

Close encounters of the drone kind

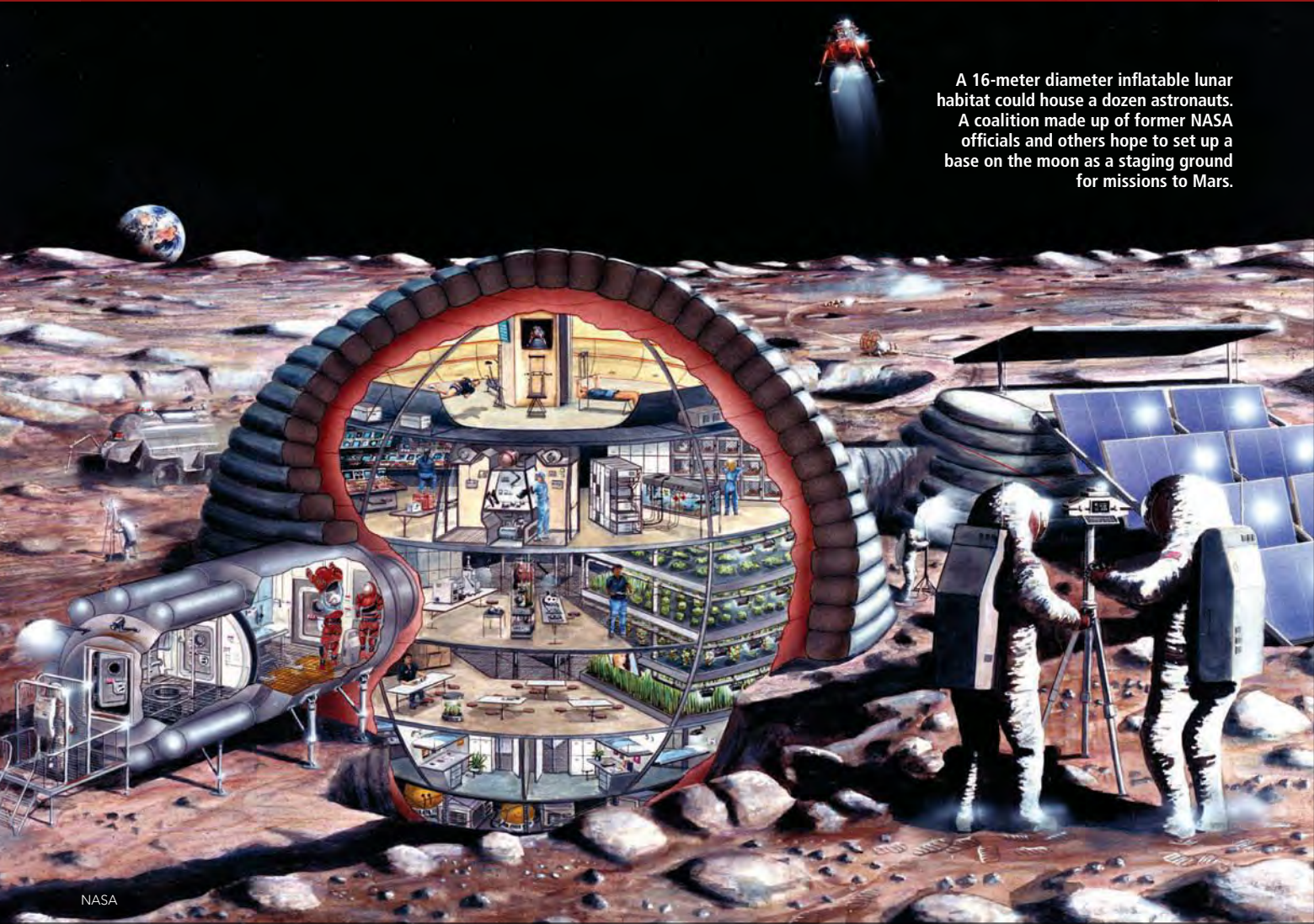
How vulnerable
are airliners? [page 18](#)

**21st century
spacesuits/10**

**Fuel-efficient
fighter jets/14**

**Mastering design
complexity/32**

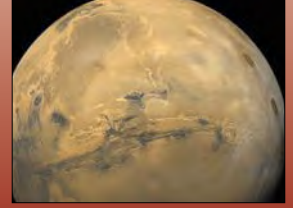
MARS via



A 16-meter diameter inflatable lunar habitat could house a dozen astronauts. A coalition made up of former NASA officials and others hope to set up a base on the moon as a staging ground for missions to Mars.

