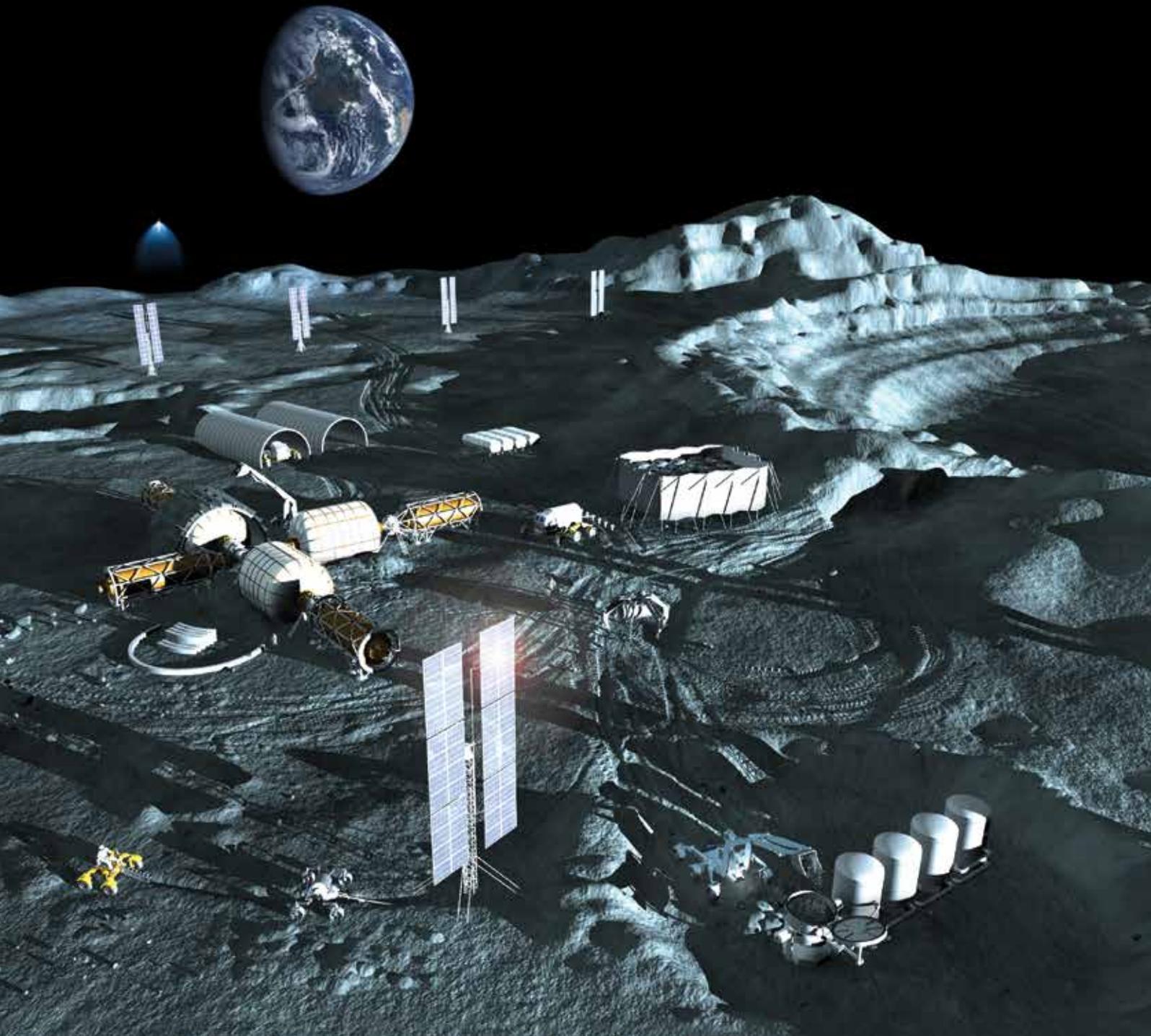


WINTER 2015

# BACK TO THE MOON

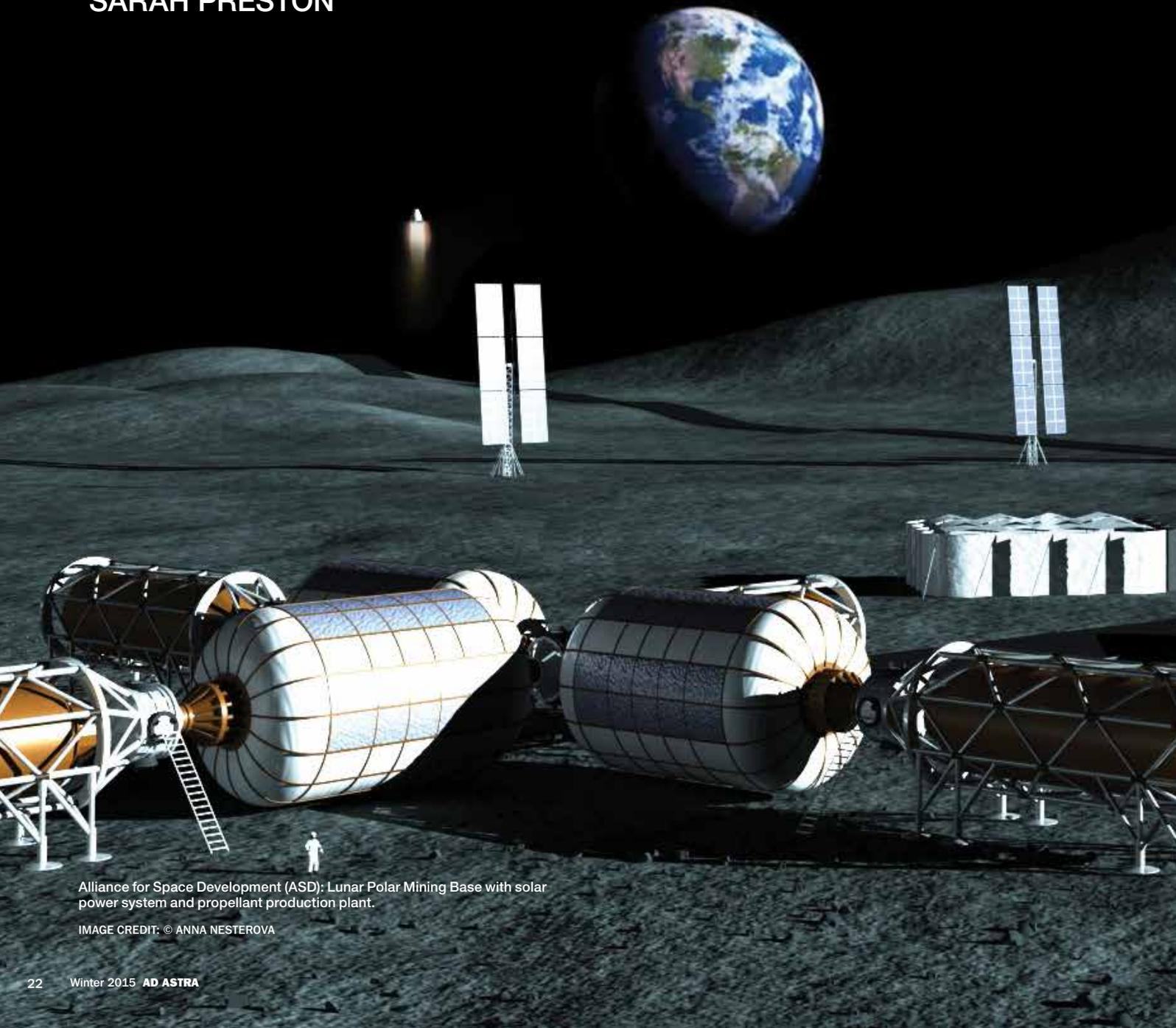
## Getting There Faster for Less



# BACK TO 1

## GETTING THERE FASTER FOR LESS

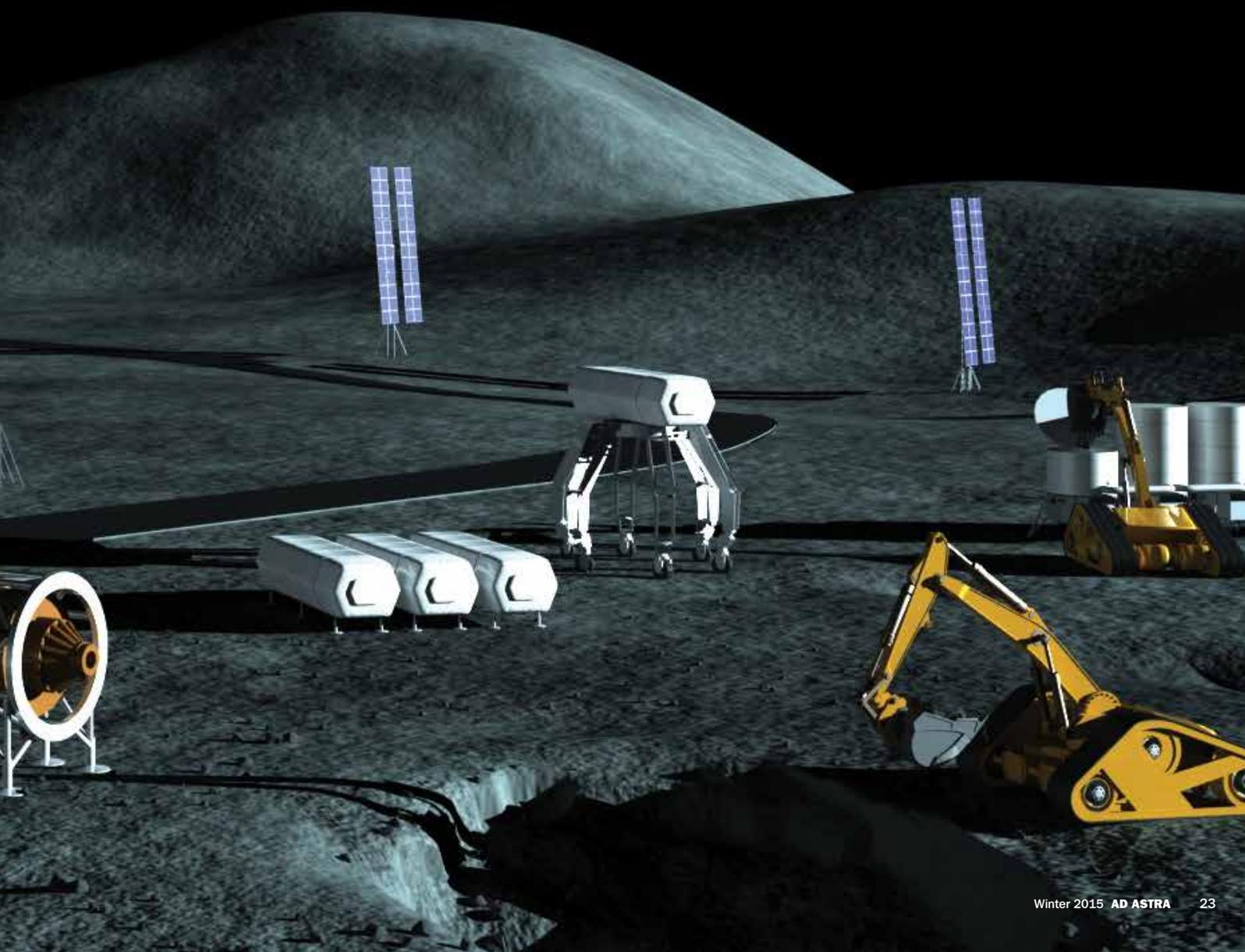
BY CHARLES MILLER AND  
SARAH PRESTON



Alliance for Space Development (ASD): Lunar Polar Mining Base with solar power system and propellant production plant.

IMAGE CREDIT: © ANNA NESTEROVA

# THE MOON



The National Space Society's two predecessor organizations—the National Space Institute and the L5 Society—were formed in the aftermath of Apollo's success, when anything was possible. Since that time, a question has haunted the members and leaders of the National Space Society. If we could put a man on the Moon in 1969, why can't we do so in 2015?

