BUILDING THE NEXT SPACE

INSTEAD OF DESTINATIONS AND DEADLINES, THE U.S. SPACE PROGRAM SHOULD

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WHEN SPACE SHUTTLE FLIGHTS ENDED IN JULY 2011 some observers were struck by the fact that 50 years earlier in May 1961, President John F. Kennedy declared the goal of putting a man on the Moon. If that speech—and the ambitious program that followed—opened an era of manned spaceflight for the U.S. then the last landing of the Space Shuttle *Atlantis* was surely the close of that era.

After nearly three decades under development, the completion of the International Space Station, the current dependence of the U.S. on Russia to transport its astronauts to and from the ISS, and the growth of space ambitions and capabilities around the world have prompted critics to lament the demise of U.S. space leadership and the end of U.S. human spaceflight.

Those critics are misreading the moment.

We're experiencing not just the closing of one era, but a transition to a new one. But to enter that new era, the conception of U.S. spaceflight must move beyond Apollo-style flags-and-footprints missions. The endeavor must generate scientific, economic, and societal value in a sustainable manner that is worth the risk and the cost.

The space community's task for the next generation is to discover whether and how this can be achieved.

A key element to this transition is the emergence of an assortment of commercial entities that will be able to fully assume functions formerly the domain of the government, such as the launching of humans into orbit. In the next few years, this could become a largely private-sector endeavor in the U.S.

But that's just the beginning, as entrepreneurial companies with names like Deep Space Industries and Planetary Resources Inc. aim to mine extraterrestrial materials and eventually establish in-space manufacturing enterprises.

FACTORIES, NOT JUST FOOTPRINTS
For our future in space to be sustainable, we must work there, drawing on resources from the Moon or asteroids.

AGE

DEVELOP TECHNICAL CAPABILITIES. BY JAMES A. VEDDA

The old destination-driven strategy—often called the "Von Braun paradigm" after the legendary rocket engineer Wernher von Braun—may sound inspirational, but if our intention is to expand our capacity to productively move into space while also bringing direct benefits to Earth, our goals should be driven by capabilities, not arbitrary targets and deadlines. But the new path is still poorly articulated and faces resistance from entrenched interests.

Some of that resistance stems from mistaking Kennedy's 1961 speech as a strategy for creating a permanent presence in space and opening the Moon to human expansion, followed by the rest of the solar system. It's true that Kennedy spoke of space as "this new ocean" and pledged that the U.S. "does not intend to founder in the backwash of the coming age of space." But behind that rhetoric were near-to-medium-term political goals. It is well documented that Kennedy's objectives included boosting U.S. technological prowess and industrial production, demonstrating superiority over the nation's Soviet adversary, and winning over hearts and minds in non-aligned nations.

Kennedy was not a space enthusiast, aside from recognizing what it could do to further other national goals. Establishing a permanent, productive presence in space was never part of the Apollo program, and the infrastructure created to carry out the lunar landings was not designed to support such an eventuality.

The Apollo program happened at an anomalous time during which geopolitical, technological, economic, and cultural factors came together in ways that we cannot expect to recur. Nonetheless, the Apollo-style destination-driven approach has been recycled for decades because it is familiar, easy to understand, and seems to absolve decision-makers of any further need to justify or expand on the vision. That includes explaining its underlying purpose and the benefits it brings to the nation and the world that are worth the cost and risk.

The Cold War coming to a close at the beginning of the 1990s should have prompted a reconsideration of strategy and justification for human spaceflight. The program had indeed fulfilled some major national purposes: it contributed to prestige, promoted research and development, and boosted science and engineering employment. These benefits sufficiently justified the investment and risk during the Cold War. And although those purposes still existed after the Soviet threat disappeared, they were no longer sufficient to justify an indefinite continuation of the program in the United States. (The situation may be different in emerging spacefaring nations such as China and India.)

In a post-Cold War world, we must recognize that space exploration and development will not evolve as they did in the Cold War era. The U.S. government should not be expected—and in fact, is not able—to fund, build, and operate all the needed research programs, services, and infrastructure. The community of participants in research, operations, and funding needs to be enlarged.