NASA

the MOON



The 2016 U.S. presidential election is sure to be an opportunity to reconsider just about everything the government does. The Obama administration's Mars exploration strategy is no exception. Debra Werner spoke with the experts who want the next president to incorporate the moon into the country's Mars plan.

Standing before a crowd of about 700 people in Florida in 2012, then-presidential candidate Newt Gingrich made an unusual appeal for votes during the Republican primary. If he became president, Gingrich pledged, the United States would establish a permanent lunar base within eight years, paid for with government and private investment. He was largely echoing the previous Republican administration's call for a return to the moon no later than 2020 and a permanent outpost by 2024. But Gingrich's rivals lambasted the former House speaker as desperately out of touch:

"Ground Control to Major Newt: Nevada Needs Jobs, Not Moon Colony," was the title of a press release issued by the campaign of Mitt Romney, which put a \$500 billion price tag on Gingrich's idea.

Yet despite the drubbing Gingrich took, backers of a moon base are not giving up. A coalition of former NASA managers and engineers hope one or more of the

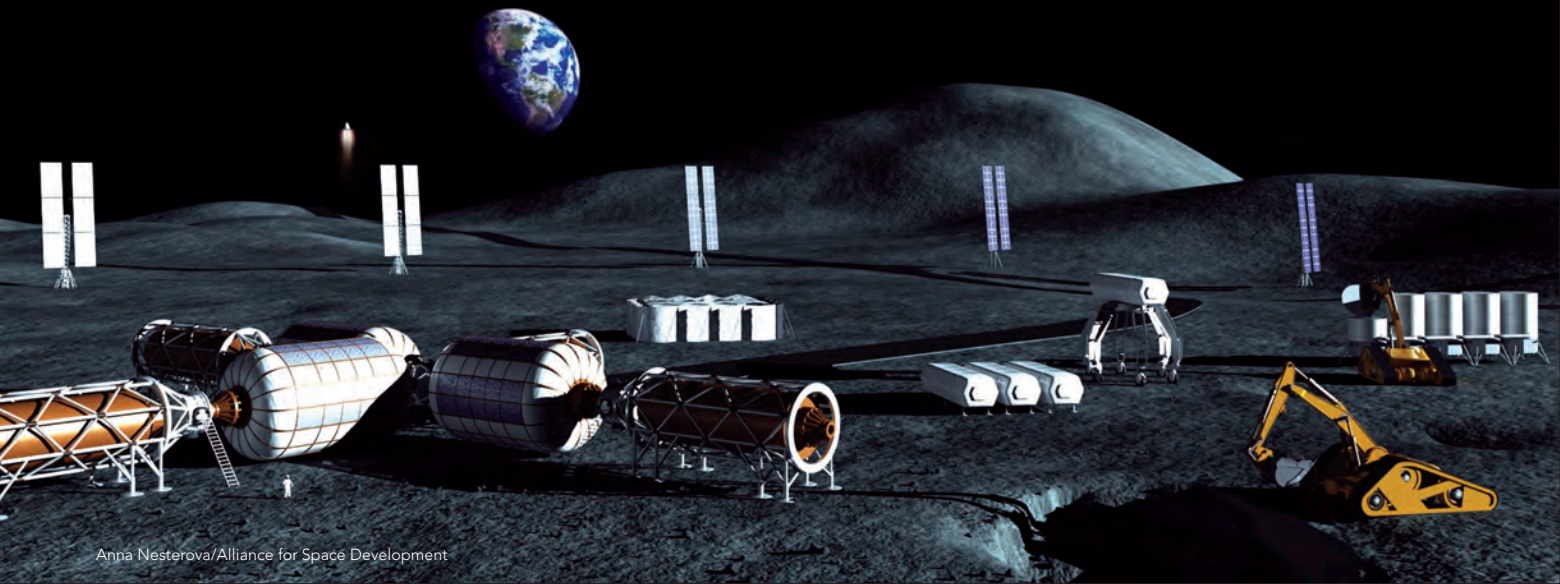
2016 Republican or Democratic presidential candidates will adopt the idea of a privately owned moon base as a staging ground for missions to Mars. Development could be funded and managed by a NASA-led international group patterned after the European Organization for Nuclear Research, or CERN, the group that built the Large Hadron Collider for physics research.