Humans have not traveled beyond low Earth orbit (LEO) since the end of the Apollo program in 1972, but not for a lack of trying. We have made three major attempts since Apollo—the Apollo Space Task Group, the Space Exploration Initiative (SEI), and the Constellation program. All these initiatives collapsed from a lack of affordability. SEI's estimated cost was more than \$900 billion (FY15) to send humans to the Moon and Mars. The Constellation program cost more than \$120 billion (FY15) to place the next human footstep on the surface of the Moon. These attempts provide clear, unequivocal evidence that American taxpayers are not willing to spend hundreds of billions of dollars to send humans to the Moon and Mars.

Fortunately, there is another way. NASA recently funded a study titled "Evolvable Lunar Architecture That Leverages Public-Private-Partnerships" that assessed a new strategy. The study demonstrates that humans can establish a permanent industrial base on the Moon within NASA's existing budget. The report was announced to international media by the NSS and the Space Frontier Foundation on July 20, 2015 at the National Press Club. It provides evidence disproving the widely held opinion that an American-led human return to the Moon needs to cost taxpayers \$100 billion or more.

NASA funded NexGen Space LLC, which assembled a team of former NASA executives and engineers to assess the economic and technical viability of an "Evolvable Lunar Architecture" (ELA) that leverages commercial capabilities that are existing or likely to emerge in the near term. The ELA



Artist's conception of lunar mining, after 2020. Many believe that the resource rich Moon may one day sustain human efforts to remain in space indefinitely.

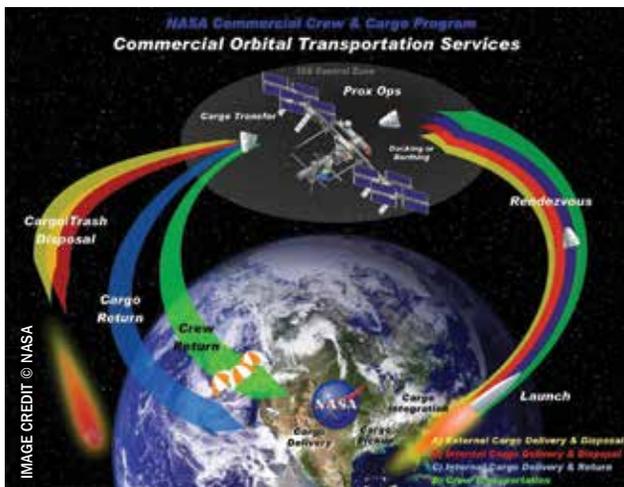
assumes the use of public-private partnerships that NASA has recently proven with its COTS (Commercial Orbital Transportation Services), ISS Commercial Resupply, and Commercial Crew programs.

The ELA is a plan to incorporate the Moon into the Earth's economic sphere of influence. The immediate, most valuable economic resource on the Moon is water or hydrogen discovered in the cold traps of the lunar poles. Scientists estimate the Moon may have 10 billion cubic meters of water at the poles, useable for creating liquid oxygen (LOX) and liquid hydrogen (LH2) propellant. A commercial industrial lunar base could extract water from the regolith, convert the water to propellant, and then transport the propellant to a depot in lunar orbit. The ELA strategic goal is to develop a commercially owned and operated lunar mining base from which NASA and others could purchase propellant to enable low-cost deep space missions to Mars and elsewhere in the Solar System.

The study results were independently reviewed by a team of nearly two dozen former NASA executives, led by Joe Rothenberg, former head of NASA human spaceflight. NexGen Space selected a specific architecture and destination to examine whether public-private-partnerships are technically feasible for deep space human spaceflight, and how much they would cost. The same COTS-like partnership might work for other architectures and destinations...assuming the same step-by-step commercial-friendly strategic principles are observed.