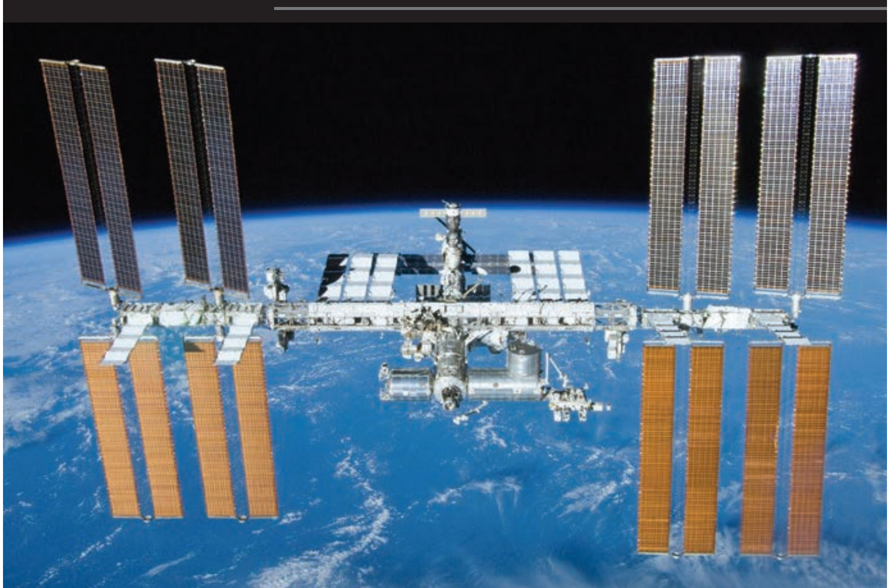
To accomplish this, we need a long-range national policy with clearly defined approaches to managing the evolution of the civil space sector and facilitating the growth of commercial space. The organiz-

ORBITING BEACHHEAD *(Right, below right)* Astronauts working at the International Space Station are reliant on supply shipments from Earth for food, water, even air.

SOUTHERN OUTPOST *(Below left)* The Amundsen–Scott South Pole Station is so hard to provision that it houses only about 200 scientists during the annual summer research season.

PLACES SUCH AS THE ANTARCTIC THAT ARE AT THE END OF COSTLY, SPECIALIZED SUPPLY CHAINS HAVE NO PERMANENT INHABITANTS.

IN CONTRAST TO THE "FLAGS AND FOOTPRINTS" MODEL, FRAMING SPACE STRATEGY IN TERMS OF CAPABILITIES WOULD BRING BENEFITS TO EARTH AND PREPARE US TO MOVE OUTWARD TO THE REST OF THE SOLAR SYSTEM BY FIRST DEVELOPING OUR OWN BACK YARD—THE EARTH-MOON SYSTEM.



ing principle behind that policy must be building a set of capabilities that enable space operations to create value sufficient to justify their costs.

INDIVIDUALS MAY EXPLORE FORBIDDING regions for the most idiosyncratic of reasons. But when societies as a whole decide to undertake costly activities in unfamiliar and challenging environments, they are motivated only by a couple of factors. First, they go where the high-value resources are, even when that leads them to the ocean floor, the polar regions, treacherous terrain, and underground mines. The risk is worth it, because economies often boom when new resources are introduced.

Societies also explore to find ways to solve problems and improve living conditions. People will move to escape environmental degradation, political or religious persecution, or any other conditions that prevent them from thriving.

But the human drive to expand is limited. Settlements only prosper in places where essentials such as water, food, energy, and materials, and the tools to adapt to the climate, terrain, and other environmental factors are available either locally or through routine, sustainable supply chains. Places such as the Antarctic that are at the end of costly, specialized supply chains have no permanent inhabitants.

Right now, all human needs in space, from high-tech manufactured items to building materials to breathable air, must be satisfied by carrying supplies up from Earth. That limits our presence there to small scientific stations with rotating crews, sustained by expensive, government-subsidized logistics.

If we want it to be something more, we need to stop asking "What's the next destination?" and start investigating the pertinent questions. First, what integrated set of technical systems would be required to enable humans to "live off the land" in space? Alternatively, how much can be achieved with robotic systems alone? Second, can expansive space operations consistently create value—scientific, economic, and societal—sufficient to justify the cost and risk?

In other words, we need to build capabilities that will sustain us in space, and will make our operations self-sustaining.