If all goes as advocates hope, a crew of four private-sector astronauts would use robots to convert lunar ice into propellant and sell it to NASA. And it would cost a fraction of Romney's guesstimate: A July study paid for in part by a NASA grant concluded the new approach could have humans back on the moon in seven years at a cost of \$10 billion spread among government and private sector partners. A permanent base could be established 10 years to 12 years later for an additional \$30 billion.

The issue for the U.S. is whether it should stick with the Obama administration's moonless exploration plan once the

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A study partly funded by NASA envisions a lunar base where astronauts would oversee the work of machines digging up water ice, breaking it down into liquid hydrogen and liquid oxygen, which would be stored in tanks.



Anna Nesterova/Alliance for Space Development

president leaves office in January 2017. The current strategy calls for sending humans to an asteroid in the 2020s, followed by Mars missions in the 2030s — all without ever touching the moon.

The next president could captivate the nation by proposing “an audacious, inspirational mission and do it within [NASA’s] existing budget,” says Charles Miller, a former NASA official and the informal spokesman for the lunar coalition. Miller says NASA would need to spend about \$2.8 billion per year on the mission.

NASA seems to harbor no philosophical opposition to a moon base. Still, it’s not embracing the idea too warmly, either. The Office of the Chief Technologist last year paid \$100,000 to NexGen LLC of Arlington, Virginia, the five-person consulting firm where Miller is president, for a detailed evaluation of the lunar base concept.

Nonetheless, the agency cautioned against reading too much into NASA’s intentions based on a single study grant.

“We hope this and our other grants provide new insight and innovative new ideas that help us advance our understanding of these processes as we advance our

journey to Mars,” a spokesman says.

NASA received the “Evolvable Lunar Architecture” report in July. Miller, the lead author, was NASA’s senior advisor for commercial space from 2009 to 2012, when NASA’s Commercial Orbital Transportation Services program took root with the privately owned capsules and rockets of Orbital Sciences and SpaceX.

“I knew this model, if properly applied, had significant implications beyond getting cargo and crew to the space station,” Miller says. “I thought we should take a serious look at whether it could be used elsewhere.”

Miller says he did not have time to evaluate the various previous proposals for a moon base until he won the \$100,000 NASA grant in December 2014.

Under the proposal, robotic vehicles would travel to the lunar equator to test the new lunar lander and vehicle to return crew to Earth. In the second phase of the program, astronauts would travel to the lunar poles and set up mining and propellant production equipment. A spacecraft would transfer 200 metric tons of propellant a year to a depot positioned beyond the Earth and moon at the second Lagrange point, one of the places

where a spacecraft can remain in orbit with little energy. Spacecraft bound for Mars would stop at this depot to take on propellant.

If any presidential candidates do consider this plan, they are likely to embrace it very quietly in light of Gingrich's experience.

"You won't hear much about it until Jan. 20, 2017," predicts Howard McCurdy, a space policy expert at American University in Washington, D.C., and a member of the review board that evaluated the report's conclusions.

Even if no one discusses the proposal publicly, the effort is important because the next administration is likely to take a fresh look at U.S. space exploration plans. In the past, that type of analysis often prompted NASA to change course. In 2010, for instance, President Barack Obama announced plans to cancel President George W. Bush's Constellation program aimed at sending astronauts to the moon and then Mars, opting instead to prepare crews to travel to an asteroid in preparation for Mars missions. Obama dismissed the notion of returning to the moon by saying, "We've been there before."

The been-there-done-that sentiment, however, may be waning.

"In general, there is a little bit of a drift back toward the idea of not just robotic but human lunar exploration," says Michael Lopez-Alegria, a former astronaut and former president of the Commercial Spaceflight Federation, a Washington-based industry association. "I'm glad to see this perceptible, not dramatic, but perceptible shift in the conversation."