### Study Conclusions

The NASA-funded study concludes that it is technically feasible for humans to return to the surface of the Moon within five to seven years after industry has the authority to proceed. For a total estimated cost of \$10 billion (+/- 30%) America could stimulate two independent commercial lunar transportation service providers, such as SpaceX and the United Launch Alliance. We could then incrementally evolve



Commercial Orbital Transportation Services (COTS)

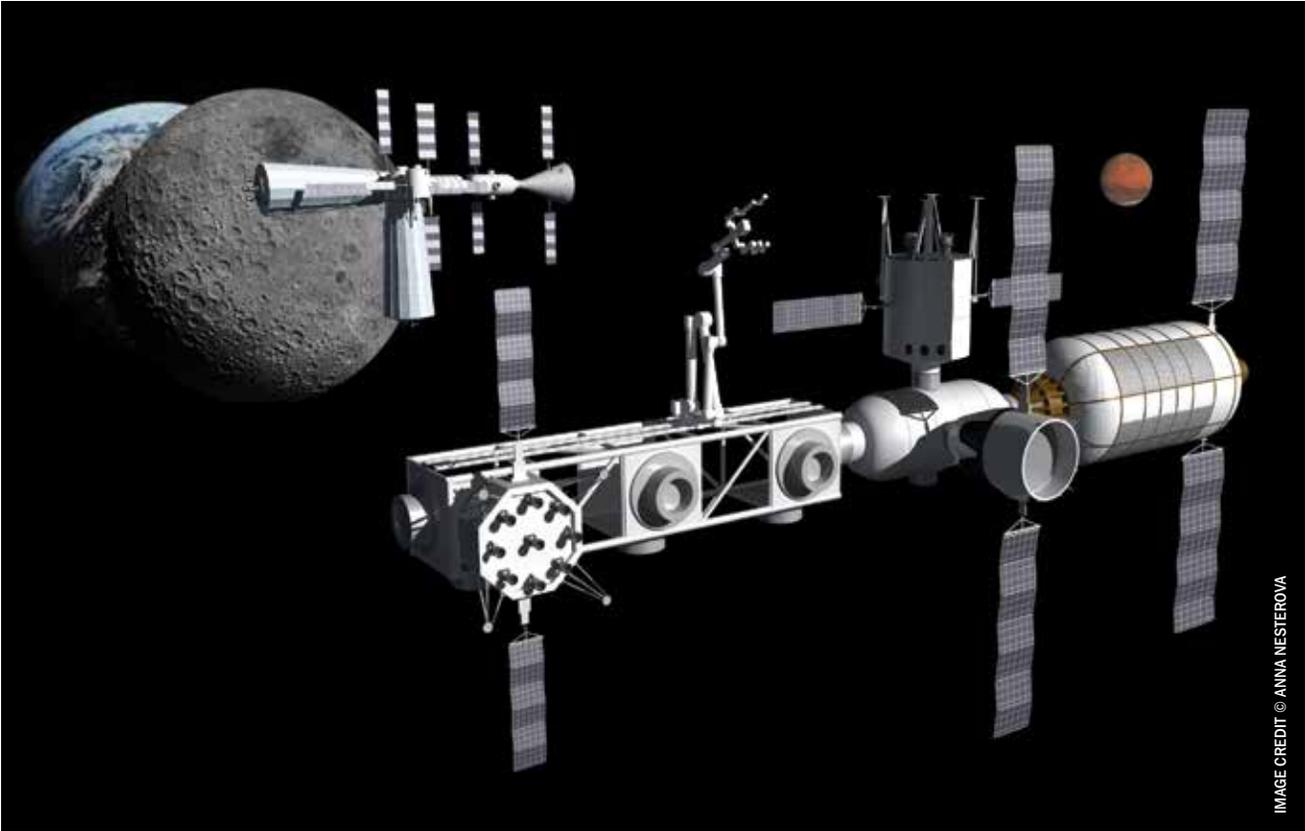


IMAGE CREDIT © ANNA NESTEROVA

Alliance for Space Development (ASD): Propellant depot fueling a Mars transit vehicle (background) & crewed waystation at Earth-Moon LaGrange Point.

this capability—staying within NASA’s existing human spaceflight budget—to a permanently crewed lunar base and mining facility that could produce the 200 metric tons of propellant per year needed by NASA for human missions to Mars. The estimated cost of this permanently crewed industrial base on the Moon is \$40 billion (+/- 30%).