There are indications that this capabilities-driven approach is catching on. In the government arena, President Barack Obama has pushed for more technology development funding at NASA, as well as government support for emerging commercial launch providers that eventually will take over routine spacelift operations. Also, his National Space Policy of June 2010 directs NASA to "identify potentially resource-rich planetary objects"—a prerequisite for self-sustaining activity in space. A proposed mission in the 2014 budget request for NASA would capture a small asteroid and deliver it to lunar orbit for study.

Those steps have not been universally embraced; members of Congress have repeatedly questioned NASA initiatives by asking, "How does this put us on a path to Mars?" But in contrast to the "flags and footprints" model, framing space strategy in terms of capabilities would bring benefits to Earth and prepare us to move outward to the rest of the solar system by first developing our own back yard—the Earth-Moon system, also known as cislunar space. Some have called this approach Cislunar-Next. That alternative would de-emphasize sending humans to destinations beyond the Moon for now, and make in-space capabilities, infrastructure, and experience the top priorities.

IF WE RUSH TO SEND HUMANS TO FAR-OFF DESTINATIONS BEFORE ACHIEVING THE INDUSTRIALIZATION OF CISLUNAR SPACE, THE COMMERCIAL SECTOR WILL TEND TO PARTICIPATE PRIMARILY AS GOVERNMENT CONTRACTORS, AND WILL NOT BE THERE AS A SUSTAINING FORCE.

Cislunar-Next is not a go-slow approach. If done properly, it would be the fast track to a purposeful, sustainable future in space.

Although policy-makers have yet to fully grasp the strategic transition that is under way, many in the entrepreneurial space community have a clearer perception and are acting on it. Companies like Deep Space Industries and Planetary Resources Inc. recognize that the future of spacefaring lies in the ability to find, extract, process, and use material and energy resources in space to support a broad range of human activities there. Eventually, there may be markets on Earth for space products and services beyond the communications, navigation, and remote sensing services that have already proliferated.

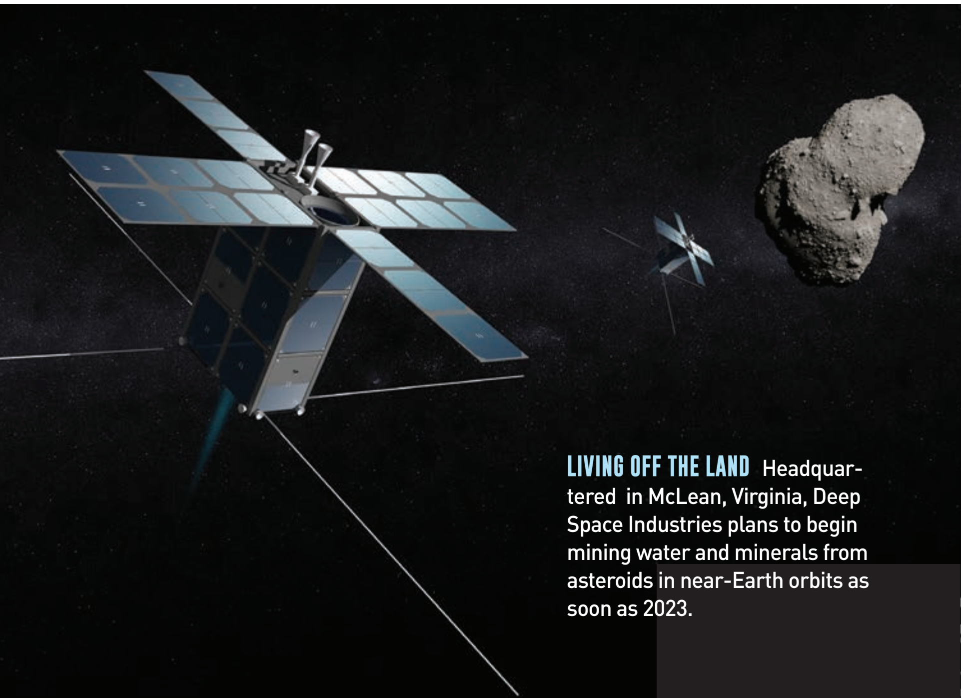
Space exploration and development need to evolve through three stages. Stage One uses space as a training ground for technical systems and operational experience, yielding useful applications that employ the vantage point of space. That's where we've been for the past half century.