While that shift might be taking place in the U.S., elsewhere space agencies and commercial firms are forging ahead with robotic lunar missions of their own. Sixteen teams are competing in the \$30 million Google Lunar XPRIZE competition, a race to land the first commercial robotic vehicle on the moon by the end of 2016. Meanwhile, India, Russia, China and Japan are building spacecraft to reach the moon. Johann-Dietrich Wörner, the European Space Agency's director general, is promoting the idea of nations joining forces to establish an international moon base, as distinct from the privately-owned base advocated in the July report.

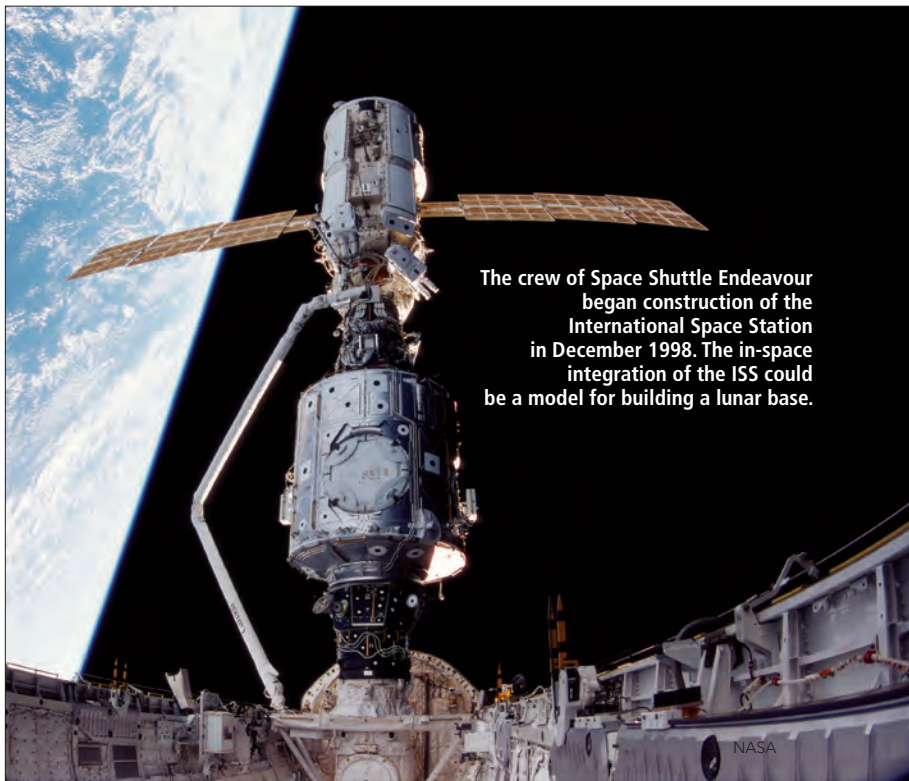
"India, Russia, China, Japan, ESA all have interest in the moon more so than an asteroid" as a proving ground for technolo-



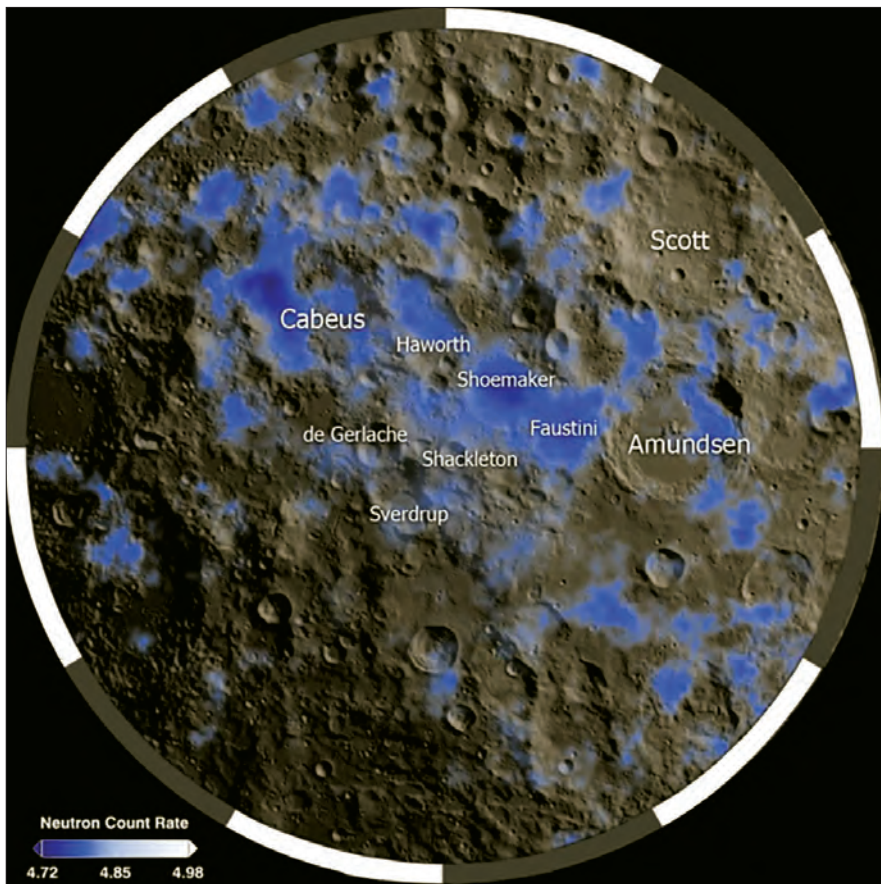
The crew of Apollo 17 poses with a lunar roving vehicle trainer. Their mission in December 1972 was NASA's last moon mission.