The ELA concept is to develop a large, fully reusable lunar lander that uses the propellant produced on the Moon (to minimize the launch requirements from Earth) to transport 200 metric tons of propellant per year to a propellant depot located at the Earth-Moon L2 region. This is the amount of fuel NASA needs to transport its standard Mars Transfer Vehicle (MTV) to Mars and to return it to Earth once every 26 months.

One of the study’s implications is that much more affordable and realistic human trips to Mars are feasible. Instead of throwing away the MTV after every trip, which is extremely expensive and wasteful, the MTV would return the Mars astronauts to the Earth-Moon L2 depot to be reused. The astronauts returning from Mars would exit the MTV at the L2 gateway and return to Earth. At the L2 gateway, the MTV would be refueled, filled with food and water, repaired as needed, and be boarded by astronauts for the next trip to Mars. The result would be a reusable Mars spaceship, championed by Buzz Aldrin and others for its huge cost

savings for human trips to Mars.

One of the interesting results of this strategy is that it could end the fight between the Moon and Mars. NASA could stay focused on Mars as industry would operate the lunar base. Lunar industry and its advocates would become the biggest proponents of NASA going to Mars as NASA’s Mars program would be a major customer of the commercially operated lunar base. We believe this strategy offers the possibility of a peace treaty, and future cooperation, between Moon and Mars advocates.

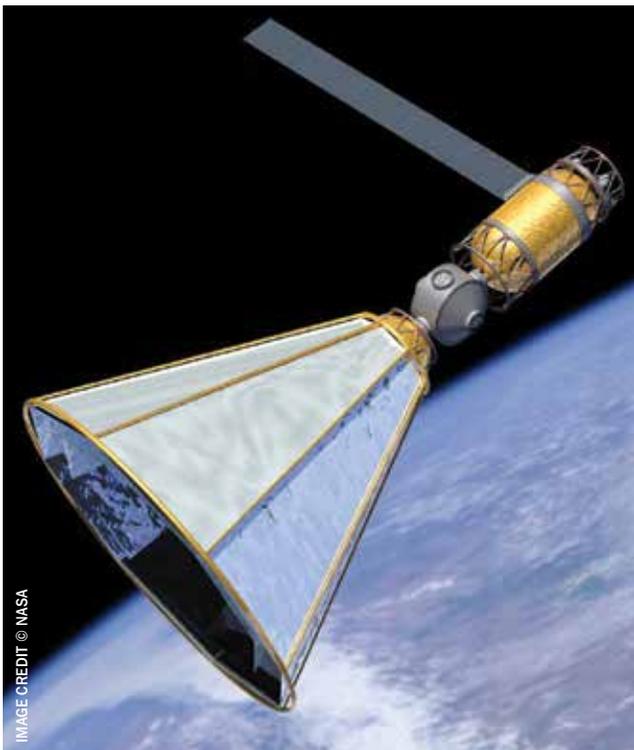
### A Step-by-Step “Evolvable” Lunar Plan

The ELA plan has three incremental step-by-step phases, and maximizes the use of commercial technologies that either exist or are in development. In phase one, three parallel independent activities will begin. First, commercial robotic prospectors will be sent to many different lunar polar sites to scout for the best place to construct a lunar base that produces propellant. Proving that water is easily and economically accessible near the surface is a top priority. In parallel, at least two private companies will begin development of the systems needed to return humans to the Moon. The study assumes incremental upgrades to crew capsules (Boeing CST-100 Starliner and the SpaceX Crewed Dragon) and the development of lunar landers by SpaceX

and ULA. ELA will use launch systems that either exist today, or that are already in development, such as SpaceX's Falcon 9 and Falcon Heavy, and ULA's Vulcan. Using this approach, we can develop two independent and competing systems, with standardized rendezvous and docking systems, which can each land humans on the Moon. This kind of dissimilar redundancy is critical to safe, reliable and robust operation of the lunar base—as demonstrated by the dissimilar redundancy of both crew and cargo systems to the ISS. Both of these systems can be commercially developed for a total estimated cost of \$10 billion. Finally, in phase one, we will develop the technologies needed for LEO propellant storage and transfer, demonstration of which is the key transition point to phase two.