In Stage Two, we'll turn cislunar space into an industrial park where we begin generating value from extraterrestrial resources. Over the short and medium term, that means we need to develop capabilities. We'll need to exploit the unique characteristics of space, such as microgravity, vacuum, and high-intensity solar exposure, as well as learn how to harvest and process extraterrestrial materials and energy resources. We will have to build progressively more sophisticated structures in Earth orbit and elsewhere in cislunar space, and construct installations on the Moon using local materials to the greatest extent possible. And engineers will have to develop advanced space robotics so as to minimize the need for human presence in activities that are hazardous or remote, and to provide direct assistance to humans where human involvement is required.

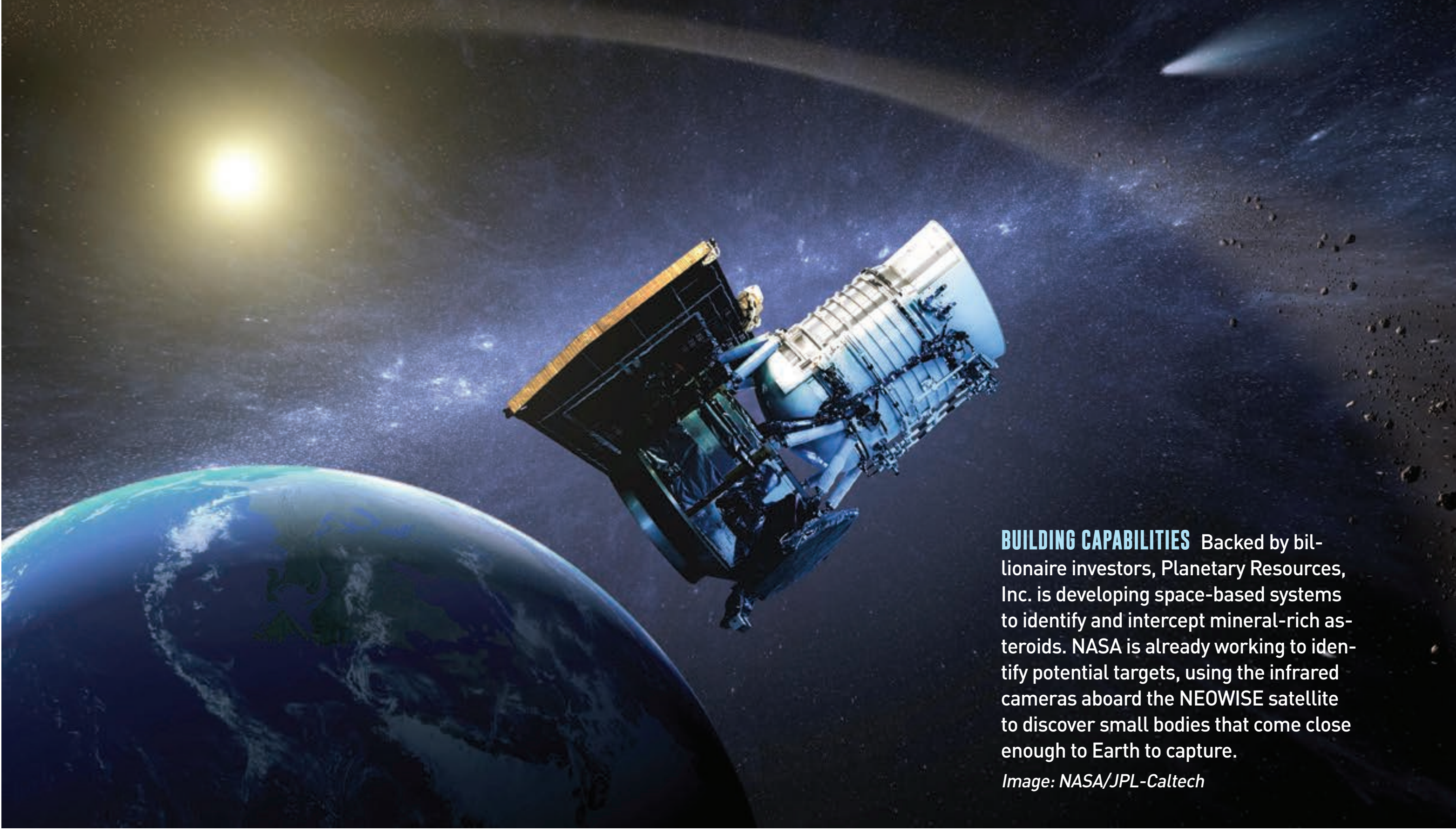
Stage Three commences with the sustainable, permanent settlement of cislunar space and the initial expansion of human activity out to the rest of the solar system. In that stage we'll have to construct and operate advanced structures that minimize their dependence on supply lines from Earth, designed for science, commerce, and other purposes. Those structures will then have to be aggregated into industrial parks at locations deemed valuable for their proximity to space resources, stable orbital positions, or other attributes. And above all, these activities will have to realize significant contributions to the terrestrial economy through energy and manufactured products for use on Earth and in space.