gies that would later be needed for missions to Mars, says Rob Kelso, a former manager of lunar commercial spacecraft at NASA's Johnson Space Center and one of the authors of the July report. "Using the moon as a place to do technology development and test systems to learn how to operate on Mars always made sense to me."

The report suggests that the U.S. try to marshal that global interest into an international partnership that would combine space agency expertise with private sector



The crew of Space Shuttle Endeavour began construction of the International Space Station in December 1998. The in-space integration of the ISS could be a model for building a lunar base.



Locations of water ice deposits on the Moon's south polar regions taken by NASA's Lunar Reconnaissance Orbiter. Advocates for a privately owned moon base envision mining the water and breaking it down to produce liquid hydrogen and liquid oxygen propellant, which would be sold to NASA.

ownership and innovation, such as participants in the Google Lunar XPRIZE design.

The Apollo program cost about \$25 billion, which with inflation works out to about \$250 billion today. Miller and his team estimate that lunar missions could be conducted for one-sixth or one-seventh of

the Apollo costs. McCurdy agrees a dramatic reduction is possible.

"If you are really careful and you rely upon the accumulation of technological knowledge up to now, you can go back to the moon for a lot less than we spent the first time," he says. "We had to invent the Saturn 5 rocket, human orbital flight, lunar orbit rendezvous, flight computers and deep space communications. None of those things needs to be reinvented."

Plus, commercial firms are developing and producing spacecraft that can send mass into orbit at a much lower cost than previous generations of government-owned and operated launch vehicles. If the Saturn 5 still existed, in today's dollars it would cost NASA about \$12 million to \$15 million per metric

ton of cargo delivered to low Earth orbit. By comparison, NASA's Space Launch System is designed to that job at a cost of \$7 million per metric ton when it begins flying in 2018. SpaceX says its Falcon Heavy will cost \$2 million per metric ton to low Earth orbit when it starts launching satellites in 2016.

Although less expensive, the Falcon Heavy is not powerful enough to boost astronauts along with their lunar lander toward the moon. If NASA or an international coalition decided to use Falcon Heavys or United Launch Alliance's still-to-be-developed Vulcan rocket for lunar missions, it would need to upgrade their second stages, add propellant to the existing second stages in low Earth orbit, or couple the various elements of a lunar mission — such as the crew capsule, habitat and lunar lander — with an additional propulsion system in orbit and assemble them there.

That assembly does not worry Gene Grush, a former propulsion and power division chief at NASA's Johnson Space Center and member of the team that reviewed the report. He favors sending astronauts to a permanent moon base using low-cost commercial rockets coupled with additional stages to propel them to lunar orbit.

"The International Space Station sets the bar for in-space integration," he says.

The authors of the July report suggest creating a program similar to NASA's Commercial Orbital Transportation Services effort, which spawned the SpaceX Dragon and Orbital Sciences Cygnus capsules. NASA shared the development costs of those vehicles, while holding out the promise that it would later award multibillion-dollar, fixed-price service contracts.