In phase two, with the advent of LEO propellant storage and transfer, the same systems used to transport humans and cargo to the lunar equator can now transport humans to the lunar poles to begin work on the lunar mining facility. In parallel, we will accelerate the work to develop the technologies and systems: A) to convert lunar ice into propellant, B) to store and transfer LOX and LH2 propellants, and C) to create a large reusable lunar lander that uses the propellant.

We transition to phase 3 when the propellant production, propellant storage, and large reusable lunar lander have become operational. The existence of the reusable lunar lander that uses lunar propellant produces a tremendous improvement in the economics of the lunar base. Up to



Artist's concept of a proposed United Launch Alliance propellant depot with sun shields.



This image shows a single-stage, dual thrust-axis lunar lander with "ut-rigger" hypergolic propellant tanks.

this point, in phases 1 and 2, we can only afford "sorties" to the Moon within NASA's existing budget. After the large reusable lunar lander becomes operational, we can afford a permanently crewed outpost of four civilian astronauts. This reusable lunar lander will deliver 200 metric tons of lunar propellant to the L2 waystation per year, and also transport large habitation modules, such as the Bigelow 330, and many other pieces of critical equipment to the surface of the Moon.

At this point, we will have established a gateway to the entire Solar System. With an operational Solar System Gateway, it will be much more affordable to send humans to Mars, and much larger robotic spacecraft almost anywhere in the Solar System. Further, the marginal cost of a private week-long trip to the surface of the Moon will be \$200 million or less. While the study does not evaluate the size of the commercial market, there are a hundred or more countries that can afford, and probably want, to send their first citizen to the Moon. Further, there are more than a thousand billionaires on planet Earth who could afford to take a trip to the Moon. At this point, it is possible the lunar base could become economically self-supporting, and we could be on the path for the permanent human settlement of the Moon.

### Lowering Costs is the Key

Dream as we may, many forget there are always costs to consider. The unique part of the ELA is using a new strategy to achieve affordability. Public-private partnerships that leverage multiple customers, combined with competition, are the key to reducing costs. Competition forces companies such as ULA and SpaceX to constantly innovate and watch the bottom line, and provide a much more efficient alternative to government-owned infrastructure in space.

The Saturn V cost \$46,000 per kilogram to LEO, and the

Space Shuttle cost \$60,000 per kilogram delivered to LEO when you account for development and fixed costs. But SpaceX's Falcon 9 is \$4,750 per kilogram placed into LEO when fully priced.

We now have a proven formula for success. The COTS program, and the similar EELV program before it, both used funded Space Act Agreements. Together, they have produced four successful American launch systems in a row (Delta IV, Atlas V, Falcon 9, and Antares). The ELA would use the same proven method to produce the same cost-lowering results. Industry will own the launch vehicles, the L2 depot, and all the industrial infrastructure on the lunar base. NASA will serve as a customer, buying commercially-provided propellant at the L2 gateway for its own missions.

### **Conclusion**

The ELA represents a new strategic approach by leveraging public-private partnerships. This NASA-funded study shows it is a more affordable and sustainable way to achieve human expansion into space, and to enable the large-scale human settlement of the Solar System. After more than four decades of repeated failure of the big government paradigm

of sending humans to deep space, it is time to try something different.

*A copy of the fully study report is available at <http://www.nss.org/docs/EvolvableLunarArchitecture.pdf>.*

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*Charles Miller is the president of NexGen Space, LLC, and the principal investigator of the ELA study. Miller is the co-founder of Nanoracks, and former NASA senior advisor for commercial space. He is a former administrator of the National Space Society, and started his first chapter of the L5 Society in 1983.*

*Sarah Preston is the director of communications for the Alliance for Space Development, and a senior at American University. She will graduate in May 2016, and is looking forward to a long and successful career in the commercial space industry.*