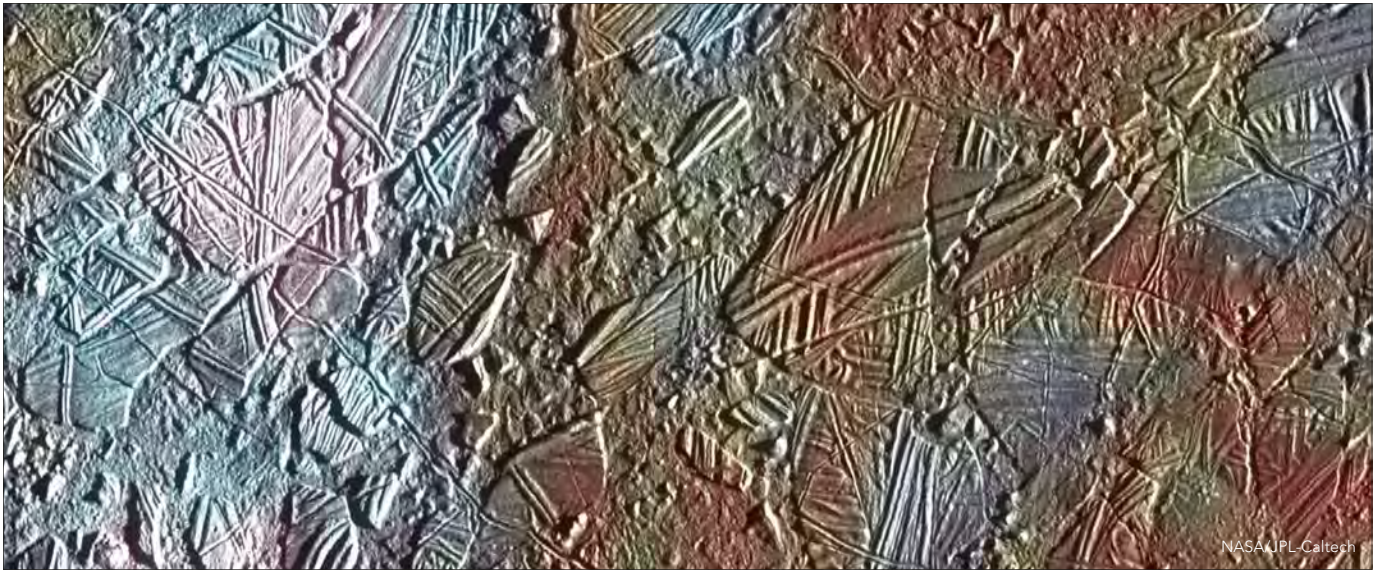
"We don't know what the surface of Europa looks like at the scale of a lander, if it's smooth, if it's incredibly rough," Curt Neibur, NASA's Europa program scientist, said in 2015 during a press conference to announce scientific instruments for the Europa spacecraft. "Without knowing what the surface looks like, it's difficult to de-

sign a lander that could survive."

Those concerns have not stymied engineers at the Jet Propulsion Lab. They've applied the extra funds from Congress to study concepts for landers that would be sturdy enough to survive harsh terrain. Instead of standing on metal legs, the Europa lander will be shaped like a polygon and be capable of landing on any side, says Culbertson, who gets periodic briefings from JPL engineers. NASA used a similar approach for the 1997 Mars Pathfinder landing on Mars. An airbag bounced to a halt and deflated as planned. Three triangular metal petals opened to serve as solar arrays, and the Sojourner rover rolled out.

NASA is identifying sites on Earth where the terrain is thought to be similar to what is expected on Europa. They'll go to those sites to evaluate potential landers and the difficulties they would face. "We specifically look for Earth analogs to the images which we do have for Europa, choosing the worst of these, and then to be more conservative design to pathological worst case scenarios," says Barry Goldstein, NASA's Europa project manager at JPL, by email.

Before the new Europa lander touches down, NASA will have far more imagery to study, Culbertson says. If a



NASA/JPL-Caltech

The possibility that life forms might exist under Europa's icy crust makes Jupiter's moon one of the solar system's most intriguing worlds.

lander travels to Jupiter at the same time as the orbiter, it would remain in a very high orbit to limit its radiation exposure while the orbiter spends a year or two mapping Europa and obtaining extremely high resolution images of potential landing sites near the cracks in its surface. Scientists suspect these cracks might be hydrothermal vents that bring material from Europa's ocean up to its surface. Jupiter's radiation would destroy organic molecules that remain on the surface too long, but material near the cracks might give scientists a glimpse into the chemistry of the underlying ocean. Once scientists settle on a location to land, the second spacecraft will carry the lander toward the surface of Europa. A sky crane will unspool a tether to set the lander onto Europa, similar to the way the sky crane set NASA's Mars Science Laboratory onto the surface. Culberson predicts "a very soft, safe landing in the most favorable location."

"Brown gunk"

Once it touches down, it is anyone's guess what the lander's instruments will discover. Scientists would be excited with organic molecules, although Culberson and others are hoping for more.

If Europa has water plumes shooting from its surface, which the Hubble Space Telescope may have detected with an imaging spectrograph in 2012, the orbiter will fly through those fog-

like plumes and use its onboard mass spectrometers to look for organic molecules. If no plumes are spotted, NASA will attempt to land near cracks in Europa's surface that show fresh deposits of whatever is coming from the water below. For now, NASA refers to the stuff visible around the cracks as "brown gunk."

"We'll look for places on the surface where there are fresh deposits around cracks," says Jonathan Lunine, director of the Cornell Center for Astrophysics and Planetary Science and a co-investigator for one of the Europa mission's mass spectrometers.

With a seismometer on the lander, NASA also will gauge the depth of the ice because the best way to find out what is under Europa's icy shell is to drill through it. NASA does not yet know exactly how it would do this, but Culberson wants engineers to get started developing technology to melt a hole in the ice.

"This will probably be after I'm dead and gone, but I'll make certain that the ground work is laid for us to land a penetrator and use some kind of very hot source to melt through that ice, drop out into the Europa ocean, use sensors to sniff out black smokers on the bottom and transmit signals back up to an antenna that's left dangling below the ice sheet," Culberson says. "It's absolutely achievable."

Culberson is similarly confident NASA's near-term mission to Europa will proceed. "Europa is the only mission it is illegal for NASA not to fly," he says. ♠