To return to the moon, the authors say NASA could pay two competing commercial spaceflight providers \$5 billion each to develop new or upgrade rocket stages and crew vehicles. Then, private companies rather than government agencies would own and operate the spacecraft, the lunar base and the infrastructure to support that base with NASA and other space agencies serving as customers for the base and propellant produced there.

“The secret in all of this is public-private partnerships,” Lopez-Alegria says. “It capitalizes on the commercial spaceflight industry, which has proven itself far more successful than most people anticipated.”

Since NASA would want to share the development costs, the agency would have to convince companies that the entire project would not disappear with the next election or financial crisis, Miller says. That’s why the proposed International Lunar Authority, which would be modeled after CERN, is so important. Government payments to CERN are established by international treaty, and something similar could be done to develop the moon base.

Later, when the moon base begins mining water and breaking it down to produce liquid hydrogen and liquid oxygen fuel, the International Lunar Authority would wean itself from government support and pay for ongoing operations with user fees and fuel sales.

Three-phase strategy

The base would be technically challenging to build.

“We haven’t built a lunar habitat in over 40 years,” says Grush, the former propulsion and power chief at Johnson Space Center. “Lunar dust and the thermal environment make it very difficult.”

Plus, no one has ever produced propellant on the moon or set up an orbiting fuel depot. Before tackling any of those jobs, NASA and its international partners would need to make sure the water on the moon is accessible. Several space missions have detected water ice. Most recently, NASA’s Lunar Crater Observation and Sensing Satellite, or LCROSS, was purposely crashed into a shadowed crater in 2009 so researchers could look for evidence of water, which they found in the resulting impact plume. Researchers do not know how much ice exists or whether it is buried deep beneath the surface.

“We need to know as soon as possible how much water is available and how easy or hard it is to get to,” Miller says.

In the first phase, NASA and its partners would land the crew near the lunar equator and then come home. During this phase mission partners also would demonstrate the life support systems needed for future manned missions.

Meanwhile, back on Earth, companies and space agencies would be developing technologies for mining lunar ice and producing, storing and transporting liquid hydrogen and liquid oxygen propellants.

Astronauts would travel to the lunar poles in the second phase to begin testing



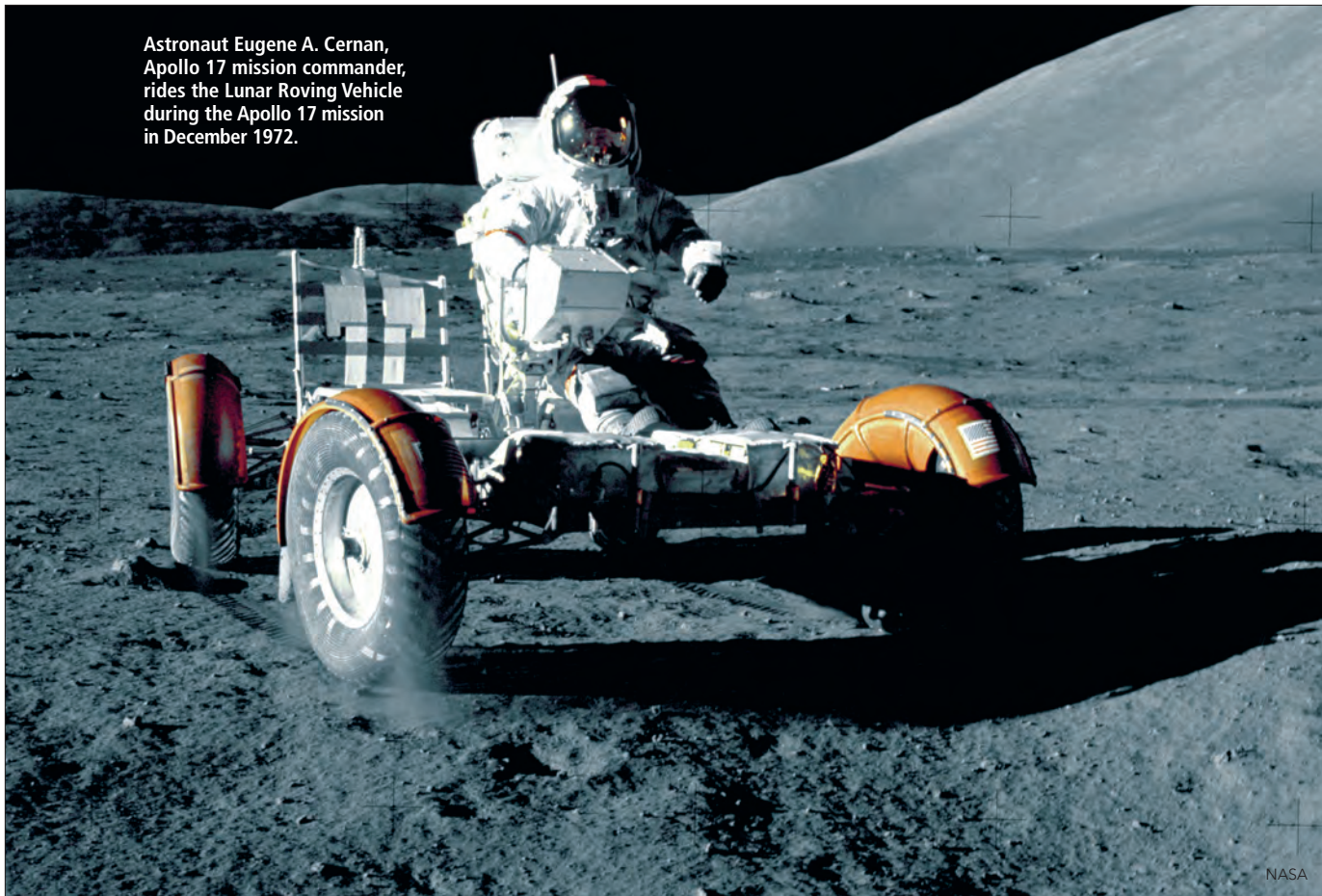
Learning to live off the land on the moon or Mars would enable humans to push farther into deep space. NASA plans to land the robotic resource prospector vehicle on the moon’s south pole to map ice and other substances.