These stages can't be shuffled or skipped over if we want to create an enterprise with lasting value.

With these goals established, we need to devise a set of high-priority proof-of-concept projects. Technical and industrial innovation will require more than evolutionary improvement of the things we're already doing in space, which mostly consist of transmitting electromagnetic signals back and forth.



LIVING OFF THE LAND Headquartered in McLean, Virginia, Deep Space Industries plans to begin mining water and minerals from asteroids in near-Earth orbits as soon as 2023.



BUILDING CAPABILITIES Backed by billionaire investors, Planetary Resources, Inc. is developing space-based systems to identify and intercept mineral-rich asteroids. NASA is already working to identify potential targets, using the infrared cameras aboard the NEOWISE satellite to discover small bodies that come close enough to Earth to capture.
Image: NASA/JPL-Caltech

In any approach to expanding human spaceflight, life sustainment systems will require continuous improvement in the knowledge and techniques for dealing with the physiological and psychological stresses of long-duration missions. Life support systems need to become more reliable, lower maintenance, and less dependent on frequent resupply. This is an area that is already getting a good deal of attention aboard the International Space Station and in some Earthbound studies. But we lack the facilities to do all that is needed.

The crew conditions being studied on ISS are confined to six-month stays (and one full-year mission planned for 2015) in zero-gravity in low Earth orbit, giving us a very limited sample of what we'll encounter as we move outward. This is far short of the time needed for any interplanetary journeys or extended cislunar missions, and provides minimal ability to prepare us for the radiation levels that confront us when we go beyond the relatively benign environment of low Earth orbit. Radiation exposure may be the greatest potential showstopper to long-duration spaceflight and habitation unless adequate mitigation measures can be developed.

Another ISS limitation is that it tells us nothing about how to function on a planetary surface with gravity that is a fraction of Earth's. The weightless environment of the ISS needs to be supplemented by a variable gravity facility that can simulate planetary gravity environments that we expect to encounter, such as one-sixth g on the Moon or one-third g on Mars. Also, the facility can help determine if spinning spacecraft make sense for long flights, and if so, at what gravity level. A one-g environment may not be necessary to maintain good health and full functionality, and there are technical advantages to designing a spacecraft for lower spin rates.

Some other big questions that desperately need answers may receive cursory attention if we choose a spaceflight approach that only looks beyond the Moon and is overly eager to put human footprints on alien worlds. Under a Cislunar-Next program, developing the technologies and experience that enable efficient, sustainable, expandable space operations would be top priority.

Here are some of the essentials: standardization of systems and interfaces, on-orbit servicing, interorbital transportation, in-space fuel storage, microgravity materials processing (including applications as diverse as metallurgy and pharmaceuticals), extraterrestrial resource mining, energy collection and distribution, and other in-space utilities.

Significantly, a capabilities-driven strategy would be the best way to get the commercial sector on board as indispensable partners. Private interests will have greater incentives to invest, and their partnership—perhaps even their leadership—will eventually propel the movement beyond cislunar space. If we rush to send humans to far-off destinations before achieving the industrialization of cislunar space, the commercial sector will tend to participate primarily as government contractors, and will not be there as a sustaining force.

Our metrics for success should not focus on how quickly we get to Mars or how many people we have living in space; rather, we should be measuring how much we're gaining in capabilities and knowledge, leading to increased prosperity, global solutions, and discovery. This level of achievement means doing things that generate scientific, economic, and societal value, bringing quantitative and qualitative benefits to Earth that justify the continued exploration and development of space.

For humanity's future, the cost of not doing these things may be unaffordable. **ME**

JAMES A. VEDDA is a senior policy analyst at The Aerospace Corp. in Arlington, Va. He is the author of *Becoming Spacefarers: Rescuing America's Space Program*, from which this essay is adapted, and *Choice, Not Fate: Shaping a Sustainable Future in the Space Age*. The opinions expressed here are solely those of the author.