these in-situ resource utilization techniques and select the site of a permanent lunar base. The astronauts would test drive rovers. Back on Earth, government and private researchers would be busy developing and testing reusable liquid fueled rockets as well as habitats to accommodate astronauts living on the moon for months at a time.

“You would encounter all sorts of new challenges that weren’t faced by the Apollo astronauts,” who spent at most a few days away from Earth, McCurdy says. “They went on camping trips. They didn’t shave, didn’t bathe, shook the dust off their space suits and came back.”

Once those challenges are ironed out and the habitat, transportation and fuel

Astronaut Eugene A. Cernan, Apollo 17 mission commander, rides the Lunar Roving Vehicle during the Apollo 17 mission in December 1972.



production facilities are up and running, the International Lunar Authority would begin full-scale fuel production and delivery of liquid hydrogen and liquid oxygen to the propellant depot, where fuel could be transferred to spacecraft headed to Mars or other destinations. In this third phase of the program, a revolving crew of four international astronauts would live and work in the lunar outpost.

Obstacles

Miller predicts that the base can be built within NASA's top-line budget, but it also would mean identifying resources for a series of hitherto-unplanned lunar missions. Paying for the lunar proposal could complicate efforts to build and test NASA's next generation of space exploration vehicles, including the Orion astronaut capsule and the heavy-lift Space Launch System.

NASA receives \$3 billion to \$4 billion a year from Congress to fund human exploration beyond low Earth orbit, with most of that money going to Orion and SLS. There is no money for human lunar exploration

and even many elements of a planned Mars mission have received little funding, including a space habitat for crews during their multi-month journey, a Mars lander and an ascent vehicle to carry astronauts back into orbit for the journey home.

However, there is one major part of NASA's budget that may shrink in the next decade, leaving room for new initiatives. NASA, Russia and Canada have agreed to support operations of the International Space Station only until 2024. The space station's other two partners, the European Space Agency and Japan Aerospace Exploration Agency, have not yet announced how long they will fund it.

When space station operations end, NASA might be able to begin funding lunar missions, "but I think it would be tough to find support in the short term because it's politically difficult and operationally illogical to scrap a current program and embark on something new," Lopez-Alegria says.

Unless, of course, a new president has other ideas. ▲